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IMPERIAL ETHIOPIAN GOVERNMENT

NATIONAL WATER RESOURCES COMMISSION

ETHIOPIA - FRANCE COOPERATIVE PROGRAM

WABI SHEBELLE SURVEY

IN COLLABORATION WITH

FRENCH MINISTRY OF FOREIGN AFFAIRS

NATIONAL WATER RESOURCES COMMISSION

BCEOM-ORSTOM-EDF IGN-BDPA

V

Soil Survey of the Wabi Shebelle Basin

1973

CONTENTS

የኢትዮጵያ ንጉሠ ነገሥት መንግሥት

ብሔራዊ የውሃ ሀብት ልማት ኮሚሽን መሥሪያ ቤት

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The Soils of the Wabi Shebelle Basin

Management and Utilization

with a soil map at 1/1.000.000

ORSTOM

ign

OCTOBER 1973

- The soil map at 1.000.000 of the Wabi-Shebelle basin is annexed

- The four utilization soil maps

  ARUSSI - NORTH BALE

  HARAR - CHERCHER

  MIDDLE BELT

  LOWER OGADEN

  are not included.

The present report is a summary of the pedological studies undertaken from 1968 to 1972 by the Soil Science Division of the WABI SHEBELLE Project, for the entire Basin of the Wabi Shebelle.

The scientific studies were conducted from 1968 until the achievement of this report by M. SEGALEN, Consultant in Ethiopia, "Inspecteur de Recherches" O.R.S.T.O.M. (France).

To the soil-science studies participated the following engineers and technicians :

- Christian MASSONI, "Maître de Recherches" O.R.S.T.O.M. (France), Chief of the Soil Science Division of the Project.

- Gilles RICHE, "Maître de Recherches" O.R.S.T.O.M., (France), Chief of the Soil Science Division of the Project.

- Jean Oliver JOB, "Ingénieur chimiste" O.R.S.T.O.M. (France), Chief of the Laboratory for soil analyses.

- Jean François MERGAUX, I.G.N. cartographer (France).

- Zawde TILAHOUN, Head Technician of the Water Resources Commission (Ethiopia).

- Melle Guerra GEBREMESKAL", Ingénieur chimiste of the Water Resources Commission (Ethiopia).

TABLE OF CONTENTS

Figures, Tables and Plates

I. INTRODUCTION

The soil survey of the Wabi Shebelle basin was carried out on a total surface of approximately 190.000 km2. A survey map at 1/1.000.000 was drafted using many land traverses based on a careful study of aerial photographs. The mapped area presents very particular features, such as :

- A relatively steady variation of altitude, from the source of the Wabi Shebelle at 3.000 m., down to 200 m where the river flows into the Somalian Republic.

- A very pronounced climatic variation, from temperate to sub-arid with various intermediate forms.

- Abundant limestone and gypsum rocks in a climate with rainfall less than 600 mm whereas, at the same latitude, other intertropical regions with a much more humid climate present acid granite-gneiss rocks.

The specific features of the Basin of the Wabi-Shebelle, especially as regards climate, brings out some new aspects in several soil categories.

- The particular situation of the catchment basin and its steadily varying altitude does not allow to find there the types of climates observed in Central and West Africa. Mediterranean or temperate climatic conditions appear as the temperature decreases and intergrades between several regimes can also be noted. However, the particular types observed are specific to the region under study.

- The profile observation shows the existence of three different zones, i.e. :

The first is characterized by a morphology showing that soil is derived from the underlying rock. This is the case for the Northern and North-Western border of the basin where the parent-rock nearly always consists of basalt.

The second is characterized by rocks covering the soil in situ. From this recent rock is sometimes derived a different soil from the underlying material as, for instance, hydromorphic soils on ash resting on an ancient vertisol (Kofele-Adele region).

The third is represented by stone-line soils corresponding to the greater part of the Basin area. Two categories may be observed. In the first, the stone-line is relatively close to the surface (Babile region), but in the second and more usual category, the stone-line is very deep (down to 10 m). The stone-line exists in very different climatic regions. Consequently, the differenciation of soil did not take place in a material derived from the rock located at the base of the profile, but in another material formed elsewhere, transported to its present place and separated from the subjacent rock by a line of pebbles.

- Calcareous soils may result from two completely different forming-processes, i.e. :

The first category of soils is derived from limestone rocks (Kebri Dahar limestone) where calcium carbonate is at the dissolution stage. Rendzina, brown calcareous soils and brown calcic soils were identified and classed quite naturally with calcimagnesimorphic soils.

The second category is derived from original calcareous or non-calcareous rocks or material (calcareous sandstone, limestone, basalt, plagioclase granite or gneiss etc....). The secondary limestone of pedological origin in the profile must be considered distinctly from the former limestone.

For the French classification, as regards isohumic soils the first element taken into consideration is the nature and distribution of organic matter, the climatic type being considered next;whereas, the presence of limestone is only taken into account for the sub-division into groups or even sub-groups.

Apart from very distinct cases, the accumulation of organic matter being very low, this factor does not allow classifying the soils easily. On the other hand, various and very distinct calcareous manifestations exist and correspond to logic pedologic processes. Consequently, it was decided that the classification should be changed in order to adopt the method of A. RUELLAN and classify these soils among soils with a calcareous differenciation.

- Soils with gypsum occupy different positions in the classification. As for calcareous soils, a soil class with a gypsum differenciation was created and copied on the former.

- The classification of "brown" soils, diversified at the level of the sub-class and based on climatic considerations, also raised some problems. In fact, no valuable criterium exists allowing to classify them with soils of humid temperate climates rather than with soils of tropical regions.

- Ferrallitic soils observed in the Southern region of Africa and in Madagascar present some specific features from which no morphological characteristics may be determined. The morphology usually representing ferrallitic soils has a very high saturation degree (80 to 100 percent) and presents clay minerals in which kaolinite is accompanied by abundant illite. All this shows that here soils are real intergrades between ferrallitic and fersiallitic soils.

It must be noted that on the surveyed area, most of the soil classes included in the classification were observed except for podzolized soils. Besides, apart from small stretches of hydromorphic soils, no soils presenting an iron migration process, concretions or hardpans where observed, whereas in the South of Sudan or in Uganda which are relatively near, ferrugineous induration with all its various forms is the main element of landscape and soils. Except in several not very extended zones, all the soils are neutral, present a high saturation degree, are rich in calcium and are not characterized by acidity and the existence of hydroxides as may be observed in most regions of tropical Africa.

Some particular soil features are apparently due to the climatic, geomorphological and petrographic conditions of the Basin with a low altitude where the ORSTOM soil scientists usually work.

These particular circumstances made it necessary to modify the classification, without however altering the general plan.

Finally, as regards the terms used, two innovations where made with "melanic" and "pallid"horizons defined in the F.A.O. "Definition of soil units". These terms seem to apply very well the soil class with a calcareous differenciation.

II. SOIL FORMING FACTORS

The Basin studied in East Africa near the Equator presents very great differences of altitude between the downstream and upstream parts, and remarkable characteristics in the soil forming factors may be observed. The climate presents particular and considerable variations. The vegetation and hydrography being studied elsewhere are not closely examined here. The parent material is mainly of sedimentary and volcanic origin. Owing to very recent tectonic movements, the fracture system of the zone is very pronounced.

A. CLIMATE

Some ancient data on the climate of the Basin of the Wabi Shebelle, for Harar, are available from several classic works but all the data concerning other stations are due to the installations placed by the hydrologists of the Wabi Shebelle Project. Temperatures are unfortunately recorded in very few points but as these are well distributed (Adaba, Harar, Medagalola, Gode, Hamaro, Ticho), it is possible to extrapolate for the neighbouring regions with very few errors. However, though there are more rainfall stations (44), observation years are few (3 or 4 years) and several months are sometimes lacking in the recorded observations. Despite this incompleteness, the available data allow to get a correct idea of the main climatic conditions in the Basin.

1. Characterization of the climatic conditions

In order to characterize the climatic conditions, Peguy's grid (1961) was used to determine the predominant feature of a particular month. This grid presents the following subdivisions (Fig. 1) :

- "Pluviothermic" P, both warm and humid.

- Arid month or A, with scarcely no humidity and temperatures either warm or cool.

- Optimum month, or O, when humidity and temperatures are neither too high nor too low.

- Cold month, or C, when the temperature is always less than 16° and rainfall is variable.

The climatic regimes taken into consideration are, i.e. :

- equatorial regime : the number of pluviothermic months is approximately 10 with 2 arid months.

- tropical regime : the number of arid and pluviothermic months is variable.

- xeric regime : more than 10 arid months with 2 pluviometric or optimum months. The total rainfall is less than 150 mm.

- subtropical regime : the year is characterized by pluviothermic and optimum months. This regime is not represented in the studied zone.

- mediterranean regime (1) : the year is characterized by optimum and arid months.

- temperate regime : optimum months predominate with several cool months.

Within each different regime, subdivisions exist based on the number of months for each category. For instance, the tropical regime presents various types of climate in West Africa (Aubreville, 1949) :

Guinean with 7 - 9 pluviothermic months and 3 - 5 arid months

Sudanian with 5 - 7 pluviothermic months and 5 - 7 arid months

Sahelian with 2 - 4 pluviothermic months and 8 -10 arid months.

The various climatic regimes are easily known but the types of climate are numerous and only present a local interest.

2. Factors modifying the various climates of the Basin :

These factors are mainly the geographical position and altitude.

2.1. Geographical position

The drainage basin under study is located between 5° and 9°30 N. latitude. The Southern part of the Basin is approximately in the latitude of Bangui, Douala or Abidjan, where more considerable rainfall and an equatorial climatic regime may be observed. The Northern part of the Basin is situated in the same latitude as Garoua in Cameroun and Korhogo in the Ivory Coast. The climatic conditions in points located at 5° and 9°30' on

(1) This term is used though this regime concerns a geographical zone which is much greater than the Mediterranean basin. Bagnouls and Gaussen suggest the term : "xerotheric".

either side of Africa present very few common features. Southwards, the climate is subarid and Northwards, rainfall is more abundant.. However, in the Southern end of the Basin, the sun reaches its zenith twice a year with long intervals in-between, and the two rainy and two dry seasons are consequently very distinct. As one goes Northwards, the interval between two culminations becomes shorter and the four seasons are gradually reduced to one dry season and one rainy season. The precipitation curves show two maxima which tend to be gradually closer until they meet, but a decreasing effect can however be observed in the middle of the rainy season. Consequently, in spite of a pronounced aridity in the South, two rainfall periods exist as is usually observed near the Equator. In the North, rainfall increases but the rainy periods progressively stretch throughout the year (see fig.2.).

The low monthly amplitude of temperatures is also due to the geographical position. In Gode, the warmest month corresponds to 29°7 and the coolest month to 27°1. The mean monthly temperatures vary from 20°5 to 18°9 in Harar and from 13°9 and 10°5 in Adaba.

The difference between the mean monthly maximum and minimum temperatures increases from the South-East to the North-East and from the lower parts to the upper parts of the Basin.

2.2. Altitude

The Basin generally slopes down to the South-East but its edges rise considerally in the North and North-West : The mean altitude is approximately 200 - 300 m in the South-East, 500 to 1.000 m in the Centre, 1.000 to 2.000 m in the North, 2.500 m in the North-West. The North-Western edge is surrounded by a few summits more than 3.000 m high.

This form of relief affects the mean annual temperature which is 28° in the South-East, 20°6 in the centre, 19°9 in the North and 12°8 in the North-West, but the temperatures on the high peaks are not known.

The relief also affects rainfall and the mountainous regions are more humid than the South Eastern plains.

The climatic features of the Basin may be summarized as follows, i.e. :

- The South-East is warm and dry and the North and North-East cool and damp.

- Four distinct seasons exist in the South-East and are progressively reduced to two seasons in the North-West

- The mean annual temperature decreases from the South-East and in the North-West ; the mean monthly temperature is steady throughout the year for each station, and the monthly and daily amplitudes slightly increase from the South-East to the North-West.

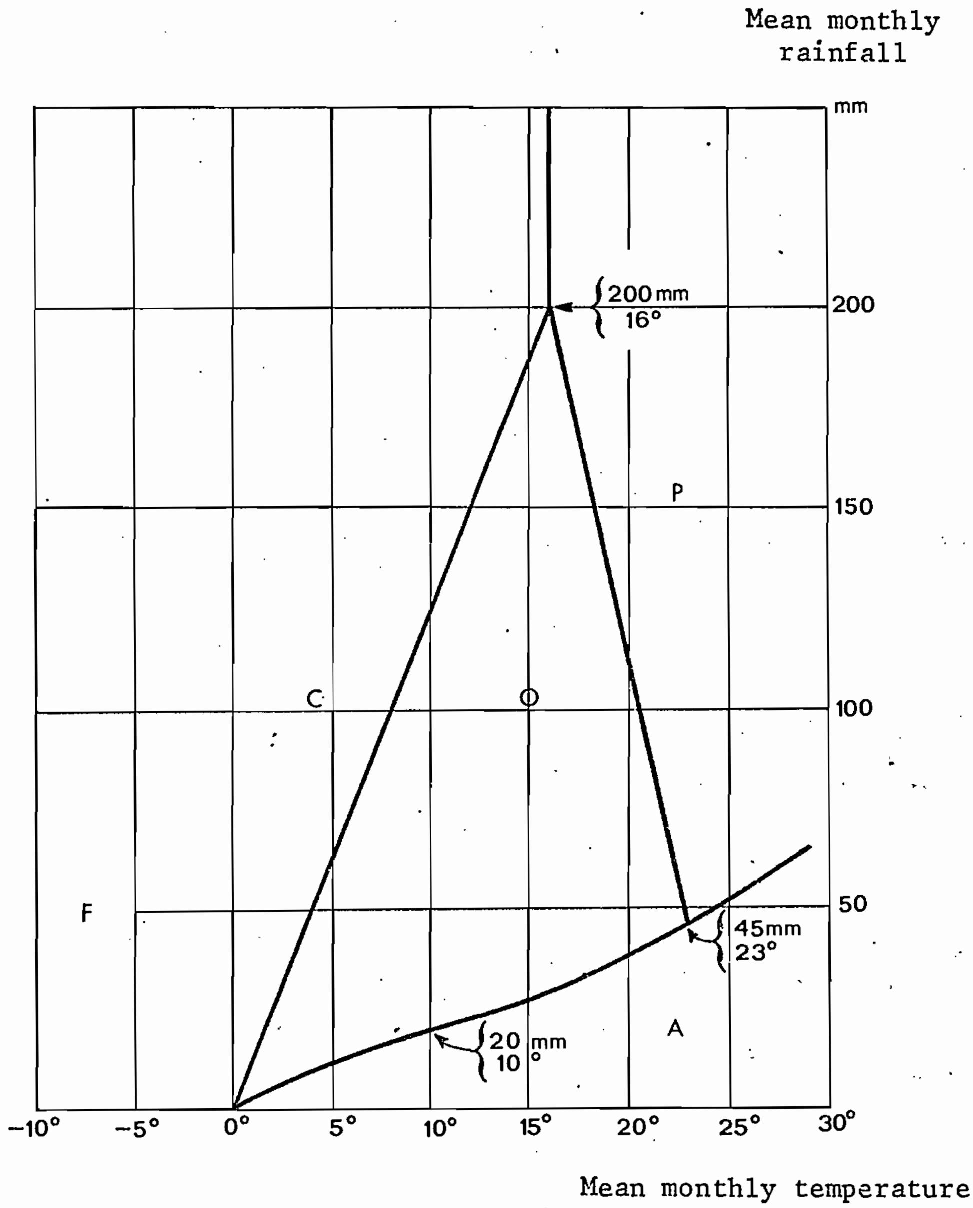

FIG. 1 - Grid used to determine the dominant climatic feature of a month (Peguy, 1961), namely :

F : freezing ; C : cold ; O : optimum (or temperate) ;
P : pluviothermic ; A : arid.

3. Attempt at classifying the climates of the Basin (see fig.2)

Using the previous definitions, tropical,mediterranean and temperate regimes were determined. Intermediate forms exist between tropical and temperate and between mediterranean and temperate climates.

3.1 Tropical regime

It concerns the whole South-Eastern region of the Basin. Relying on the observations from Gode Station which represent the whole sector relatively well, the mean annual temperature is 28°2 with a small monthly variation (from 29°7 to 27°1) Rainfall varies between 170 mm in Kelafo and 436 mm in Duhun.

The monthly characteristics for Gode are 9 arid months and 3 pluviothermic months. This distribution is similar to that of the Sahelian type (or Senegalian) but, the main difference with the latter is the existence of only two rainy seasons. The term suggested for this climate is : tropical climate of "Ogadenian" type.

3.2. Intermediate form between tropical and mediterranean regimes

This climate concerns the Chercher region or Northern border of the Basin. The altitude varies from 1.000 to 2.000 m. The mean annual temperature is 19°9 with a maximum of 20°5 and a minimum of 18°4. The mean annual rainfall varies from 800 to 1.200 mm. The two seasons are very distinct.

The monthly characteristics for Harar are 4 optimum months, 5 arid months and 3 pluviothermic months. Consequently, the term suggested for this type is "Ethiopian" climate as it is very similar to the climate of the capital.

3.3. Mediterranean or xerotheric regime

It concerns the part of the Basin situated between Lower Ogaden and the Northern limit and called the "Middle Belt".

The altitude is higher than in the previous sector (500 to 1.000 m). The mean annual temperature is 20°6 and monthly variations are 19°5 to 21°8. The annual rainfall is greater (400 to 800 mm) and is well distributed throughout most of the year : the rainy season lasting 9 months and the rainless period 3 months. Two seasons instead of four may be observed.

The monthly characteristics for Medagalola are 9 optimum months and 3 arid months. The term suggested for this type of climate is "Fikian"

3.4. Intermediate form between mediterranean and temperate regimes

This regime corresponds to the Guedeb plain at 2.500 m altitude in the upstream part of the Basin.

The mean annual temperature is 13°3 with a variation from 11°8 to 15°1. The annual rainfall is 800 mm. The year is distributed in 2 cool months, 6 optimum months and 4 arid months. This type of climate is termed "Guedebian"

3.5. Temperate regime

This regime may be observed in part of the Western end of the Basin where the altitude is more than 2.500 m. Two types of months exist : optimum and cool months. Two sectors have been surveyed :

- The first sector occupies the Eastern part of Arussi where the mean annual temperature is 12°8 with a monthly amplitude of 11°7 and 13°9. It rains practically without interruption throughout the year but a distinct abatement may be observed in November and December. Rainfall varies from 1.000 to 1.700 m. The monthly characteristics for Ticho are 10 optimum months and 2 arid months. This is the "Tichean" type of climate.

- the second sector occupies a discontinuous area along the North-Western limit of the Basin and corresponds to the mountain peaks rising to 2.500 and 3.500 m. The mean temperature is less than 12° and rainfall is approximately 1.600 m. The cool periods probably represent more than 2 per cent of the whole year. This is the "Boraluku" type of climate.

In the Basin of the Wabi Shebelle, several climatic regimes are represented. The tropical regime is the most largely spread but owing to altitude, mediterranean and temperate regimes also exist.

None of these types of climate being really similar to those studied elsewhere, some new terms have been found to name them.

4. Situation of the Basin compared to West-Africa as an entity

The Ethiopian High Plateaux constitute a relatively humid sector in a generally arid or subarid region. In fact, it is surrounded by a discontinued but arid belt in the North-East (Sudan), in the East (along the Red Sea in Erythrea and Somalia) and in the South (North of Kenya).

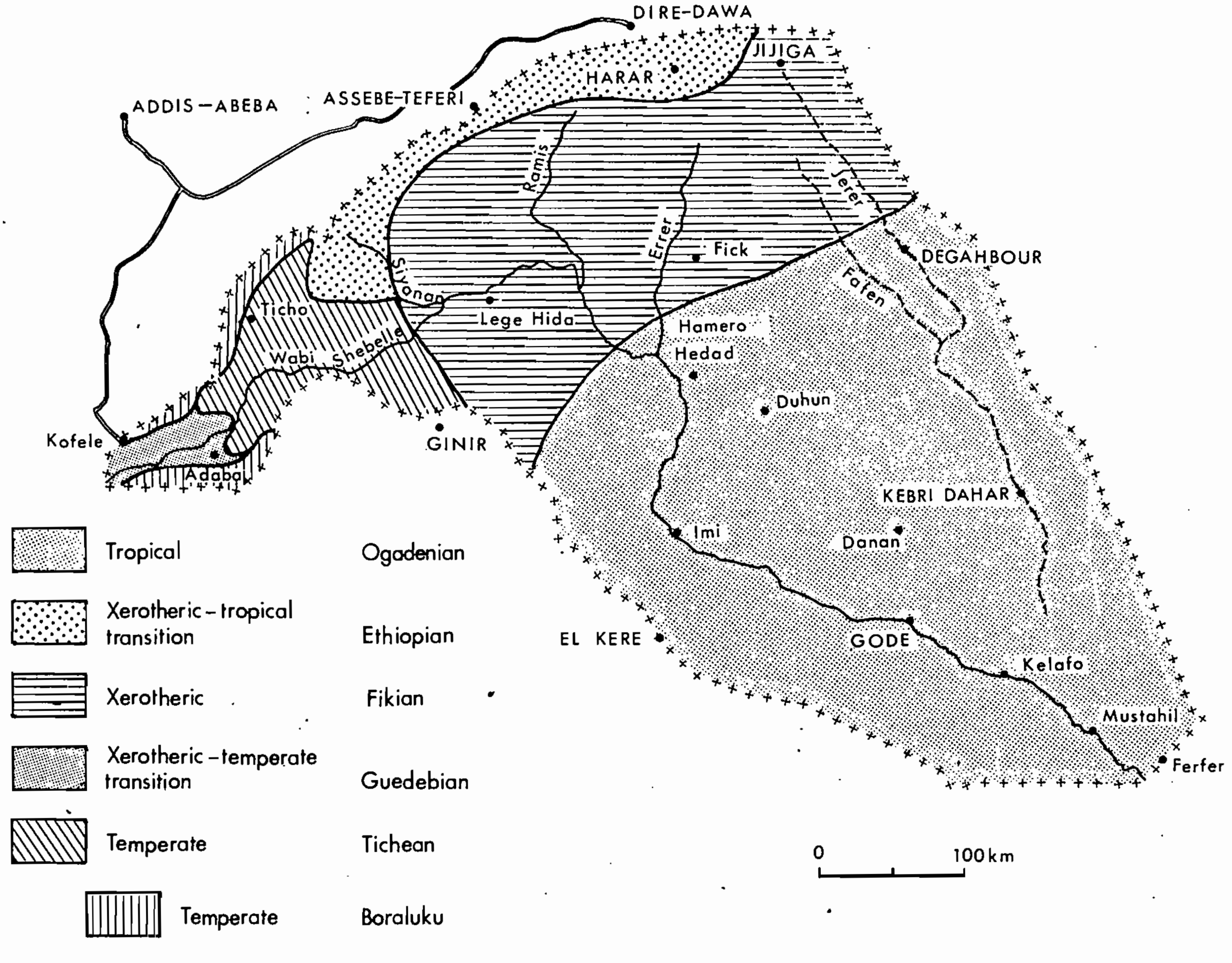

Fig. 2 CLIMATIC SKETCH OF THE BASIN OF THE WABI SHEBELLE

The central part of Ethiopia is divided by the Rift Valley.

The High Plateaus present an intermediate climatic regime between tropical and mediterranean climates. Several discontinuous zones to the North of the High Plateaux and West of the Basin of the Wabi Shebelle present a temperate climatic regime, and the Eastern border of the plateaux has a xerotheric climatic regime. Four seasons exist in the tropical Eastern part of the Basin (Ogadenian). A Sudanian climate may be observed in the Rift Valley and on the Western border of the High-Plateaus.

B. VEGETATION

The data on vegetation given here are developed in the "report on the vegetation of the Basin of the Wabi Shebelle" by J.L. GUILLAUMET ORSTOM botanist who considers distinctly : two zones according to the altitude climate, vegetation and geological substratum".

1. High altitudes above 1.700 m

These are characterized by an intermediate climate between tropical and temperate regimes for the lower zones, which becomes a temperate climate above 2.500 m. The climacic vegetation of the forest type has mostly disappeared owing to land clearing in very high altitudinal zones. The following vegetation zones may be observed, i.e. :

- Alchemilla spp zone above 3.700 m "crowning" the big mountain ranges of Arussi and Northern Bale.

- Ericaceae zone from 3.400 m to 3.700 m on the higher slopes of these same mountains.

- Juniperus procera and Podocarpus gracilor: from 2.400 to 3.400 m : these associated species have been severely damaged by crop-growing on the basalt plateaus and no longer exist except on steep slopes or, very loosely, in certain cultural zones on red soils (Sire region).

- Croton macrostachys and Cordia abyssinica : from 1.700 to 2.400 m on limestone or sandstone plateaus, South of Chercher and in the East of Arussi. Degradation due to cultivation practises is less serious than in the previous zone but climacic forests seem to have completely disappeared. M. GUILLAUMET distinguishes the following floristical species as a function of the geological material and of the lie of the land, i.e. :

- Terminalia browni facies on the granite chaos of Babile.

- Euphorbia abyssinica stands on the warmer slopes of basalt, granite or limestone hills.

- The forms of degradation of these various facies or stands

- The belt of Acokanthera shimperi and Carissa edulis which constitutes "the lower limit of the high-montane vegetation and the transition with the shrub formation of Acacia spp and Commiphora spp".

2. Mean and low altitudes from 1.700 m to less than 200 m

These include the main part of the Basin of the Wabi Shebelle with the Middle Belt and Lower Ogaden where climatic conditions become progressively drier from the North to the South and from the West to the East.

- The Acacia spp zone which corresponds to the Middle Belt consists of a relatively loose thicket with numerous shrubs 5 to 6 m tall, a herbaceous stand and some gramineae covering approximately 30 percent of the area. This formation is well represented on all the limestone plateaus of the Middle Belt (North Fik, North Godane, Soddu, etc,..).

- the Acacia spp and Commiphora spp zone stretches over all Lower Ogaden in a subarid climate with rainfall approximately 300 mm. The types of vegetation are largely influenced by the local edaphic conditions which are determined by the base-rock and the soil drainage.

Plateaus and hills of Lower Ogaden

- Gypseous formations of Lower Ogaden on either side of the Wabi-Shebelle : Boswellia spp and Jatropha rivae thicket.

- Plateaus on Kebri Dahar limestone between Degah-Medo and Danan : Boscia miniflora and Delonix elata thicket.

- Plateaus on Mustahil limestone, South of Kebri Dahar and Gode : Commiphora sp. and Andropogon cyrtocladus thicket.

- Plateaus and sandy colluvial deposits on Gesoma sandstone in Shilavo region with Gardenia ind. and Cordia gharaf thicket. The vegetation is always a thicket, whatever the base-rock may be, and its mean height is 3 to 5 m with here and there, scattered graminea tufts.

The vegetation is not so dense on gypsum but it is denser on limestone plateaus and usually become very thick and well developed on sandstone plateaus, a sandy layer keeping the soil humid in the depth. (see soil-family n° 44).

Colluvial and red alluvial deposits of Lower Ogaden : These zones are well drained and present a shrubby stand with mainly Girocarpus habbensis and Cassia. The undergrowth consists of an ephemeral herbaceous stand.

Brown and yellowish-brown alluvial deposits flooded or not of the Wabi-Shebelle and Fafen : The graminea cover mainly consists of annual plants with a very quick growth during the rainy season after which it soon disappears.

Natural levees of rivers : On the latter grows a fringing forest of variable width. Along the Wabi, in the Hamero-Hedad and Mustahil region, palm-trees with several heads or Hyphaene thebaïca are dominant.

In the Imi and Kugno region, Tamarix nilotica stands growing on large sandy areas are usually associated with Terminalia brevipes.

Long flooded zones in the Mustahil and Shebelle plains : the medium or tall herbaceous vegetation consists of Scirpus maritimus, Cyperus cf. fenzelanium, Ipomea sp., Indigofera sp. and Dichantium annulatum.

Halophyte community : it grows on the gypseous alluvial and colluvial deposits but the presence of salt is particularly emphasized in the Ferfer region by a vegetation of Urochondra setulosa, Cucumella Kelleri, Cenchrus biflorus and several species of Limonium.

C. GEOLOGIC FORMATIONS : AGE, CHARACTERIZATION GEOGRAPHICAL LOCATION

1. Granite formation at the base

Age : Precambrian

Characteristics : It consists of amphibole granite usually deeply metamorphized resulting into a formation with predominant migmatites and abundant black mica and amphiboles with feldspar beds. In some places gneiss with amphiboles and amphibolites may be seen. The granite chaos often consists of granite with two types of mica.

Location : It is only represented in the Harar region

- In Harar and farther North, in the vicinity of Alemaya and Kersa, it is usually covered with a weathering layer.

- In the Babile region, it forms some remarkable chaos with typical boulders.

- Made apparent by weathering, outcrops are visible in the Gobelle, Errer and Fafen valleys and are at the same level as the present base of the upstream course of these rivers.

2. Adigrat sandstone :

Age : though still debated, it is probably Pre-Lusitanian.

Characteristics : This term characterizes the arenaceous formation directly overlaying the cristalline substratum. This sandstone is reddish, presents a coarse texture and is usually very friable. Its origin is a debated matter but the lack of fossiles tends to prove that it is continental.

The thickness of this formation is variable but is never more than 30 m in the area surveyed. It is unbroken but it frequently disappears as the overlying Kebri-Dahar limestone often rests directly on the cristalline base (Akin-Gara near Harar).

Location : This formation is very liable to weathering and disappears when it is insufficiently protected by harder overlaying beds. Consequently, this formation seldom outcrops in situ, except in several zones of Chercher, at the bottom of the valleys of the Galetti, Deneka, Ramis and of one of the latter's right bank tributary. The formation may also be seen in some places around Harar, at the bottom of the "Lavakas" cutting the hill-sides, and on the crest-line which separates the Basin of the Wabi Shebelle from the Awash Basin (Kersa and Kulubi region). The red layer of weathered deposits overlaying Harar seems to be partly derived from the dismantling of this formation.

3. Kebri Dahar limestone

Age : Jurassic

Characteristics : It rests (forming a distinct limit) on the Adigrat sandstone, when the latter exists, or directly on the cristalline soil and consists of massive beds of milky limestone with very few marl intercalations. This generally compact and scarcely friable formation is cut by deep vertical canyons due to fluvial erosion.

The thickness of this formation is variable but decreases from the South to the North. It is 1.000 m thick in the zone of Hamaro-Hedad Lageida and only 300 m in the Harar region (Akim Garan, Kondudo).

Location : This formation outcrops in the medium part and in the upper part respectively corresponding to one third of the Basin and appears as large plateaux bordered by hills where very active erosion may be observed.

- Its Southern limit forms a line, approximately S.E-N.W, starting from the South of Kebri-Dahar towards Duhun, then following the Wabi Shebelle up to 100 km North of Imi and continuing Westwards in the direction of Ginir and Shek-Hussien.

- West of the Basin, the Kebri-Dahar limestone disappears either under the arenaceous formations of Gesoma sandstone (region of Minne and Mitcheta) or under the large volcanic flows of the High Plateaus of Arussi and North Bale,

- To the North, it largely spreads in Higher Chercher and is often crowned with basalt flows and Gesoma sandstone (Gara Muleta) whereas, in the Harar region, only some hillocks remain.

- In the centre of the Basin, it covers vast areas between Lege-Hida and Degahbour and constitutes the geological substratum of what is usually known as the "Middle Belt".

4. Main gypseous formation

Age : Upper Jurassic and Lower Cretaceous.

Characteristics : It consists of well-stratified gypsum and calcareous-marl beds. The gypsum beds are on the average 1m thick, whereas the marl beds are 5 to 10 m. thick. Thin limestone beds (2 to 3 m thick) are often intercalated in this formation as well as zoogenous sandstone beds in the Imi region.

- Gypsum presents various facies usually of a fine, translucent and massive saccharoid type and sometimes with fine, sinuous, coloured stripes in the mass. When gypsum deposits form thin layers, gypsum is generally platy and transparent.

- The grey to greenish-grey marl is often stratified and saline but fossiles are scarce.

It is difficult to determine the thickness of this formation as, though the higher limit is distinct (Mustahil limestone), on the other hand, the lower limit is not characteristic.

In the Duhun region, the contact between the main gypsum formation and the Kebri Dahar limestone is nevertheless visible. In this region, the formation is approximately 200 m. thick and the drillings already carried out allow to believe that it is much thicker in the Gode and Kebri Dahar regions.

Location : This formation largely stretches in all the Southern part of the Basin where it outcrops in the area approximately delimited by the towns of Mustahil, Godere, El Kere, Duhun, Kebri Dahar, Mustahil.

It either forms large "flats" : Mustahil, Godere, El Kere, or hill zones approximately 50 m high and deeply cut by erosion, or rolling lands such as in the Gode, Kebri Dahar and Imi regions.

North of Imi and mainly on the right bank of the Wabi, small, 20 to 30 m. high tabular hills present a very broken up bluff consisting of zoogenous sandstone with undetermined small molluscs.

5. Mustahil limestone

Age : Barremian - Lower Cenomanian

Characteristics : It consists of reddish limestone at the base and dolomitic limestone at the top. This formation is generally very hard with abundant fossiles such as Brachiopods, Echinids, Lamellibranches, Gastropods, Belemnits and Ammonits. Its mean thickness is approximately 30 m in the Mustahil region and seems relatively the same all along.

Location : Mustahil limestone stretches in the South and South East of the Basin where it contributed in forming the limestone plateaus typical of this region. It crowns the main gypsum formation constituting the bluff of the tabular hills which limit the horizon in all the Southern part of the Basin.

To the South East, this limestone covers all the hills from Mustahil to Kebri Dahar and across Kelafo and Gode. In the South, it spreads uninterruptedly from the limit of the Basin to a line passing approximately through Kelafo, El Kere.

The Godja hills, East of Imi, and other big hills, West of Imi in the direction of Ginir, are remnants of the ancient Mustahil limestone which extended over this region.

In the El Kere region, it appears again as large outcroppings more than 50 m thick and well covered with Gesoma sandstone.

In Duhun, it is only about 15 m. thick and is also overlain with Gesoma sandstone.

6. Ferfer gypsum

Age : Cenomanian

Characteristics : It consists of greyish-green and sometimes motley gypsum intercalated between marl layers rich in sodium chloride with Lumichell fossiles. Other fossiles such as Mytilus, Anomia and Corbules have also been identified.

Location : This formation, the thickness of which is not exactly known, is weakly extended in the Basin. It is mainly represented in the Ferfer region (small hills) and in the last drainage basin of the Fafen (flat Iglole zone) and also to the South-East of El Kere forming small pitons surmounting the Mustahil limestone plateaus.

7. Belet Uen limestone

Age : Cenomanian

Characteristics : Limestone is dominant in this series : limestone conglomerates with intercalated motley gyspsum with fossiles such as : Echinids, Lamellibranches, Gastropods and Ammonits.

In the surveyed zone, the mean thickness of this formation is 20 m.

Location : The Belet Uen limestone outcrops East of Ferfer and South of Shilavo at the Eastern limit of the Korahe plain.

From Shilavo to Korahe, to the East of the track, can be seen small, 20 to 30 m high, limestone hills with some gypsum intercalations (hills North of Shilavo). Surrounding the Dobowein depression on the Eastern side, and from Shilavo to Iglole, it forms large flats with a "tiger-striped" vegetation and is often covered with deposits derived form Gesoma sandstone (regions of Northern-Shilavo, North-Eastern Shilavo, Iglole).

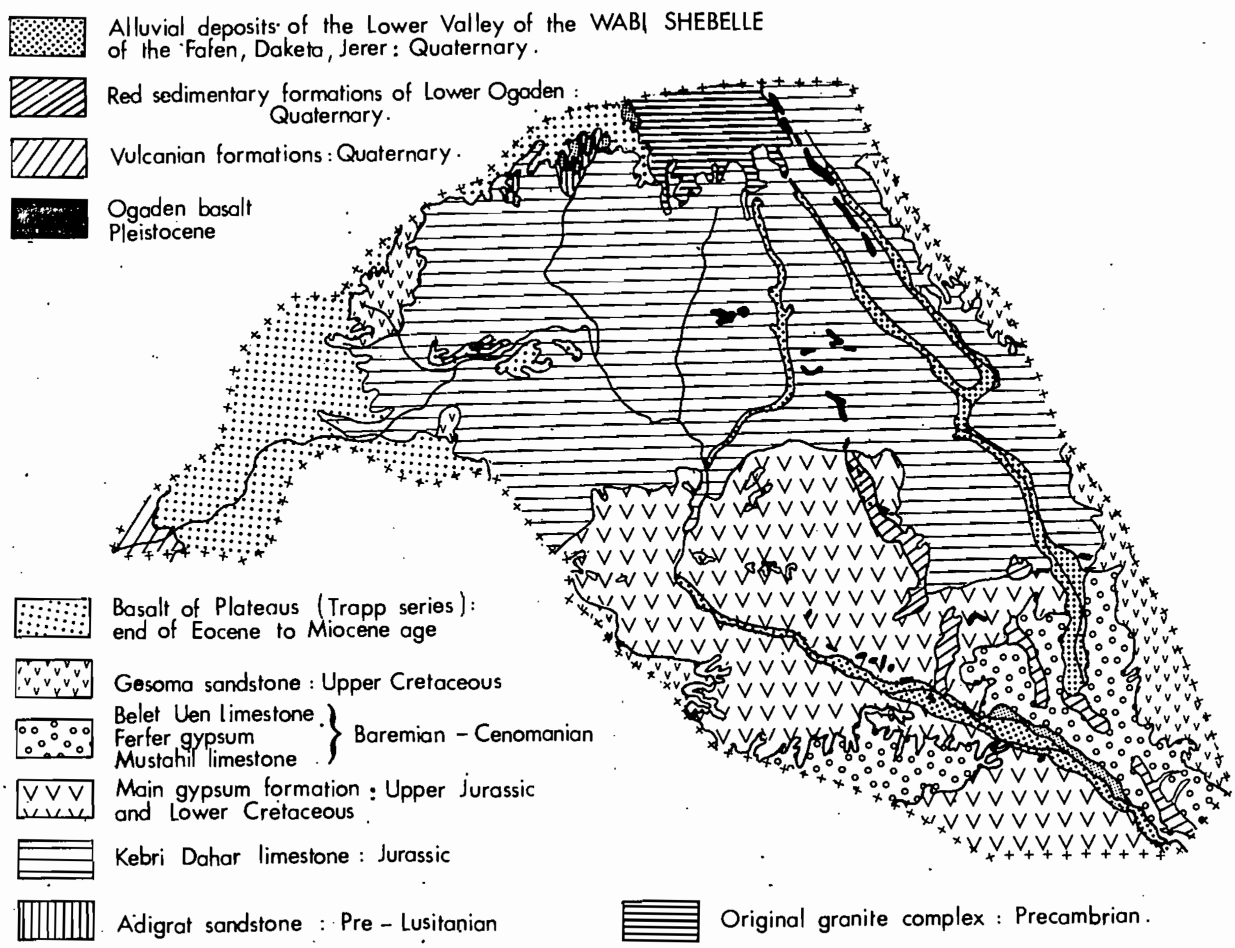

Fig. 3 : GEOLOGICAL SKETCH OF THE BASIN OF THE WABI SHEBELLE.

8. Gesoma sandstone

Age : Upper Cretaceous

Characteristics : This sandstone presents the following various facies, i.e. :

- very hard and fine-grained sandstone, either white, purplish, bluish or white with purple haloes.

- coarse-grained and very friable sandstone, either red, purple or brown.

No fossiles exist but the ancient-sea origin of this formation is almost certain. This transgressive sandstone rests on Belet Uen, Mustahil or Kebri Dahar limestone.

Location : mainly at the Eastern limit but large remnants may be seen in the West and North-West.

East of Shilavo, the formation largely spreads to Warder and consists of red coarse-grained and very soft sandstone which has soon been dismantled, forming a bright red weathering layer. The limit of the Basin is only marked, 25 km to the North West of Shilavo, by a 4 m high cliff which rises 20 m higher in the North of Ferfer. Several hillocks, about 10 m. high, precede these cliffs and are covered with friable motley sandstone.

In this region, the formation overlays the Belet Uen limestone. East of Jerer, Gesoma sandstone forms tabular plateaus ending as cliffs, 50 m high and very distinctly seen to the East of Degahabour :

The cross-section of the cliffs, from the top to the base, corresponds to :

- Bluish quartzite sandstone : 3 m thick
- Purplish, very hard sandstone : 7 m thick
- Red, coarse-grained and soft sandstone with intercalated small, purplish sandstone beds : 40 m thick.

The hard top sandstone has protected the subjacent soft sandstone against weathering and it constitutes the steep and concave edges of plateaus.

In this zone, Gesoma sandstone rests directly on Kebri Dahar limestone and disappears in the centre of the Kebri-Bayah township. In the regions of Kulilitcho Mine and Mechiarra, Gesoma sandstone is largely developed. It is red or yellowish, usually coarse-grained and frequently weathered.

In the upper zones, it forms hills deeply cut by erosion and in lower zones, some large and gently rolling plateaus. It directly overlays the

Kebri-Dahar limestone. In the Ginir and Shek Hussien regions, this formation is represented at the top of the Ouatou and Shek Hussien mountains as red coarse-grained sandstone leaving thick deposits on the neighbouring areas. This sandstone is 200 m thick on Ouatou Mountain and 400 m in the Shek Hussien mountains and it directly overlays the Kebri-Dahar limestone.

This formation also constitutes the El Kere group in the South West of the Basin (altitude 200 m compared to the general level). In this region, sandstone is more than 100 m thick and consists of thick red layers intercalated with softer white clay beds and it rests directly on the Mustahil limestone. The limit between these two formations is in fact marked by a series of springs.

The Duhun mountains are 280 m high, compared to the general level, and consist in the upper part of 115 m thick bright red Gesoma sandstone near Duhun, forming vertical cliffs several dozen meters high and resting on the Mustahil limestone which is not very thick in this region.

9. Trapp volcanic series

Age : Eruptions began during the Eocene, were most active during the Oligocene and ended at the Miocene age when the fracture system of the Rift Valley began appearing.

Characteristics : The series consists of basalt and trachytes with intercalated pink tuff, these formations belonging to the Magdala group characterizing the volcanic series of East-Central Ethiopia. However, the upper parts of plateaus usually consist of basalt flows giving the Arussi plateaus their characteristic tabular aspect (called "Ambas" by the Ethiopians).

The thickness is variable and often considerable but may not be easily estimated. In the Legehida region where only strips remain, thickness does not attain more than 100 m., in the Malka Wacana region it is 300 m, on the Arussi Plateaus it attains 800 to 1.000 m and in the mountainous zones (Boraluku-Kaka-Enkolo) it is probably more than 2.000 - 2.500.

Location : The Trapp volcanic series form the entire belt of the High Plateaus of the Basin and of the mountain range limiting the latter to the East and North, except for the Harar and Gedeb zones.

Further South, some remnants cover the Jurassic sedimentary series : Karamara mountains (Jijiga), or the Cretaceous sedimentary series : Legehida plateau and Shek Hussien mountains.

The lower limit of the formation on the High Plateaus has been observed in Northern Chercher where the Trapp series usually rests directly on the Kebri Dahar limestone with zones where red sandstone is once more intercalated between these two formations. In Western Chercher, the series probably overlay the Gesoma sandstone.

In the Malka Wacana region, the series is in contact with the Kebri-Dahar limestone.

10. Pleistocene and Quaternary formations

Linked to the formation of the Rift Valley, West of the Basin, less considerable tectonic movements occurred in Lower Ogaden leading, in particular, to the formation of the tectonic basins of the Wabi Shebelle (NW-SE) and of the Fafen (N.N.O.-S.S.E.)

Faults in the sedimentary plateau with limited basalt flows can be observed. Besides, the volcanic activity in the Rift Valley and Awash affected several regions of the High Plateaus.

10.1. Basalt formation of Ogaden

These formations consist of basalt with abundant ferromagnesium and olivine and sometimes of green rocks, and form hills approximately 50 m. high with a characteristic morphology presenting a crescent,arched or "caterpillar" aspect.

They appeared at the same time as faults in sedimentary formations when tectonic movements affected the Rift Valley. These formations cross-cut the faults and are displayed in the following directions :

- Gode - Northern Imi line : S.E. - N.W.
- Dagamedo-Fick line : S.S.E. - N.N.W.
- Danan-Duhun line : S.E. - N.W.

Several isolated outcroppings also exist in the axis of the Fafen Valley : East of Kebri Dahar and West of the Dobowein depression.

10.2. Vulcanian formations of Arussi

The Quaternary volcanic eruptions of the Rift Valley and of the Awash Valley mainly consist of ash, pumice and acid lava (bombs). This material covering all the region of the lakes and of the Awash plain is also deposited beyond the tertiary volcanos of Kaka, Enkolo and Boraluku, on the plateaus of Arussi and Northern Bale.

10.2.1. Vulcanian formations of the Gedeb plain

Limited by the Dodola-Adaba track in the South, by Mount Kaka and Enkolo in the North and the Malka Wacana falls in the East, the Gedeb plain entirely consists of volcanic material of vulcanian type. A cross-section at Andassa ford on the Wabi Shebelle shows more than 50 m thick alternated ash and lime tuff with an intercalation in the upper part of a 4 m thick ryolithic scoriaceous layer, all this material resting on tertiary black basalt.

10.2.2. Vulcanian formations of Kofele

They are located at the Western end of the Basin and consist of ash layers intercalated with relatively thin ryolithic layers. These formations are more than 300 m. thick and present a characteristic morphology with "half-orange"-shaped hills deeply cut by erosion and flat valleys.

10.2.3. Surface ash-formations of Gedeb and Arussi

This grey ash is seldom more than 40 cm thick and covers the weathered basalt in situ. It results from the powdering of volcanic ash from the quaternary volcanos of the Rift Valley and of Awash. This ash is mainly located between Kofele and Dodola and on the Robi plateau in the Kula and Adele regions.

10.3. Sedimentary formations of Ogaden

The upsetting of the equilibrium profile of streams due to an elevation of the peripheral zones of the Basin causing a general rise to the N.W. of sedimentary layers, produced a resumption of the erosion process in the form of considerable sedimentation in Lower Ogaden, in particular, i.e. :

- Filling in of the basins of the Wabi Shebelle and Fafen (Korahe and Dobowein depressions) by alluvial deposits of volcanic origin from the High Plateaus.

- Spreading of material of local sedimentary origin in the other zones by weathering of sediments in situ : Gode area (alluvial deposits with pebbles), North-West of Imi, Danan, North Danan, part of the Dobowein depression and the last depression of the Fafen.

D. GEOMORPHOLOGY

The Basin in general, consists of a series of sedimentary and volcanic strata overlaying the rocks forming the base and outcropping in the Northern part as well as in the South of Somalia and in the South of the country bordering Kenya. These layers present a very small South-Eastwards dip.

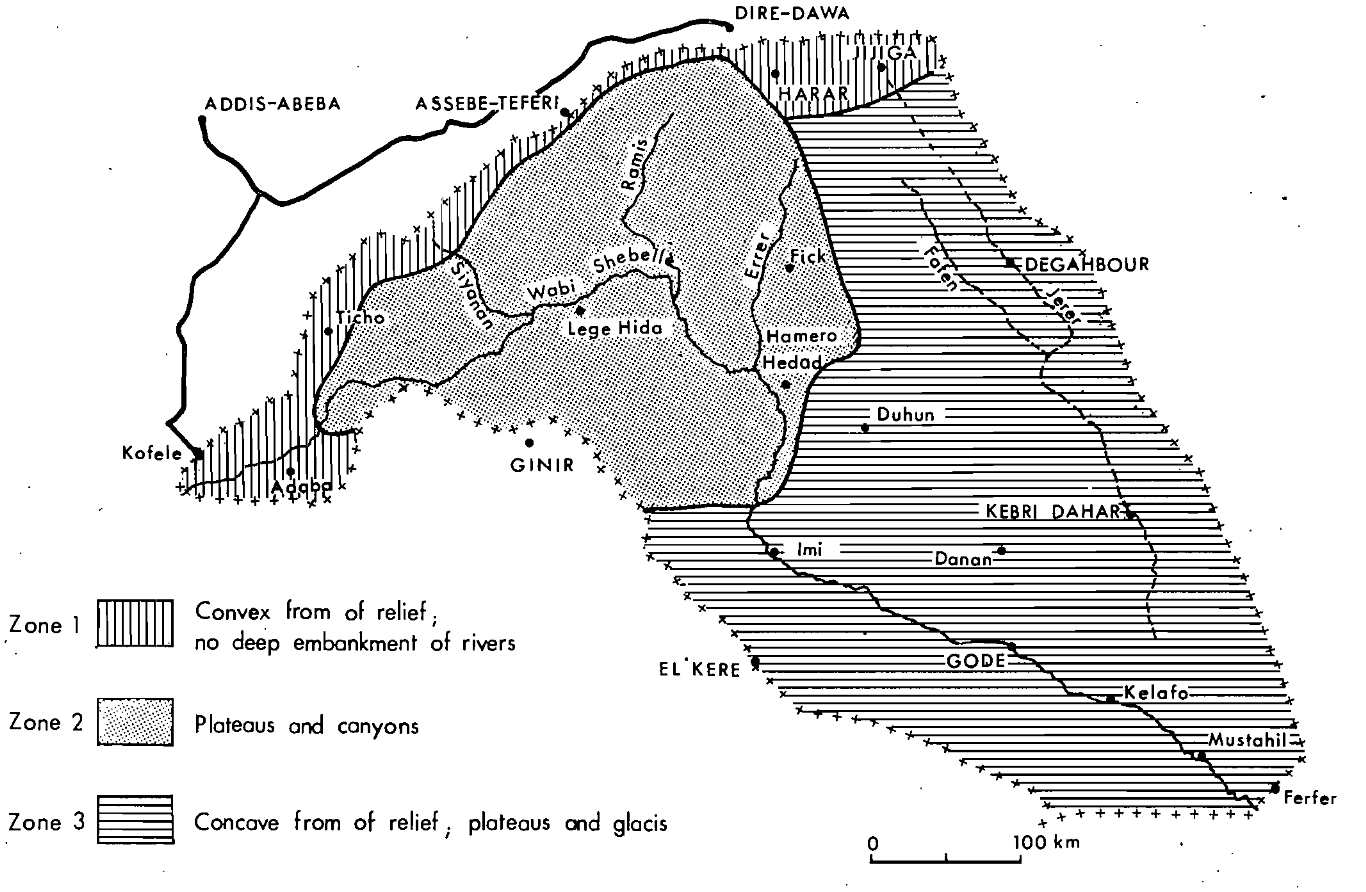

Fig. 4 GEOMORPOLOGICAL SKETCH OF THE BASIN OF THE WABI SHEBELLE

The sedimentary soils deposited during the Secondary age were most probably no longer flooded during the Tertiary age and levelled by weathering. Two main events occurred during the Tertiary and the Quaternary : thick volcanic flows covered Central Ethiopia, the Rift Valley collapsed whereas its edges were probably elevated and new volcanic material spread out.

The rising of the Northern and North Western part of the basin caused the rivers to sink into very deep canyons.

As a consequence of these events, three zones appear and present different types of relief : (see fig.4) :

1. Northern and North-Eastern border of the Basin :

Its altitude varies from 2.000 to 3.000 m. Isolated mountain groups of volcanic origin are more than 4.000 m. high. The substratum consists of granite-gneiss and limestone in the East and basalt in the West. Despite the altitude, the relief is not pronounced and is usually even. Slopes are frequently convex or convexo-concave. Streams are not deeply embanked and the bottoms of valleys are sometimes underdrained (region of Northern Harar). The effects of weathering are not very distinct and all the more so as the remnants of forests cover most of the high mountainous groups. This region is limited by two very distinct and very steep slopes, one of them corresponding to the limit of the Rift Valley. A series of faults displayed in the form of steps leads to the bottom of the breach. But, Southwards, the limit is very sinuous and corresponds to the upstream part of canyons where the rivers suddenly sink. The width of this zone varies from several dozen kilometers to some hundred meters.

2. The second zone

continues the first towards the South East but is very broken up by canyons several hundred meters deep. The old basalt or limestone plateau is cut into E.S. strips and consequently, it is difficult as well as expensive to set up communication media between the plateaus. This part of the basin is usually known as the "Middle Belt".

3. The third zone

corresponds to the rest of the Basin and includes the Eastern and Southern parts of the area under study. Large plateaus edged by relatively abrupt sandstone or limestone bluffs may be observed but these seldom rise to more than 100 m above the landscape. The valleys are usually wide and, apart from the valley of the Wabi Shebelle which receives water from Arussi, seldom occupied by rivers. Long, concave slopes with a small angle of dip and bluffs and usually covered with trees form the link between the bluffs and the drainage areas. The material of the minor beds of streams............

is transported only by water except for the Wabi Shebelle river bed. Elsewhere, the material is torn off from the steep part of slopes and distributed at a short distance in the downstream part.

Relation between the type of relief and the spreading of material from which soils are derived.

In the high altitude zones of the Northern and North-Western areas, the profile observation does not show a discontinuity between the surface and the soil subjacent rock. This is the case for soils derived from basalt, volcanic tuff and limestone sediments. It seems that the soil or material from which it is derived has not been altered.

Conversely, in the Eastern and Southern area of the Basin, the weathering of rocks was accompanied by often considerable movements of material. In this case, at the base of profiles, especially when they are located in a plain at some distance from bluffs, a real line of stones continuing the upper part of the profile and consisting of loose and relatively homogeneous material, may be observed. Soils originate from this material transported from upstream and are not derived from the weathering material of the underlying rock.

E. AGE

At present, no suitable chronological elements giving an idea of the age of soils, are available.

The soils of the High Plateaus are among the oldest soils and the overlying vertisols are probably relatively ancient. This is also true for soils on the limestone plateaus in the Centre and South of the Basin.

On the other hand, some "brown soils" derived from basalt on steep slopes were certainly rejuvenated by erosion. The soils of the glacis of the Centre and South are relatively recent though the material from which they are derived was formed in remoter periods. All the soils derived from ash (chernozem, for instance) are also relatively recent.

III. SOIL-FORMING PROCESS

To the soil-forming factors examined previously are due the manifestation of soil-forming processes which are widely represented in many regions of the intertropical zone. It is interesting to note that the leaching process (washing down of clay from the upper part of the profile with accumulation in the lower part) is seldom observed and concretioning and induration of sesquioxides are unknown in the surveyed basin. Conversely, the various forms of calcareous accumulation constitute a fundamental process in a considerable part of the Basin.

A. FORMATION AND ACCUMULATION OF CLAY MINERALS

Soil clay minerals have not been systematically examined in the main soil categories of the Basin. However, the results already obtained are sometimes at variance with the general observations made on categories of soils similar to those existing in the Basin.

Minerals of the Kaolinite family are identified in the ferralitic soils derived from basalt of the North-Western border and in the fersiallitic soils of the Northern and North-Eastern area.

Minerals of the illite family are identified in many soils among which, the chernozem of Arussi.

Smectites were identified in the vertisols of the High Plateaus. The alluvial deposits of the Wabi Shebelle in the Gode region present abundant montmorillonite which certainly originates from the High Plateaus.

Not well defined minerals, the study of which could not be completed, were extracted from various soils associated with the limestone and gypsum of the South-Eastern area of the Basin.

As regards the genesis of minerals, definite rules may not yet be determined. In the wetter part of the Basin, synthesis is the rule and the clay minerals of ferrallitic soils, fersiallitic soils, vertisols etc... were formed accordingly. Conversely, in the drier area, in soils derived from limestone rocks as well as in alluvial soils in early stage of development, minerals result from a drifting process. It is difficult to speak of a "transformation" as no study is yet accurate enough to reveal this. Though iron hydroxide is abundant in some soils of the Basin, the existence of alumina hydroxide is not proved.

B. FORMATION AND ACCUMULATION OF AMORPHOUS MINERAL MATERIAL

Along the Northern and Western outskirts of the Basin, the high mountains culminating at more than 4.000 m receive considerable rainfall and present a generally low temperature. The original material consist of basic volcanic rocks forming a succession of mountain masses. The relatively low forest of epiphytes is often replaced with a bushy vegetation.

The conditions existing in these mountains are favourable for a considerable accumulation of organic matter as well as of amorphous mineral material. Hydrolysis of the minerals constituting the rocks causes almost all the alkaline and earth alkaline bases to disappear as well as a great quantity of silica. Perhaps on account of the high amount of organic matter, there is no crystallization of mineral products which accumulate as amorphous material. The particular characteristics of soils such as their high water content, their very low specify gravity and their smeary feeling are due to the abundance of organic matter and of amorphous mineral material.

The existence of amorphous material may be revealed by the Fieldes and Perrot test (1966) which consists in treating a soil sample with sodium fluoride in the presence of phenolphtalein. The presence of amorphous material sets OH ions free and this causes the colouring to turn purplish. This test was also made on other soils of the Basin but the result was always negative.

Thus, the soils which contain considerable quantities of amorphous material are called "Andosols" in the French classification. The individual character of this class has often been questioned but is now accepted. It is divided in two sub-classes according to the existence or not of a weathering horizon (B).

In the American classification, the andosols are but a sub-order of inceptisols of "andepts". In the F.A.O. soils units, these soils are also called "Andosols".

In the Basin, andosols do not extend far and their practical use is very limited.

Relatively low contents of amorphous material in other soils derived from volcanic ash were also identified as, for instance, the chernozem of Arussi.

C. ACCUMULATION OF ORGANIC MATTER

In this Basin, rainfall considerably varies from 200 mm. to 2.000 mm and the temperature, from 12°8 to 28°. A remarkable feature is the more or less extended rainfall distribution throughout the year. Even in the South-East of the Basin, the two rainy seasons partly reduce the impression of aridity due to such low rainfall.

In the medium and upper zones of the Basin, the rainy season lasts at least 7 months and sometimes 9 months or more.

The mean monthly temperatures present small variations throughout the year and are gradually lower from the South East of the Basin to the North and North-East.

The whole Basin is generally well drained. The variations of altitude being often very sudden facilitate drainage but, on some plateaus, small areas allow a local stagnation of rain-water. But in the Lower Valley, a zone located between Kelafo and Mustahil is locally underdrained. A cyperacea vegetation grows and is emphasized by a distinct thickening of humic horizons.

The natural vegetation does not seem much deteriorated except in densely settled zones. Shrubs are numerous and scattered in the downstream part of the Basin and gradually, as one penetrates in the more humid sectors, the size and number of trees increase. Gramineae are present everywhere, first in isolated tufts and then in denser stands. In some areas, trees are scarce or non-existent as in the Gode or Gedeb plains. In a region where trees exist almost everywhere, it seems difficult to explain their absence by climatic or pedological causes and the local and intense action of man (cultivation and livestock breeding) is the probable reason.

Fire is not a generalized factor as in other regions of Africa or Madagascar, and stretches of savannahs burnt every year are never seen here. This may be due to the length of the rainy season in the upstream part and to the bad quality of the vegetative combustible in the downstream part.

The resulting content of organic matter is variable. It is always very weak in the Lower Valley : less than 1 percent and often approximately 0,6 percent.

The content gradually increases and is about 3,4 percent in the Harar region, 6 - 8 percent in Arussi (plains) and more than 20 percent on the volcanic peaks in the North West.

The distribution of organic matter in the profile is always gradual and this is true in sub-arid zones as well as in rainy zones. For instance, in Arussi, the distribution of organic matter in chernozems and other soils (ferralitic and vertisols) is not very different.

In the subarid zone of the Lower Valley, the content of organic matter is hardly visible in the upper part of the profile. In other areas the horizon presents a particularly distinct colour.

The organic matter content is an important characteristic of several soil classes : " brown soils ", some soils with a calcareous differenciation, andosols and vertisols.

In the andosols located at the divide between the Awash Basin and the Wabi Shebelle Basin, organic matter is acidic and the content is higher than 20 percent.

In chernozems , the humic horizons are particularly dark ; pH is neutral to slightly acidic. The content is not more than 6 - 7 percent at the surface.

The vertisols of the High Plateaus are generally very dark. The structure of the upper horizon is very divided up. The organic matter content is slightly less than in chernozems and varies from 4 to 6 percent.

The vertisols of drier regions are much browner and the content of organic matter is distinctly lower.

The brown soils of the high mountain ranges of Chercher have a neutral reaction and a high content of organic matter.

D. ACCUMULATION OF SALTS IN SOILS

1. Limestone in soils

Owing to the importance of limestone rocks as original material of soils, the presence of calcium carbonate appears as an important differenciating factor.

However, it is essential to make a difference between primary limestone present in soils and which is a residue resulting from the incomplete dissolution of rocks still in process, and lime resulting from the formation of secondary calcium carbonate in soils. In the first case, it appears as rock-fragments at a weathering stage and, in the second case, it is a synthesis of the mineral in the profile during the pedogenesis. Consequently, considerable differences will be observed in the factors of the soil-forming processes.

Dissolution of calcium carbonate : In some soils, limestone is at a dissolution stage and may be found in soils as fragments of variable sizes but with generally smooth sides though some grooves may be observed. Sometimes the presence of limestone increases from the upper part to the base of the profile. This category of soils belongs to the calcimagnesimorphic soil class in which can be found brown calcareous soils, rendzinas and some brown calcic soils.

Formation of calcium carbonate : This concerns numerous soils in all the area where, at present, temperate, xerotheric and tropical climates exist. The second and third climatic regimes are those corresponding to the most deeply marked individual characters.

In fact, powdery calcareous accumulations, heaps, nodules and crusts may be observed. All these forms of accumulations result from the pedogenesis and is sometimes accompanied with an accumulation of organic matter, but in most soils, the latter is either weak or scarcely visible.. Consequently, it seems reasonable to classify these soils according to the presence of limestone, as suggested by Ruellan (1972).

According to the nature of the accumulation, the soil is described as : a slightly differenciated calcareous profile (diffuse lime or pseudo-mycelium) to a medium differenciated limestone profile (limestone being discontinuous, in heaps, nodules or concretions) or a strongly differenciated limestone profile (limestone appears in a continuous form as a friable or hard crust, a crust or film).

It must be noted that some vertisols also contain large quantities of secondary limestone.

2. Gypsum in soils

Gypsum outcrops on a vast area in the South East of the Basin. Two Jurassic and Cretaceous layers mainly, characterize the zone under study, especially in the drier area. As in the case of limestone, dissolution processes as well as other processes due to rainfall may also be observed for gypsum.

On large areas, gypsum is divided and at a dissolution stage, in which case the soils belong to the weakly developed soil class.

But even in a sub-arid zone, owing to the great solubility of gypsum (2 g/l) which locally increases in the presence of salt, gypsum is mobilized and reprecipitated. Consequently, soils with a gypsum differenciation exist but only two types out of three were observed, namely : soils with a slightly differenciated gypsum profile where sulphate is distributed homogenously in the profiles, and soils with an important differenciation of the gypsum profile and crusts of variable thickness.

3. Accumulation of sodium chloride in soils :

Sediments with much sodium chloride are nowhere observed. Water from the Wabi Shebelle is scarcely salt-loaded and consequently, the salt accumulation in soils is relatively limited, not largely spread and only appears in the drier regions such as the farthest South-Eastern part of the Basin between Kelafo and Ferfer. Saline efflorescences are visible there and halophyte plants grow on relatively large areas between Burkur and Ferfer. Soils turn powdery at the surface.

The fixation of sodium on the absorbing complex is nowhere apparent and no modification of the structure suggesting solonization or an unusually high pH are observed.

E. ACCUMULATION OF IRON OR ALUMINIUM SESQUIOXIDES IN SOILS

In the wetter parts of the Basin a reddening of soils may be observed together with a distinct deepening of profiles. These soils mainly exist in the Northern periphery and in different isolated points in the Centre. Rainfall in most cases is more than 800 mm but mean annual temperatures vary between 13° and 18°.

Goethite and amorphous material are the main constituents.

The existence of these materials is surprising in the climatic conditions described for Chercher and Arussi. In fact, no temperate zone presenting deep ferrallitic soils which might be comparable in similar climatic conditions seem to have been observed yet.

It is therefore necessary to consider either a change of climate or both a change of altitude and of climate. This last assumption seems valid in the zone surveyed.

Besides, ferruginous or manganesiferous concretionnings are seldom observed probably owing to two reasons, i.e. :

- there has been in the past no generalized formation of hardpans as may be observed in Central or West Africa where hardpans have fossilized very old levelled surfaces.

- no conditions exist at present allowing the mobilization and concretionning of iron. In fact, drainage seems suitable almost everywhere and the redox conditions are not favourable for iron reduction and migration. However, in the brown mesotropic soils of the Kofele region where pH is slightly acidic, abundant ferruginous and manganesiferous concretions may be observed which can exist in a slightly drained sector until a friable crust is formed (Kofele - Sire track).

F. FORMATION OF GLEY AND PSEUDO-GLEY

Alkali or neutral soils are unfavourable for the formation of gley or pseudo-gley. Hydromorphic characters are only revealed by the existence of calcareous accumulations of nodules in certain soils. However, in slightly acid or ashy material, distinct migrations of iron and manganese may be observed but these hydromorphic processes are limited.

In the Basin, hydromorphic soils are consequently scarcely-developed and tropical ferruginous soils are unheard of.

IV. REMARKS ON THE CLASSIFICATION OF SOILS

The classification of soils adopted for the Basin of the Wabi Shebelle is drawn directly from the document drafted by the C.P.C.S. (1) in 1967. This was considered by its authors as a provisional study which ought to be resumed as certain classes seem to have been determined more accurately than others.

Ethiopia is a country where a very short knowledge of pedological conditions existed when the survey began. The Basin of the Wabi Shebelle presents original features.

- From the climatic point of view : on a large area, aridity is very pronounced in spite of the proximity of the Equator and of the existence of two rainy seasons. A great part of the Basin has a tropical regime but large sectors have climates close to the mediterranean or temperate regimes without presenting at the same time all the usual features of the latter. This gave rise to some difficulties when determining certain soil sub-classes on climatic bases.

- From the parent-rock point of view : the predominance of rocks with abundant calcium (carbonate, sulphate, basalt) is an exceptionnally important feature.

- From the geomorphological point of view : the monoclinal display of sedimentary layers with a small South-Easterly dip, a landscape broken into plateaus, residual hills and valleys are the main characteristics.

C.P.S. (1) "Commission de pédologie et de cartographie des sols" (Pedologic and soil-mapping Commission). This document is in fact the result of studies classified according to the first French soil-classification (Aubert and Duchaufour 1966) and of the O.R.S.T.O.M. studies.

The general classification could be applied to this region without any real problem for most of the soils. Nevertheless, the isohumic soil-class cannot be used as it is in the Ethiopian context.

Of the twelve classes of the classification, the raw mineral soils and podzolized soils are the only soil classes which are not represented.

Soils in early stage of development.

The sub-class of xeric soils in early stage of development with the grey soil group has been noted.

The sub-class of non-climatic soils in early stage of development with eroded, colluvial and eolian soils are well represented. In most of the groups and sub-groups, the influence of limestone and gypsum is considerable.

Vertisols

These soils are characterized by their morphological features (dark colour, shrinkage cracks, slickensides). All of them belong to the class of vertisols with a limited external drainage. In fact, they are derived from rocks with abundant calcium, and are formed on very level topographies (basalt flows, limestone plateaus or alluvial deposits).

The structure of the upper part of the profile is always rounded and much divided (grumosolic horizon). Vertic characters are well marked everywhere but two sub-groups are particularly interesting, i.e. :

The yellowish-brown to reddish brown sub-group with powdery lime and gypsum crystals is well represented in the drier parts of the Basin. The profile is not so thick as in the wetter areas where the greyish-black sub-group predominates with a profile often several meters thick and, in many cases, a high content of organic matter at the surface.

Andosols

These soils are characterized, in particular by abundant amorphous mineral material which may be identified locally by the Fieldes and Perrott test. The recent outline set up by a survey group on andosols was used for this class.

The presence of a (B) horizon enabled classifying andosols in the sub-class of differenciated soils. Their low saturation grade allows considering them as desaturated soils and because of their colour, they belong to the melanic sub-group.

Soils with abundant calcium carbonate and sulphate

Soils with calcium carbonate or sulphate raise more problems. Three distinct units are determined at the class level :

In the first, soils with limestone obviously inherited from the parent rock at the dissolution stage. These are calcimagnesic soils.

In the second, "soils with a differenciated gypsum profile" ; the calcium sulphate is redistributed in the profile in a powdery form or as a crust.

In the third "soils with a differenciated calcareous profile" ; the calcium carbonate is redistributed in the profile in numerous forms recently described by Ruellan (1971). This name was preferred to the traditional term of "isohumic soils" for the following reasons :

- The typically isohumic distribution is that of chernozems in the Basin of the Wabi Shebelle but it can also be observed in other soils such as vertisols and ferrallitic soils.

- The usual subdivisions of the class are based on climatic considerations which are not valid here, and consequently, it seemed more suitable to take only into account morphological, physical or chemical considerations.

- The two factors : organic matter and limestone are "competitive" here. Only chernozems present an "organic profile" which may be used to define them. Conversely, in most soils, the content of organic matter tends to be very weak and often less than 1 percent and in some soils, the humic horizon is scarcely distinct. But in all these soils, whether they are derived or not from limestone, calcium carbonate is always well differenciated and accordingly, the different types are easily and logically considered distinctly.

- Calcium sulphate plays in the Basin an important role similar to that of calcium carbonate. Consequently, it is useful to put these two salts together in the classification.

Calcimagnesic soils

These soils are divided in carbonaceous soils and saturated soils. The carbonated soils include the following groups : brown carbonaceous soils and rendzina. In these soils there is no calcareous differenciation.

Saturated soils and the groups of brown calcic soils and calcic rendzina do not react with acid.

Soils with a gypsum differenciation

Though no sub-class is determined, two groups are observed : with powdery gypsum (with the modal and vertic sub-groups) and with crusts (modal). No group with accumulations and nodules seem to exist.

In these two groups, the gypsum of the profile results from an oblique redistribution through dissolution (finding its origin upstream) which is followed by a reprecipitation.

Soils with a calcareous differenciation

Two sub-classes were observed. In the first exists a thick, dark and saturated humic horizon (corresponding to the specific features of the melanic horizon of the F.A.O. "Soil Units"). In the second, this melanic horizon does not exist but instead, a "pallid horizon" (corresponding to the description in the F.A.O. Soil Units) is observed.

In each of these sub-classes four groups are included :

Group 1 : with an invisible diffuse calcareous accumulation.

Group 2 : with a visible but discontinued calcareous accumulation (with heaps and nodules).

Group 3 : with a continued, visible but friable accumulation.

Group 4 : with a visible, continued but hard accumulation (various types of crusts).

The sub-groups envisaged are for group 1 :

a modal sub-group (which is the equivalent of the carbonated sub-group).

For the following groups :

- a carbonated sub-group : the part of the horizon around the accumulations also consists of limestone.

- a calcic sub-group : the part of the horizon surrounding accumulations does not consist of limestone.

- a vertic sub-group : slickensides may be seen in the depth.

Thus, all the soils with an isohumic distribution of organic matter and a calcareous differenciation may be distinguished quite easily on the field. In every case, the calcium carbonate of soils is derived from the limestone formed during the pedogenesis.

"Brown soils"

In the C.P.C.S. classification, soils are differenciated according to the types of climate. The most suitable sub-class is probably that of the "brown soils" of humid, temperate climates, as these soils are present in the temperate and humid zone of the Basin.

The group of brown soils with modal and scarcely developed sub-groups and the group of brown mesotropic soils with an hydromorphic facies are well represented.

Soils with iron sesquioxides

They are represented by the two classes of fersiallitic and ferrallitic soils observed on the Northern and North-Western border of the Basin.

Characteristic saturated fersiallitic soils exist in the Harar region. They are derived from various base-rocks such as granite, Adigrat sandstone, Kebri-Dahar limestone. They can be identified on the field owing to their moderate thickness and a prismatic structure in the depth.

Ferrallitic soils are represented especially in the West of the Basin. They were identified on the field mainly because of their morphology (Developed C horizon and deep weathering, deep colouring of very friable B horizon often presenting pseudo-sand). Their analytical features show that they should be classified in the sub-class of weakly desaturated soils. In fact, they are often practically saturated. Furthermore, the determinations of clay minerals reveal the frequent presence of illite together with kaolinitic minerals and iron hydroxide. This leads to believe that, in fact, these are intermediate soils between fersiallitic and ferrallitic soils. No induration process was observed (concretion or hardpan), and no hydromorphy in the soils.

A single very characteristic group with three sub-groups (modal, humic and scarcely developed) were observed.

Hydromorphic soils

They are formed through the influence of high ground water table or of long action of ground water and they belong to the sub-classes of mineral and moderately organic soils. In all these soils, limestone exists; and in all the groups with gley or humic with gley, they are represented by sub-groups with powdery lime or in heaps and nodules.

V. DESCRIPTION OF THE MAIN CATEGORIES OF SOILS

- In this part of the report the physico-chemical characteristics of soils are described and the various soil categories are presented in the same order as in the soil legends of the soil maps joined to this report.

- These soil categories are limited to the soil family corresponding either to a type of geological material for soils in situ, or to alluvial and colluvial deposits for soils on transported material.

- As 65 soil families exist, the morphological and detailed physico-chemical data are limited to the most extensive soil categories in the Basin, as well as to those presenting an economic import even though they are not largely spread. Other families are studied more shortly but their main physico-chemical characteristics are mentioned.

A. CLASS OF SOILS IN EARLY STAGE OF DEVELOPMENT

Xeric soils in early stage of development

1. Grey gypsum soils derived from the main gypsum formation (1a) and from Ferfer gypsum (1b).

These soils spread on a total area of 6037 km2 in the farthest South-Eastern part of the Basin.

They occupy :

- on the one hand : vast absolutely flat gypsum areas, the monotonous aspect of which is only disturbed here and there by small reddish limestone beds, intercalated with gypsum forming 50 cm to 1 m high bluffs which are distinctly seen in the Godere region.

- on the other hand, gently sloping banks on the Ferfer gypsum under the Belet Uen limestone between Bargun and Ferfer. The vegetation consists of a usually dense thicket of *Boswellia* spp. and *Jatropha rivae* with a characteristic "tiger-bush" pattern on aerial photographs. Annual rainfall is only approximately 150 mm and soils are scarcely developed.

Morphology : Profile observed 4 km to the North of Godere ;

0 - 10 cm A_1	: Yellowish-grey (2,5 YR 8/4) ; loam; single-grained, and powdery ; many disaggregating gypsum nodules ; dry and friable ; some rootlets ; short transition to :
10 - 60 cm C	: Grey weathering layer of gypsum in situ forming 5 cm thick friable strata alternated with yellowish-grey powdery layers of very compact gypsum ; some rootlets ; sudden and uniform transition to :
60 cm + R	: Greyish, massive and not very hard gypsum slab.

Physico-chemical characteristics :

The yellowish-grey (2,5 YR 8/4) upper horizon A1 of soil consits of a fine gypsum powder, the real texture of which is not easily determined but which appears as loam to silty loam, the whole structure resting on a gypsum slab. The depth of the latter varies in relation to the local colluvial deposits, from 10 to 80 cm depth. Above the slab, not yet completely weathered gypsum nodules may be frequently observed and may constitute a real C horizon.

- These are limestone soils (21 percent in the horizon above the slab).
- The content of organic matter is low : approximately 1 percent.
- Alkaline pH, approximately 8,0.
- Conductivity is high with 15 mmhos of the saturation extract. In fact, large quantities of sodium chloride exist with calcium sulphate in the gypsum formations.

These soils present no economic interest but may constitue a large game reserve.

Non-climatic soils in early stage of development.

Group : erosion soils.

These soils on steep slopes and resulting from weathering are consequently not very thick. Two groups are differenciated in relation to the presence or lack of limestone.

Sub-group lithic soils with powdery lime

2. Yellowish-red soils derived from Kebri-Dahar limestone

They spread over 7663 km2, on the steep slopes of the canyons of the Wabi and of its tributaries and correspond to one fourth of the Basin in the North-Western part. The vegetation on the slopes mainly consists of *Boscia minimifolia* and *Delonix elata*.

The soil presents 90 percent of calcareous elements of variable sizes, from worn gravel to 30 to 40 cm large angular limestone blocks, and 10 percent corresponds to fine yellowish-red earth : lime-clay loam (30 percent of calcium carbonate. This soil overlies the gypsum in situ at a small depth of 10 to 20 cm. When the slope is too steep, soil is inexistent and the rock is bare.

These soils present no economic interest.

3. Lithic soils with diffuse calcium sulphate on shallow slab derived from the main gypsum formation.

These soils are formed on the small "cockade-shaped" gypsum hills of the main gypsum formation which occupies a very considerable area in all Lower Ogaden to the South of a line : Duhun-Kebri-Dahar. They are associated on the maps with soils with a gypsum differenciation ; modal soils with crust (family 54) developing on the colluvial and alluvial deposits of foothills (Association I Lower Ogaden) and in the Duhun region with the soils of families 42 and 48 (Association IV, Duhun). They stretch over 20.000 Km2 but the importance of the hills compared to the deposit zones varies according to regions.

South of the Wabi, particularly between El Kere and the Wabi, the gypsum hills are close to one another and water spreading zones are very limited. Temporary rivers flow deeply embanked in gypsum which is very steeply cut by erosion.

Conversely, North of the Wabi between Duhun and Danan, between Gode and Kebri-Dahar and North of Imi, water spreading zones predominate,the gypsum hills only forming small greyish rounded peaks scattered in the midst of alluvial deposits and of red to yellowish-red colluvial deposits.

The gypsum hills present the driest pedoclimate in Lower-Ogaden, hence a particular scanty vegetation consisting of a very loose bush, approximately 1,5 m to 2 m high, through which one may move easily when not hindered by the curved thorns of small acacias. The characteristic vegetation association of gypsum zones is represented by the *Boswellia spp.* and *Jatropha rivae* group.

Morphology : The soil presents the following mean profile :

0 - 10 cm A_1R : Yellowish-grey (2,5 Y 8/4) ; silty-loam ; single-grained structure ; powdery ; some rootlets ; sudden transition to :

10 cm + R : Greyish-white translucent gypsum slab.

Consequently, the soil layer is very thin and the gypsum slab often outcrops at the surface forming concentric lines around the hills and thus conferring a "cockade" aspect. The flashes of light observed from planes are due to sunlight reflected on the gypsum sheets acting as mirrors.

Colluvial local deposits may also be observed but in this case the soil is thicker :

0 - 20 cm A_1R : Yellowish-white (5 Y 8/3) ; loam ; single-grained structure ; very powdery and friable ; some rootlets ; short and uniform transition to :

20 - 50 cm A_1R	:	Yellowish-white (5 Y 8/3) ; loam coating gypsum elements ; not very hard, tending to powdery ; very few rootlets ; sudden transition to :
50 cm + R	:	Gypsum slab in situ.

The upper horizon therefore consists of a regular gypsum powder resting on the gypsum slab. Disaggregation and exfoliation in situ of the gypsum slab may be observed and this is manifest in horizon A_1R in the second profile described. Part of this gypsum is solubilized by rain-water and accumulated in water spreading zones on colluvial or alluvial deposits located in a lower position and it provides soils with crusts (family 54), but on the hills, there is no neocrystallization of gypsum. For this reason, these soils are classed among soils with powdery lime since they contain from 10 to 20 percent of carbonate.

Physico-chemical characteristics

The yellowish-grey to yellowish-white superficial horizon therefore consists of very finely divided gypsum mixed with a small quantity of organic matter corresponding to less than 1 percent. pH is approximately 8,0 but the high conductivity of the saturation extract which varies from 10 to 15 mmhos/cm reveals the presence of a great quantity of soluble salts mainly composed of sodium chloride and gypsum. The large quantity of salt existing in lower zones is due to the weathering of gypseous marl and gypsum.

Cultural and pastoral fitness

These soils are unsuitable for cultivation. During the rainy season they constitute meagre pasture grounds which are nevertheless relished by animals because of the high mineral-element content (especially salt) of plants. These pastures would constitute a vast game reserve along the Wabi Shebelle river. (See Ch. VI G).

4. Lithic soils with powdery lime on shallow gypsum slab, derived from Ferfer gypsum.

These soils occupy the small outcroppings of Ferfer gypsum crowning here and there the large limestone plateau between Bariy and El Kere. They spread on approximately 500 km2 in the mapped association n° II, South of El Kere.

These soils with a gypsum slab very near the surface and which often outcrops present a 10 cm thick brownish-grey horizon. Their cultural and pastoral fitness is practically of no interest.

5. Brownish-grey soils derived from Ogaden basalt

These soils occupy the chain of basalt hills rising among sedimentary layers :

- along the valley of the Wabi Shebelle, between Gode and Imi,
- along the line : Danan Degah-Medo ;
- between Degah-Medo and Fik.

The total extent of these soils is 331 km2

Morphological and Physico-chemical characteristics

Numerous basalt boulders may be seen on the thin soil layer. An horizon of fine earth consisting of light brown silty sand overlying without any transition the weathered-basaltic horizon may generally be observed.

In these sub-arid zones, the weathering of basalt presents the following features : weathering in boulders with at the surface a film or a white ribbon-shaped limestone crust. The thickness of the limestone at the surface of boulders increases from the South (Gode) to the North (Degah-Medo-Fik). The mobilization of limestone is more important owing to a slightly increasing rainfall as one goes Northwards and to a lower temperature. Besides, the increasing thickness of the weathering basalt horizon may be observed, i.e. : 40 cm at Gode and approximately 100 cm at Fik and Degah Medo.

. These soils are slightly to medium calcareous in the Gode region (11 to 19 percent) and more calcareous in the Degah-Medo region : 26 percent.

. The content of organic matter is very low at Gode : 0,5 percent and four times higher in the Degah-Medo region : 2,1 percent.

. The contents of exchangeable K : 1,4 me/100 g and of total phosphorous : 4,3 ‰ are high in the Degah-Medo region.

Fitness of these soils :

These soils present no economic interest in the Valley of the Wabi-Shebelle. But, to the North (Northern Danan region, Segeg, Degah-Medo, Fik), they could be used for afforestation with species enduring dryness, chemical elements existing in large quantities in the rock at a weathering stage.

Sub-group Lithic calcic soils

6. Light grey soils derived from granitic chaos

These soils are developed on the granitic chaos of Harar, in particular in the regions of Babile, Fugnanbira, Bisidimo and East of Melkarafu and of Kurfachele. They cover a total area of 1051 Km2.

The granitic chaos often consists of granites with two micas but also of very metamorphized amphiboles granite producing a general structure with a predominance of migmatite rich in black micas and amphiboles with feldspar beds.

The weathering in boulders is particularly distinct and even remarkable between Babile village and the Daketa river. The shrubby vegetation is relatively dense with a predominance of Terminalia Browni.

At the top of the chaos and on slopes, the granite and sand layer is thin. Soil is not very thick. A yellowish-brown horizon with medium and coarse sands, approximately 10 cm thick, resting on scarcely or weakly weathered granite may generally be observed.

- The soil is non calcareous but base saturated and presents a pH approximately : 7,5.

- The content of organic matter is low with 1,3 percent in the upper horizon.

These soils present no economic interest except for afforestation when the thickness of soils and the slopes are suitable.

7. Red soils derived from Adigrat sandstone

They cover the steep slopes of the Valley, of the upstream part of the Ramis river and of its tributaries as well as of the Galetti and correspond to an area of 720 km2.

They consist of a thin red sandy layer resting on the sandstone in situ when the latter is not bare.

These soils present no economic interest.

8. Reddish-brown humic eroded soils, derived from basalt slag and basalt

These soils are developed on the basalt cinder cones or on the small basalt hills of the Gedeb plain :

- South of the Wabi, in the Dodola and Adaba regions, Malca-Wacana falls ;

- North of the Wabi, at the foot of Mount Kakka and Enkolo ;

They also exist on the hills of basalt ash of the Dixis region.

They do not extend far and for this reason are only represented on the map at 1/250.000.

Morphology and physico-chemical characteristics :

They consist of a brown (7,5 R 5/2) to reddish-brown horizon (5 YR 4/4), from 20 to 30 cm thick and resting directly on the layer of basalt scoria or basalt. At the soil surface, numerous pebbles, basalt scoria blocks or basalt may be observed.

These soils are non-calcareous.

The content of organic matter is high and usually more than 7 percent down to a 30 cm depth but they may vary from 3,5 percent on Dodola hill to 10 percent on the Dixis hills.

The exchangeable potassium content is high : 0,90 me/100 g of soil, available phosphorus is also abundant : 1,7 ‰.

Cultural fitness and afforestation possibilities

These very stony soils are nevertheless, owing to the growing density of the population, cropped to wheat, barley, peas et... Only some zones, either because they are too uneven or too stony, are left as grazing grounds ; strips of the primeval forest still exist in a degraded form with wild olive-trees and "Tids".

Owing to a gradual mechanization of agriculture in the plain these zones will be progressively turned over to forest and pastures.

9. Brown humic eroded soils derived from Gesoma sandstone and from the plateaus basalt

They are developed on the steep mountain slopes between Sebre Dollo and Shek Hussien and on the slopes of the Abdul Kassim mountains on the Northern bank of the Wabi, 20 km to the East of Shek Hussien.

These mountain ranges consist of thick red sandstone beds (Gesoma sandstone) capped with basalt. The abundance of rainfall (at least 1300 mm) and its intensity are favourable to a considerable headward erosion of the soft sandstone and to a broken up morphology with very steep slopes. On these slopes where soil covers approximately 540 km2 grows a splendid primeval forest mainly consisting of Juniperus and scarcely spoiled on some flat areas and foot slopes by few cultivated crops such as coffee and maize. These soils are included in the mapped association n° VI (Shek Hussien) with ferrallitic soils.

Morphological and physico-chemical characteristics :

These soils are not more than 30 cm thick and consist of a very humic horizon of fine sandy clay resting directly on the basalt or sandstone substratum. The horizon has a very well-developed granular structure.

The organic matter content is approximately 22 percent in the first 5 centimeters and 16 percent in horizon : 5-30 cm. Its C/N, approximately 20, is relatively high and reveals the existence of humus of the moder type. However, the pH : 7,5 and the saturation of the complex in bases without lime, indicate that these soils, owing to the importance of earth alkalis produced by basalt at a weathering stage, remain neutral without tending to acidification.

Forest is the natural vegetation for these soils and has the advantage of preventing erosion on the steep mountain slopes. But, when roads are created, the forest could eventually be turned into a cultivated forest and rationnally used, as in the mountainous regions of Europe, the climate being very favourable for coniferous.

Group of colluvial soils

- Sub-group with calcareous speckles

10. Yellowish-brown soils derived from granite (10 a and 10 b only represented on the map at 1/250.000)

These soils are developed on the colluvial deposits of granitic material, on gently sloping banks at the foot of granitic chaos in a region stretching from Harar to Babile. They cover 905 km2, are generally scarcely cultivated and the predominant vegetation consists of *Terminalia browni* (tree producing charcaol) with in some places groups of prickly-pear trees.

Morphological and physico-chemical characteristics

These brown (10 YR 4/3) to light brown soils (7,5 YR 6/4) at the surface and yellowish-brown in the depth present a medium and coarse sandy texture with numerous small quartz gravels. The structure is single-grained and the profile is generally loose.

The thickness of soils varies according to the importance of colluvial deposition. They are not thick in the Hadow region (10 a), but are more than 3 m. deep as one goes down the Erer, Daketa and Fafen valleys (10 b) ; (see details on maps at 1/250.000).

The soil is non-calcareous in the upper horizons and becomes weakly carbonated in the depth (1 to 2 percent). The segregation of carbonates appears in the form of small white speckles uniformly distributed. This weak calcareous accumulation is linked to the weathering of the plagioclases of granite located in a higher position.

The content of organic matter is medium with approximately 2 percent, but owing to the very sandy texture of soil, organic matter penetrates to a 30 or 50 cm depth.

. the nitrogen content, less than 1,5 ‰ is medium

. the content of exchangeable potassium is medium from 0,2 to 0,5 me/100 g of soil ;

. the stored phosphorus content is medium with 0,8 ‰ ;

. the $\frac{\text{Total N}}{\text{Total } P_2O_5}$ ratio indicates nutritional unbalance disadvantaging phosphorous.

Cultural fitness and afforestation possibilities

The economic interest of these soils depends on their thickness :

- for not very thick soils (10 a), afforestation is recommended (Hadow region) and all the more so as these soils are now being actively deforested in view of providing charcoal.

- for thick soils (10 b) : borders of the Erer, Daketa and Fafen valleys, mechanized cultivation is possible, taking into account the fact that these soils are easily affected by erosion. Contour ploughing and contour bed ploughing are recommended.

The fertility level of these soils is low. Basal dressing with nitrogen (urea, ammonium sulphate or ammonium nitrate) phosphorous (lime superphosphate) and potash (potash chloride) is required for a suitable yield of crops.

B. VERTISOL CLASS

Classification :

Vertisols are characterized by a very clayey texture with a predominance of minerals of the type 2/1 which confers :

- swelling and shrinkage properties characterizing their hydrous state, and to which are due shrinkage cracks delimiting in depth a broad prismatic structure with distinct slickensides on the structural elements.

- a high exchangeable capacity linked to the type of montmorillonitic and illitic clay.

In the Basin of the Wabi Shebelle, vertisols are always developed in unsuitable external drainage conditions (basin or large plateau) and belong to the sub-class of vertisols with limited external drainage.

The vertisols of the Basin are also characterized by an upper horizon with a very divided up structure constituting a very favourable element for the management and use of these soils. Owing to the rounded or grumosolic friable structure of the horizon, these vertisols may be considered as grumosols (sub-class level).

Vertisols form two groups according to the presence or absence in soil of limestone and sometimes of gypsum.

Carbonated group with two sub-groups :

- The sub-group with powdery lime and gypsum crystals includes vertisols of warm regions where rainfall varies from 150 mm to 400 mm.

These soils only exist in Lower Ogaden and mainly in the two large valleys of the Wabi and of the Fafen. Pedoclimatic conditions are unfavourable for the migration of calcium carbonate and the limestone initially existing in the original material consequently remains powdery or invisible. Conversely, soluble gypsum is gradually accumulated in the base of profiles and forms crystals.

- The sub-group with calcareous nodules includes the vertisols of the intermediate zone (Middle Belt) where rainfall varies from 400 mm to 700 mm. A calcareous accumulation forming nodules may appear but the general profile is still calcareous.

Calcic group : with a single sub-group :

- The sub-group with calcareous nodules in the depth consists of the vertisols of the High-Plateaus where the mean altitude is 2.500 m and rainfall varies from 800 mm to 1.400 mm.

These soils are characterized by the absence of lime in the fine earth of all the profile but a segregation of limestone into usually hard nodules may be observed at a variable depth exceeding 1 m.

In this case, the dynamics of limestone is distinct and may be explained by a comparatively damp and particularly cool climate favourable to a decarbonation of the profile and to an increase of the calcium percentage in soils.

The level of the calcareous accumulation corresponds to the pulsation zone of the water table saturated in calcium bicarbonate which is precipitated as calcium carbonate when the solution dries up temporarily. This is in fact a hydromorphic process which here does not concern iron but calcium.

Sub-class of Grumosolic vertisols with a limited external drainage

Carbonated group

- sub-group with powdery lime and gypsum crystals

11. Brown vertisols, derived from Ogaden basalt

They stretch over a limited surface of approximately 545 km2 at the foot of basalt hills outcropping in the sedimentary substratum, mainly of the Degah-Medo and El Har regions. They occupy basins which are flooded during the rainy seasons and are often associated in the Fik, Degah-Medo regions with soils presenting a melanic horizon (family n° 28) on the lower part of slopes. In the Fik region, these vertisols do not spread much. They are delimited on the map at 1/250.000.

Morphological and physico-chemical characteristics :

These clayey soils are dark brown (7,5 YR 4/4) at the surface to reddish-brown (5 YR 4/4) in the depth. Vertic features are distinct in the depth with clearly visible slickensides. The upper horizon with a granular or subangular structure is usually thick. The friable layer of soil may attain 80 cm thick.

The soil generally consists of limestone (20 to 24 percent). No calcareous accumulation is observed in the depth but only an individualization of gypsum forming some crystals.

- The content of organic matter is only 1,4 percent for 80 cm and the nitrogen content is not more than 0,5 ‰ in the upper horizons.

- pH is approximately 8,0

- the exchangeable potassium content is high and varies from 0,4 to 0,8 me/100 g of soil.

- the concentration in sodium chloride of the soil solution is weak in the depth : 0,4 g/100 g of soil.

- the content of total phosphorus is very high in the upper horizons : 2,8 ‰, but the $\frac{\text{Total N}}{\text{Total } P_2O_5}$ ratio is distinctly less than 1 and shows a considerable unbalance which is unfavourable to nitrogen.

Cultural and pastoral fitness

The situation of these soils in basins and their high water holding capacity is favourable for the cultivation of food-crops such as sorghum, but productivity could be increased by a network for the control of soil erosion with contour earth-ridges (see Chapter VI D) to prevent a loss of water through overland runoff, and also by adding nitrogen fertilizers such as ammonium sulphate.

These soils are also suitable semi-permanent pasture lands.

12. Vertisols on Reddish-Brown alluvial deposits derived from the Kebri-Dahar and Mustahil limestone and from the main gypsum formation.

They cover an area of 1.411 km2 in Lower Ogaden and either occupy :

- depressions (Danan and Segeg regions)
- or alluvial zones (alluvial deposits of the Fafen Valley to the North and South of Shekosh, alluvial deposits of several tributaries of the Northern bank of the Wabi, in particular of the BU-Y temporary rivers).

In both cases, these zones are periodically flooded by the floods of temporary rivers.

Morphology : Danan depression - dense graminea carpet - some tall mimosas - 300 m farther : cultivated sorghum.

0 - 30 cm : Yellowish-brown (10 YR 5/6) ; silty-clay-loam ; granular ; friable.

30 - 100 cm: Yellowish-brown (5 YR 5/4) ; silty-clay-loam ; some shrinkage cracks, coarse blocky fragments tending to prismatic with some slickensides.

100 cm + : same type of horizon with small gypsum crystals.

Physico-chemical characteristics

Soil group	Depth cm	Texture	Structure	CO_3Ca %	Organic matter %	N ‰	C/N	pH	Conductivity of sat.extract mmhos/cm	Total P_2O_5 ‰
12	0-30	SiCL	gr	20	3,6	2,0	15	8,0	3	1,1
	30-100	SiCL	pr	22	1,7	1,0	10	8,0	4	1,1
	100 +	SiCL	pr	20	1,4	0,6	13	8,2	22	1,1

These yellowish brown soils (10 YR 5/6) at the surface, to reddish-brown (5 YR 5/4) in the depth, present a heavy silty clay loam texture.

- The granular structure for the first 30 cm gives the upper horizon a very friable character.

- Below 30 cm, the structure becomes prismatic but with not very distinct slickensides.

The horizons are often interstratified but with a silty clay predominance ; numerous gypsum crystals can be seen at approximately 100 cm depth ; the limestone content is high in all the soil ; the content of organic matter is relatively high for this zone which is due to the presence of a considerable graminea vegetation linked to periodical floods.

The nitrogen content is moderate and the C/N ratio is very low, indicating a developed calcic humus which is soon mineralized.

pH is high and alkaline, but the profile is not alkalinized. Nevertheless, though the conductivity of the saturation extract is weak down to 100 cm depth, it largely increases lower down thus revealing a high chloride content in the usual pulsation zone of the water table during the rainy season. One must also bear in mind that flood water from temporary rivers is loaded with soluble salts originating from the neighbouring gypseous material.

The phosphorous content is medium.

The $\frac{\text{Total N}}{\text{Total } P_2O_5}$ ratio shows a certain unbalance unfavourable to nitrogen.

Cultural and pastoral fitness :

These vertisols together with the soils of family 51 occupy the only areas in Lower Ogaden where cultivation is possible owing to the temporary floodings of ephemeral streams.

Part of these zones is already cultivated by Somali nomads when floods subside but an increasing yield could be expected if the following measures were applied :

- Selecting more productive varieties with a good tolerance to salinity in the depth.

- A more suitable distribution of flood water by means of a network for the control of erosion consisting of contour earth ridges and the control of the direction of flood water (see chapter VI D).

From the pastoral point of view, these zones are excellent and almost permanent grazing grounds which must however be improved as regards the quality of forage.

13. Vertisols on the brown alluvial deposits of the Wabi (13 a) and of the Fafen (13 b)*

These vertisols are developed in the Lower Valley of the Wabi Shebelle, between Imi and Ferfer, on approximately 1.268 Km2, and in the Lower Valley of the Fafen, South of Korahe, on approximately 887 km2.

They are formed on alluvial deposits of basaltic origin and occupy weakly depressed or moderately flooded zones and sometimes no longer flooded zones. The vegetation mainly consists of a graminea cover the density of which is conditioned by the duration of flooding, and in some places, a loose forest of tall Acacia.

Morphology : profile observed in the Fafen valley, 11 km to the South-East of the Korahe bridge.

Dense gramineae-important gilgaï microrelief with 5 to 10 cm shrinkage cracks reaching the surface.

0 - 20 cm : Brown (10 YR 5/3); crumbly; fine sandy clay ; friable.

20 - 90 cm : Yellowish brown (10 YR 5/4); fine sandy clay ; shrinkage cracks in all directions giving friable prismatic angular blocky fragments ; generally friable.

90 cm + : Reddish-brown (5 YR 4/4) clay ; friable medium blocky fragments tending to a prismatic structure with slickensides ; few small gypsum crystals; compact.

Mean physico-chemical characteristics

Soil group	Depth cm	Texture	Structure	CO_3Ca %	Organic matter %	N ‰	C/N	pH	Cond of sat.ext. mmhos/cm	K^+ me/100g	Na^+ me/100g	Total P_2O_5 ‰
13	0-30	C	cr	19	2,4	1,2	12	8,1	2,1	1,4	0,3	1,9
	30-80	C	pr	20	1,0	0,5	12	8,0	4,1	0,9	0,5	1,8
	80 cm+	C	pr	19	0,8	0,4	11	7,9	7,7	0,7	1,1	1,8

*This soil survey is resumed with more details, particularly in the report concerning the study and reclamation of soils in the Lower Valley of the Wabi Shebelle.

These clayey to very clayey soils present a very friable crumbly to granular superficial horizon, approximately 30 cm thick, overlaying an horizon with a medium to broad prismatic structure which becomes very compact in the depth. The slickensides are usually distinct and the shrinkage cracks are from 3 to 10 cm broad. The gilgai microrelief is very pronounced. at the surface.

At approximately 80 cm depth, a gradual gypsum accumulation of crystals may be observed.

Limestone represents approximately 20 percent for the whole profile.

The content of organic matter is high for the climatic zone considered in horizon 0-30 cm and this is linked to the vegetative cover (floodings).

The nitrogen content is medium and C/N is low showing that humus is soon mineralized.

pH is approximately 8,0 and no alkalinisation process may be observed.

Conductivity of the saturation extract increases with the depth and reaches approximately 7,7 mmhos/cm, the sodium chloride content being 1g/100 g of soil. This low content corresponds to a limited salinization of soil in the depth.

- The exchangeable potassium content is high
- The phosphorus content is also high
- The $\frac{\text{Total N}}{\text{Total } P_2O_5}$ ratio, less than 1, reveals a very distinct nitrogen deficiency.

Cultural and Pastoral fitness

In the valley of the Wabi Shebelle, these soils are quite suitable for irrigation purposes and particularly for the cultivation of cotton, sugar-cane, rice and also for artificial pastures (see report on the Lower Valley of the Wabi Shebelle).

In the Fafen Valley, the rational utilization of flood water should allow longer grazing possibilities in the Korahe and Dobowein region and an improvement of the yield of food-crops in the Korahe plain (Maharato region).

14. Vertisols on the Brown alluvial deposits of the Borale and of the Higher Fafen

They stretch over 710 km2 in the higher valleys of the Borale and Fafen where they correspond to the maximum-flood plains of both these rivers.

The natural vegetation consists of a dense forest with tall Acacias and a dense gramineae cover.

These soils are developed on the brown alluvial deposits resulting from the mixed material derived from weathered granite and basalt from upstream.

Morphological and physico-chemical characteristics

These dark brown (7,5 YR 4/4) very clayey soils present an horizon with a weakly developed granular structure never more than 10 cm thick. Then a weak prismatic structure with very distinct slickensides in the clayey horizons forms a compact whole. But, in the frequent interstratified sandy layers, the structure is single-grained and the horizon is consequently friable. Sometimes, at the base of the profile (2 m depth about), calcareous spots and some gypsum crystals exist.

The soil is on the whole slightly calcareous.

Cultural and pastoral fitness

These soils may not be easily cultivated owing to floodings and particularly because of the thinness of the crumbly horizon making the tilling of soil difficult.

Nevertheless, these vertisols are very good pasture grounds long after floods recede, either for local livestock or for herds transiting from the South to the markets in the North.

- Sub-group with calcareous accumulations and nodules.

15. Brown vertisols derived from Kebri Dahar limestone

These vertisols are largely extended in the North of the Basin, at a mean altitude varying from 1.200 to 1.800 m where rainfall is approximately 600 mm. They stretch over 6.340 Km2 and are represented in particular in the Jijiga region, between Babile and Fik, Midegalola, between the Ramis and the Areri, between the Wabi and the Mojo, to the South of Boke-Tiko, between the Ungwata and the Siyanan where they spread on the vast, very flat or weakly undulated plateaus constituted by the geologic formation of the Kebri Dahar limestone. The vegetation either only consists of gramineae (Jijiga zone), or of a dense bush with a predominance of small acacias (North-Fik).

Morphology

Type profile : 21 km away from Jijiga, near the Degahbour track : overgrazed gramineae vegetation with some small acacias here and there.

0 - 30 cm : Brown (10 YR 5/3); very fine sandy clay ; coarse, medium and fine well-developed crumbly structure ; dry and very friable ;

very well-developed root system ; gradual and uniform transition to :

30 - 60 cm : Brown (10 YR 5/3) ; clay ; vertical shrinkage cracks delimiting a weakly-developed prismatic structure with not very distinct slickensides ; very friable blocky fragments giving a subangular blocky structure to a medium fine or coarse well-developed granular structure ; rather humid and friable ; dense root system ; some subangular limestone pebbles approximately 0,2 to 0,5 cm ; gradual transition to :

60 - 100cm : Dark brown (7,5 YR 3/2) ; clay ; well-developed medium prismatic structure with very distinct slickensides ; rather humid ; compact ; looser root system ; some 0,2 to 0,5 cm limestone pebbles ; short transition to :

100 - 160cm : Brown (7,5 YR 3/2) striped with red and brown (5 YR 5/3) ; clay ; medium prismatic structure with distinct slickensides ; numerous white calcareous concretions, diameter approximately 0,5 cm ; very friable giving a white powder ; relatively humid ; very compact ; some rootlets ; sudden transition to :

160 cm + : hard calcareous crust of nodule type.

Physico-Chemical characteristics

Soil group	Depth cm	Texture	Structure	CO_3Ca %	Organic matter %	N ‰	C/N	pH	T me/100 g	K + me/100g	Na + me/100 g	Total P_2O_5 ‰
15	0 - 30	vfsc	cr	20	3,6	2,0	15	8,0	57	1,0	1,7	1,4
	30 - 100	C	sub.blo gr	22	1,7	1,0	10	8,0	62	0,7	2,6	1,2
	100 - 150	C	pr	20	1,4	0,6	13	8,2	57	0,6	3,0	1,0

Clay is predominant in these brown to dark brown soils.

- The loose granular horizon is 30 cm thick.

- The prismatic horizon at a 60 cm depth with distinct slickensides is very compact, and gradually changes into a transition horizon with a scarcely pronounced prismatic structure which however remains friable and well penetrated by the root system of gramineae.

Vertisols always present a calcareous crust with strongly cemented nodules visible either on the limestone slab in situ (Babile region, Fik, Midegalola), or on friable weathered limestone (Jijiga zone). The origin of this calcareous crust is examined in the description of soils with a calcareous crust (soil family n° 35).

Below this scarcely permeable crust a calcareous segregation may be observed in the form of friable nodules.

- All this soil contains calcium carbonate (approximately 20 percent) Rainfall is consequently insufficient to decarbonate the upper horizons but friable nodules are formed owing to the presence during the rainy season of a perched ground-water table above the crust.

- The content of organic matter is high in the upper horizon with 3,6 percent and medium in the depth with 1,4 percent ; this is due to the importance of the graminea cover even when shrubby associations are predominant.

The high nitrogen content at the surface, and the C/N from 13 to 15, show that organic matter is well mineralized.

pH is approximately 8,0.

The exchangeable capacity is high which characterizes a montmorillonitic clay type.

The absorbing complex is base-saturated.

The exchangeable potassium content is high at the surface and in the depth.

Conversely, the exchangeable sodium content is relatively high in the depth but does not affect soil fertility. The phosphorus content is medium The $\frac{\text{Total N}}{\text{Total } P_2O_5}$ ratio is approximately 1 or less and reveals an unbalance which is unfavourable for nitrogen.

Cultural aptitudes

These soils are particularly interesting for agricultural purposes, as they constitute the main category of soils liable to be used for "dry farming" and for the extention of cultivation from the North to the South (see detail on soil map at 1/250.000). These soils are scarcely cultivated at present and though rainfall is relatively low, from 500 to 600 mm, they should be considered seriously because of :

- Their high water-holding capacity linked to a clayey texture.
- The presence at the surface of a granular horizon facilitating cultural practices.
- The need only of slight land-clearing, especially in the Jijiga region where vegetation mainly consists of gramineae.
- The considerable extent of these soils suitable for large sized mechanized farms.

Sorghum should be the main crop looked upon with a selection of varieties adapted to local climatic conditions.

As regards fertility, soils are very poor in nitrogen. Fractional adding of fertilizers such as urea, ammonia nitrate or sulphate and also calcium nitrate at the end of the rainy season, should considerably improve the crop yield. Other major elements such as K and P_2O_5 exist in medium to large quantities.

Wind-screens will be necessary in most cases to improve the hydrological balance of soil and to limit the mechanical action of wind on plants.

Calcic group

- Sub-group with calcareous nodules in the depth.

16. Reddish-brown vertisols derived from the basalt of plateaus and from Gesoma sandstone.

They spread on 710 km2 mainly in the Lege-Hida region and are formed on the colluvial deposits resulting from the dismantling of basaltic and sandy material of the Lege-Hida plateaus. The vegetation consists of a forest of tall *Acacia* with a dense graminea cover. The mean altitude is 1.500 m and rainfall varies from 600 to 800 mm.

Morphology

Track from Lege Hida to the Wabi river, dense graminea carpet ; some tall *Acacia* sp.

0 - 30 cm : dark reddish-brown (2,5 YR 3/4) ; clay ; granular ; friable.

30 - 140 cm : dark reddish-brown (2,5 YR 3/6) ; clay ; medium to coarse prismatic ; shrinkage cracks and distinct slickensides ; compact

140 cm + : same type of horizon but with numerous calcareous nodules.

Soil group	Depth cm	Texture	Structure	CO_3Ca %	Organic matter %	N ‰	C/N	pH	Ca++ me/100g	Mg++ me/100g	K + me/100g	Na+ me/100g	Total P_2O_5 ‰
16	0-30	C	gr.	0	3,4	1,3	15	6,7	11,2	7,1	0,5	0,15	0,65
	30-140	C	pr.	0	1,6	0,7	12	6,7	15,8	6,5	0,35	0,50	0,65
	140 +	C	pr.	2,6	0,7	0,5	8	8,1	-	-	0,50	0,35	0,4

Physico-chemical characteristics

These dark reddish-brown soils consist of clay to heavy clay and present an approximately 30 cm thick granular superficial horizon. Below : a medium prismatic structure with distinct slickensides ; very compact.

The fine earth of these soils is not calcareous except at the level of calcareous concretions where limestone represents approximately 2,6 ‰.

The content of organic matter is high in the upper horizons but decreases with the depth. Conversely, the nitrogen content is medium everywhere.

pH is slightly acidic in calcic horizons but becomes alkaline in the depth at the accumulation level.

Soil is consequently, practically base-saturated.

The Ca/Mg ratio is correct.

The exchangeable potassium content is medium and so is the phosphorus content.

The $\frac{\text{Total N}}{\text{Total } P_2O_5}$ ratio is slightly greater than 2 at the surface, which indicates that the nutritional balance is suitable between both elements but the nitrogen and phosphorus levels are medium.

Cultural and pastoral fitness

- Taking into account rainfall and the considerable specific retention, these vertisols are very suitable for crop-growing in particular of sorghum and maize. Though these soils are at present scarcely cultivated except here and there between Lege-Hida and the Wabi, they constitute an eventual extension zone for important "dry farming" cultivation.

- The addition of carriers of phosphorus (super-phosphate) and carriers of nitrogen (urea, ammonium sulphate or ammonitrate) are advisable.

- This is also an excellent pasture zone during a long period of the year.

17. Reddish-brown vertisols, derived from the plateaus basalt

These soils cover 1.382 km2 to the North of Sebre-Dollo and in the Lege-Hida and Dara-Gudo regions. They stretch on gently rolling basalt plateaus where the mean altitude is 1.700 m and which form the last basaltic steps overhanging the sedimentary formations of Ogaden. The vegetation mainly consists of wild olive-trees with a dense graminea carpet and also some euphorbias. Rainfall is approximately 800 mm.

Morphology

Profile observed on the Lege-Hida plateau :

0 - 40 cm : Dark reddish-brown (5 YR 3/3) ; clay ; granular tending to very well-developed angular blocky structure near the base ; friable.

40 - 140 cm : Reddish-brown (5 YR 4/3) ; clay ; shrinkage cracks sometimes 3 cm broad ; prismatic with slickensides ; compact.

140 - 160cm : Same type of horizon with 30 percent of calcareous nodules.

160 cm + : Basalt slab.

The depth of the basalt slab varies with the topographic position. It outcrops on the slopes or on the higher points of plateaus, whereas it is deep in colluvial zones.

Physico-chemical characteristics

Soil group	Depth cm	Tex-ture	Struc-ture	CO_3Ca %	Organic matter %	N ‰	C/N	pH	Ca ++ me/ 100g	Mg++ me/ 100g	Na+ me/ 100g	K+ me/ 100g	Total P_2O_5 ‰
17	0-40	C	gr.	0	4,9	2,3	12	6,8	15,8	8,5	0,10	2,0	0,9
	40-140	C	pr.	0	1,5	0,7	11	7,1	25,5	4,0	0,20	0,6	0,5
	140+	C	pr.	2,3	-	-	-	8,0	-	-	0,30	0,6	0,5

The dark reddish-brown to very clayey (more than 50 % of clay) reddish-brown soils have a 40 cm thick very friable horizon at the surface. Conversely, the deeper horizons present a broad prismatic structure with distinct slickensides and broad shrinkage cracks. Above the basalt layer, numerous calcareous nodules exist.

On the whole, the fine earth contains no calcium carbonate except at the level of the calcareous concretions where the calcium carbonate content is low.

The content of organic matter is high in the upper horizon and steadily decreases with the depth. This is also true for the nitrogen content.

pH is slightly acidic to neutral in non-calcareous horizons and becomes distinctly alkaline in the horizon with calcareous nodules.

However, the non-calcareous soil horizons are base-saturated.

The Ca/Mg ratio is correct.

Exchangeable potassium exists in large quantities down to a 40 cm depth and is still abundant lower down.

The content of total phosphorus is high at the surface and medium in the depth.

The $\frac{\text{Total N}}{\text{Total } P_2O_5}$ ratio reveals a suitable nutritional balance between these elements.

Cultural fitness

As the previously described soils, these soils are very interesting from an agricultural point of view.

They are largely cultivated North of Sebre-Dollo but represent only small cultivated areas on the Lege-Hida plateau.

They present favourable factors for the cultivation of coffee. Food-crops such as : wheat, maize and sorghum already exist in this region.

As regards soil-fertility, a mineral dressing consisting of nitrogen (urea, ammonitrate) together with phosporus (lime superphosphate) would considerably increase the yield of crops.

18. Greyish-black vertisols derived from the plateau basalt

These vertisols (also called "black cotton soils") are well known on the Ethiopian plateaus where they constitute the most frequently represented type of soil.

They stretch in the Western part of the Basin, on approximately 3.000 km2 at a mean altitude of 2.500 m and occupy :

- on the one hand, the large plateaus commanding the "chola" in the Arussi region (Robi, Gobessa, Sedika, Indeku townships) North of the Wabi, and the Gassara region (Northern Bale) South of the Wabi;

- on the other hand, the low banks and gently rolling hill-zones at the foot of Mount Kakka and Enkolo and of the Arene mountains (Adaba region).

In these densely settled zones, natural vegetation has completely disappeared owing to cultivation and to the existence of grazing areas. Only the alluvial zones along rivers are covered with a practically unmingled stand of tall Acacia (Acacia xiphocarpha ?) particularly in the Adaba and Gobessa regions.

Morphology

Profile observed 30 km away from Robi on the Robi-Dixis tract. Mid-slope position, gently rolling land on plateau,natural section, cropped to barley.

0 - 8 cm	: Greyish-black (2,5 YR 4/1) ; clay, crumbly to granular and well-developed ; dry and friable ; numerous rootlets ; short and uniform transition to :
8 - 70 cm	: Greyish-black (2,5 YR 4/1) ; heavy clay ; shrinkage cracks in all directions delimiting a medium prismatic structure with scored sides on the prisms ; dry and firm to relatively friable ; many rootlets ; gradual and uniform transition to :
70 - 180 cm	: Greyish-black (2,5 YR 4/1) ; heavy clay ; vertical shrinkage cracks delimiting a very coarse prismatic structure ; shiny and distinct slickensides ; dry and compact ; some rootlets ; gradual transition to :
180 - 300 cm	: Olive-grey (5 YR 5/2) ; heavy clay ; small shrinkage cracks delimiting a very coarse prismatic structure with characteristic wedge cracks ; very shiny and distinct slickensides ; rather humid and compact ; no rootlets ; some calcareous concretions in the base ; sudden transition to :
300 cm +	: Weathering scoriaceous basalt slab in situ.

- The thickness of soil varies in relation with the topographic position

Soil is usually not very thick on the top of rolling forms of relief. The basalt slab is then present at approximately 1,5 m depth but scattered small basalt boulders may often be seen at the surface. The soil thickness increases as one goes down the small slopes and as colluvial deposits become more considerable. Basalt then frequently exists at more than a 3 m depth.

The calcareous accumulation in the depth varies and depends on the internal soil-drainage conditions. If hydromorphy is not important in the depth, concretionning is not considerable (which is the case of the profile previously described). Conversely, if the temporary waterlogging of soil is more important, the stage is reached when a calcareous crust-forming process begins (which is visible in the erosion sections between Dodola and Adaba).

Physico-chemical characteristics

Soil group	Depth cm	Texture	Structure	CO_3 Ca %	Organic matter	N ‰	C/N	pH	T me/100g	EB me/100g	V %	Ca++ me/100g	Mg++ me/100g	K+ me/100g	Na+ me/100g	Total P_2O_5 ‰
18	0-20	C	gr.	0	8,2	2,8	15	6,0	35	36	1,0	25	9,8	1,0	0,2	0,9
	20-100	C	pr.	0	2,2	1,0	13	6,8	45	47	1,0	34,8	12	0,7	0,5	0,8
	100+	C	pr.	2,0	1,0	0,4	10	7,9	46					0,6	1,0	0,6

These greyish-black soils have a heavy clayey texture with 40 to 70 percent of clay.

The surface horizon always presents a granular structure and is from 10 to 30 cm thick according the profiles observed. On the other hand, the sub-jacent horizons have a broad prismatic structure to which is due their great compacity.

The olive-grey colouring frequently observed in the depth is linked to the hydromorphic conditions existing at this level.

Calcium carbonate is only present at the bottom of the profile and represents approximately 2 percent.

The content of organic matter is high at the surface with 8,2 percent but lower down, it is still 2,2 percent between 20 and 100 cm depth.

The nitrogen content is high in the surface and the medium C/N ratio reveals the presence of humus which is slowly degraded.

pH is acid at the surface : 6,0, but soon becomes neutral and even slightly alkali in the horizon with a calcareous accumulation.

The high exchangeable capacity proves the existence of vertisol montmorillonite.

The saturation degree is about 100 %. Exchangeable calcium largely prevails and these soils may therefore be classed with calcic vertisols.

The Ca/Mg ratio is correct.

The exchangeable potassium content is high throughout the profile.

The phosphorus content is high in the surface and medium in the depth.

The $\frac{\text{Total N}}{\text{Total } P_2O_5}$ is approximately 3 at the surface and only 1 at a medium depth.

Hence a nutritional unbalance detrimental to nitrogen.

Cultural and pastoral fitness

These soils are largely under cultivation on the High Plateaus. The main crops are wheat, barley, linseed and green peas as well as various vegetables.

These soils present a high fertility potential. A considerable increase of the crop-yield could be obtained by :

- improving cultural techniques, for instance : modern ploughing and harrowing methods ;

- selecting, after teating them in the local conditions, more productive crop varieties, especially in the case of cereals ;

- substituting fallow-grounds for artificial pastures ;

- a moderate use of nitrogen carriers such as urea, ammonia sulphate ammonitrates and even lime-nitrate which are likely to increase the crop-yield on these types of soils.

19. Greyish-ash-covered black vertisols, derived from the plateau basalt

The soils are different from the former owing to the presence of an ash-layer covering the greyish-black clayey weathered basalt. Its origin is linked to quaternary eruptions in the basins of Awash and of the Rift Valley which contributed to the powdering of some zones with ashy volcanic material and pumice. These soils prevail largely in the Kula Adaba regions and farther South, between Kofele and Dodola where they cover a total area of approximately 2.356 km2.

Morphology

Intersection of Kofele-Dodola track and of Assassa track. Discontinued grassy stretch of Pennisetum Schimperi.

0 - 30 cm : Grey turning white near the base (10 YR 7/1) ; loam ; crumb to single-grained ; generally friable ; floury consistency ; dry ;

many small rootlets ; numerous rusty-coloured speckles in the surface ; at the base many round, irregular and very hard ferruginous concretions ; sudden sinuous transition to :

30 - 75 cm : Greyish-black (2,5 YR 4/1) heavy clay ; 0,5 to 1 cm broad shrinkage cracks delimiting a coarse prismatic structure with some slickensides ; some rootlets ; relatively humid and compact ; gradual and uniform transition to :

75 - 140 cm : Olive-grey (5 YR 5/2) ; heavy clay ; 1 to 2 cm broad shrinkage cracks delimiting a very coarse prismatic structure with distinct slickensides ; generally friable when dry or humid ; sudden transition to :

140 cm + : Yellow-material with abundant pumice.

Note that the deeper horizon is not derived from basalt, since the latter may be overlain with a thin layer of tuff material. Nevertheless, the basaltic origin of horizons 3 - 140 cm is certain.

Physico-chemical characteristics

Soil group	Depth in cm	Texture	Structure	CO_3 Ca %	Organic matter percent	N ‰	C/N	pH	Ca++ me/ 100g	Mg++ me/ 100g	K + me/ 100g	Na + me/ 100 g	Total P_2O_5 ‰
19	0-30	C	s.g	0	4,6	1,8	15	6,0	8,0	22,0	0,30	0,2	1,4
	30-140	C	pr	0	0,7	0,58	12	7,0	27,0	22	1,8	2,4	1,4
	140 +	C	pr	1				7,1	11,0	11,0	0,6	0,7	1,2

These soils are grey with a loam texture at the surface and greyish-black with a very clayey texture in the base. They are in fact developed on polyphased material and present two pedogenesis types, i.e. :

- in the deeper clay horizons, vertic features, characteristic of the montmorillonitic clay type, may be observed.

- in the surface horizons with loam, hydromorphic features may be seen. The latter are linked to water-logging and drying-up processes which are particularly distinct at the contact with variously textured materials : they cause the formation of ferruginous concretions at the base of the horizon (zone with maximum hydromorphic features) and speckles at the surface where waterlogging is weaker.

These are non-calcareous soils except in the depth where calcareous concretions develop and where calcium carbonate averages 1 percent in fine soil.

The content of organic matter is high in the grey surface horizon but soon decreases with the depth. This is also true for the nitrogen content.

pH is acid between 0 and 30 cm but is neutral in the depth.

The Ca/Mg ratio is not balanced and is detrimental to calcium in the surface horizon. It is approximately 1 in the depth.

The exchangeable potassium content is very low in the upper horizon and very high deeper down.

The total phosphorus content is high.

The $\frac{\text{Total N}}{\text{Total } P_2O_5}$ ratio is approximately 1 and shows that the nitrogen content is poor compared to the phosphorus content.

Cultural and pastoral fitness

The cultural fitness of these soils is very poor as the ash-covered surface horizon modifies the soil quality disadvantegeously.

This horizon is waterlogged during the rainy season owing to the presence at a small depth of a clay layer, but it is soon dry during the dry season as ash has a low specific retention. Besides, it is acid and there is a considerable unbalance detrimental to calcium compared with magnesium.

These soils are poor zones used by livestock moving to other regions but they could be turned into very suitable pastures by :

- modifying the soil pH and improving the Ca/Mg ratio : using lime or fertilizers with large quantities of lime such as lime-nitrate for instance.

- planting suitable forage gramineae.

- adding nitrogen and potash carriers such as lime-nitrate, urea, ammonitrate, potassium chloride.

20. Vertisols on greyish-black alluvial deposits derived from Kebri-Dahar limestone.

These soils only cover 311 km2 and occupy the flat-bottomed valleys in the Hirna-Kuni, Bedessa and Gelemso regions. They are developed on alluvial deposits mainly derived from Kebri Dahar limestone and, in a smaller proportion, from basalt.

Morphological and physico-chemical characteristics

These greyish-black clay soils have a very well-developed, (from 20 to 40 cm thick) crumb horizon. Below, may be observed an horizon with a relatively large prismatic structure which is not always very distinct. Calcareous nodules are usually abundant at 1,2 m depth.

The pH of these soils is neutral and the latter are base-saturated.

Cultural fitness

These soils are highly suitable for cultivation mainly of cereals which is largely grown here.

C. ANDOSOL CLASS

21. Grey, melanic, desaturated and differenciated andosols, derived from mountains basalt

Andosols are developed higher than 3.200 m on the high mountain ranges limiting the basin to the West and South and presenting the following peaks : Kaka, Enkolo, Galama, Boraluku,Erosa, Bada and Gugu to the West (Arussi province), and Gorte, Korduro, Somkaru, Beranta and Crara Arewa to the South (Northern-Bale).

They cover all the extension area of the Ericacea and Alchemilla communities among which grow in some places splendid giant Lobelia.

This is the Boraluku type of climate with an annual mean temperature under 12°, rainfall less than 1.600 mm and hardly two cold months in the year. It often freezes during the dry season but it never snows during the rainy season.

The andosols of this mountain-mass are on the one hand, well-differenciated and on the other hand, desaturated. The melanic horizon is always very distinct, hence these soils belong to the differenciated sub-class, desaturated group and melanic sub-group.

Morphology :

Type profile : at an altitude of 3.500 m Mt Boraluku. Vegetation with dominant heath (1,5 m high) of the Ericacea group.

0 - 15 cm A 11 : Light brown loam ; very fine single-grained earth is held back by numerous rootlets ; humid ; "fluffy", talc-like consistency ; distinct transition to :

15 - 60 cm A 12 : Blackish-brown fine sand ; firmer single-grained structure than the former ; still many rootlets ; gradual transition to :

60 - 100 cm (B) : Reddish-brown fine sand ; structure tending to single-grained; still some rootlets with basalt gravels in the base.

100 cm + R : basalt slab in situ.

The distinct differenciation between horizons A and (B) is linked to the colouring which is not variable but is sometimes bright red as in the case of horizon (B). This is probably due to the individualization of ferrugineous constituents in relation to the deep weathering of basalt.

Physico-chemical characteristics

Soil group	Depth cm	Texture	Structure	CO_3Ca	Organic matter %	N ‰	C/N	pH	T me/100 g	BE me/100 g	V ‰	Ca ++ me/100 g	Mg ++ me/100 g	K + me/100 g	Na me/ 100 g	Total Fe_2O_3 10-2	Free Fe_2O_3	Fe_2O_3 Free/Total
21	0-15	L	s.gr	0	24,1	10,6	13,2	5,4	69,3	11,7	16,8	8,6	1,9	1,1	0,1	7,0	2,0	0,28
	15-60	fs	s.gr	0	21,6	9,17	13,6	5,6	69,5	10,	14,4	7,5	1,5	0,9	0,1	7,4	2,2	0,29
	60-100	fs	s.gr	0	14,2	5,93	13,9	5,5	54,6	5,95	10,9	5,4	0,05	0,4	0,1	10,2	2,9	0,28

These soils are mainly characterized by the abundance of amorphous material such as allophanes which are easily revealed in the field by the Fieldes and Perrott potassium fluoride test.

The dark brown colouring of soil when humid, becomes light grey when dry.

Though the texture is not easily determined, it seems to be loamy to fine sandy. The structure is mostly single-grained. However, the soil consistency is characteristic and may be compared to that of a very fine and slightly compressed powder ("fluffy").

pH is very acid and scarcely varies with the depth.

The base exchangeable-capacity is very high but the base-saturation degree is low.

The exchangeable potassium percentage is high at the surface and medium in the depth.

The free iron/total iron ratio averages 0,28, hence no migration of iron.

Cultural fitness

Owing to the altitude and rough climatic conditions, these soils are scarcely suitable for agricultural purposes. Nonetheless, some land-clearing is now being undertaken on the Western slope of Boraluku outside the limits of the Basin. It is obvious that besides the irregular cultivation conditions (except for berries such as whortleberries), erosion is considerable on the steep slopes beaten by heavy rain-falls. These zones should be kept as reserves for wild animals (see chapter VI G).

D. CALCIMAGNESIC SOIL-CLASS

This soil-class is characterized by the dissolution of the calcareous elements contained in the base-rock or in the soil. A redistribution of the calcium carbonate in situ never takes place but the latter is leached away from the profile through solubilization and drainage. Two cases may occur, i.e. :

Limestone is only partly dissolved and the soil in general remains calcareous : carbonated soil sub-class.

Limestone is completely dissolved in the soil, but remains base-saturated : saturated soil sub-class.

On the plateaus (soil families 22-24-25-26), the sub-classes include two groups of soils closely imbricated in the field and which have been mapped forming an association. These are :

- modal rendzinas : these soils are only 20 to 30 cm thick and are developed on hill slopes ; they counter-balance the erosion and weathering of the original material. The profile is of the AC type. Horizon A is dark brown with a very well-developed granular structure and directly overlays the sound rock.

- modal brown calcareous and calcic soils:developed on the flat areas or scarcely colluvial zones of plateaus. Unlike rendzina soils, here erosion is weak. The profile is consequently thicker and belongs to the type A (B) C. The structure of horizon A is also granular and very well-developed but horizon (B) of a yellowish-brown presents an angular blocky structure and is hardly compact. These soils rest directly on the sound rock. Soils are deep on alluvial deposits (family 23), and only consist of modal calcareous soils.

Carbonated-soil sub-class

22. Association of brown (22a) modal calcareous soils and of modal rendzina (22b) derived from Kebri Dahar limestone.

This association covers 9.645 km2 on the vast limestone plateaus of South Chercher and of Harar at an altitude varying from 1.000 to 2.000 m. This association is not characteristic of a given climatic type and it exists in the "Ethiopian" climate with rainfall from 800 to 1.200 mm as well as in the "Fickian" climate with rainfall less than 800 mm. Hence, various types of vegetation : in the North, the Croton macrostachys and Cordia abyssinica association and more to the South, the Acacia spp. association.

Morphology

Brown calcareous soils : The following profile is observed :

0 - 20 cm A11	: Very dark greyish-brown (10 YR 3/2) ; silty loam ; medium granular ; scarcely calcareous.
20 - 90 cm A12	: Very dark greyish-brown (10 Y 4/2) ; clay loam ; medium granular ; calcareous ;
90 - 120 cm (B)	: Yellowish-brown (10 YR 3/4) to dark reddish-brown (5 YR 3/3) fine subangular blocky structure ; calcareous clay.
120 cm R	: limestone blocks in situ.

Rendzina soils

0 - 30 cm A	: Very dark greyish-brown (10 YR 3/2) ; medium granular ; calcareous ;
30 cm + R	: Limestone blocks in situ.

The difference between these two types of soils consists in the different development of the thicker organic horizon A1 of brown soils and the absence in rendzina soils of a structural (B) horizon.

The sub-jacent limestone blocks which often also appear at the surface in the case of rendzina soils, present a smooth and worn aspect with no angles and scarcely pronounced hollows, these features characterizing the "melting" process through dissolution of the limestone in situ.

Physico-chemical characteristics

Soil group	Depth cm	Type of horizon	Texture	Structure	CO_3Ca	Organ. matter %	N ‰	C/N	pH	K+ me/100g	Na+ me/100g	Total P_2O_5 ‰
22 a	0-20	A11	SiL	gr.	1,0	4,6	2,4	11	8,0	2,7	0,4	0,6
	20-90	A12	CL	gr.	14,0	2,3	0,9	14	8,1	1,3	0,5	0,5
	90-120	(B)	C	subang blocky	15,0	1,1	0,5	12	8,2	1,8	0,4	0,4
22 b	0-30	A1	SiL	Calc. bl.	12,0	4,9	1,8	15	8,1	1,4	0,3	1,2

The texture varies from silty loam to clay for brown soils whereas it remains silty loam in rendzina soils.

- These soils have a medium calcium carbonate content but the latter is often poorer in the upper horizon of brown calcareous soils. The content of organic matter is relatively high and well-distributed in horizons A1. The nitrogen percentage is high and C/N is medium, showing that humus is deeply mineralized. Organic matter of "mull" type is closely related to mineral matter through calcium links. This is favourable to the formation of a very well-developed granular structure characterizing these soils. pH is distinctly basic and approximately 8,1 owing to the presence of calcium carbonate.

- The absorbing-complex is base-saturated owing to the too large quantity of carbonates.

- The exchangeable potassium content is high.

- The total phosphorus percentage is medium.

- The $\frac{\text{Total N}}{\text{Total } P_2O_5}$ ratio is approximately 4 in the upper horizon of brown calcareous soils. Consequently the unbalance is detrimental to phosphorus.

In the case of rendzina soils, the nutritional balance is correct.

Cultural fitness

Rendzina soils are not arable owing to the abundance of coarse elements (such as limestone blocks at the surface), to their small depth as well as to the steepness of the slopes on which they are developed.

On the other hand, brown calcareous soils are very suitable for agricultural purposes. However, because of a strongly developed granular structure, these soils are very well drained and the pedoclimate is relatively dry. Besides, their close imbrication with rendzina soils is the reason why arable areas are generally small and may not be used for mechanized cultivation. These soils are already largely cultivated in the North but in the South, owing to a decreasing rainfall, the crop-growing possibilities are very low.

As regards fertility, phosphate carriers such as lime superphosphate are recommended.

23. Brown calcareous soils on brown alluvial deposits derived from the Kebri-Dahar limestone.

These soils cover the calcareous alluvial deposits of the flat-bottomed and deeply embanked valleys of rivers which flow down from the High Plateaus of Chercher : Mojo and its tributaries, right bank tributaries of Gobelli, Jerjertu and Omashiwa. These soils occupy a total area of 964 km2.

Morphology : The mean profile is as follows :

0 - 20 cm A11 : very dark greyish-brown (10 YR 3/2) ; clay loam ; granular ; friable.

20 - 60 cm A12 : Dark greyish-brown (10 YR 4/2) ; clayey ; grey angular blocky structure, trend to granular ; friable.

60 cm (B) : Brown ; clayey ; heavy ; coarse angular blocky structure ; firm.

Physico-chemical properties

The clay loam structure, at the surface, becomes a heavy clay structure in the depth, in horizon (B). The granular to angular blocky structure confers a very friable character to horizon A1. Conversely, in horizon (B) the structure becomes broader and even in some cases, a prismatic structure in early stage of development may be observed.

The content of organic matter is high at the surface : 3,8 percent in 20 cm, and decreases very slowly in the depth.

The calcium carbonate percentage is low and increases with the depth. From 2 percent in the surface it attains 9 percent in the depth.

The nitrogen content is high with 2.2 percent at the surface and C/N is approximately 10.

The exchangeable potassium content is high with 2 me/100 g from 0 to 60 cm depth.

Phosphorus has a medium content with 0,82 ‰ at the surface and 0,74 ‰ in the depth.

The $\frac{\text{Total N}}{\text{Total } P_2O_5}$ ratio shows an unbalance detrimental to phosphorus.

Cultural fitness

These soils are very suitable for growing cereals such as maize, wheat and sorghum and the latter are already cultivated on most of these soils. An increase of the crop-yield may be expected if carriers of phosphate such as lime superphosphate are added.

24. Modal rendzina soils derived from Kebri Dahar limestone

These rendzina soils are developed on limestone hills presenting a broken-up relief and are cut by the tributaries of the Wabi flowing in deep valleys, North of Gurgura on the Southern and Northern bank of the Wabi. They represent 1.743 km2 and are covered with a dense bush.

Cultural fitness

These soils are not suitable for crop-growing owing to the steepness of slopes and to the thinness of light soil and should be used as a natural fauna reserve.

Saturated soil sub-class

Unlike the soils above-mentioned, saturated soils present no calcareous traces in the profile horizons A and (B). They are nevertheless base-saturated and are considered as calcic soils.

25. Association of brown calcic soils (25 a) and of calcic rendzina soils (25 b)

They only cover the limestone hills commanding the gently rolling landscape of the Harar plateau at a mean altitude of more than 2.400 m : from Akim Gara to Harar, Langie, Kersa Melkarafu and Betelihem region. They cover a total area of 555 km2.

Brown soils and calcic rendzina soils are closely associated ; the former are developed on the flat eroded zones of hill-tops and the latter on steep slopes.

Morphology.

These soils are close to carbonated soils from a morphological point of view, the only difference being that the various horizons do not react with hydrochloric acid (no calcium carbonate). Here, the type profile of a calcic rendzina soil is only given as a reference.

Type profile n° 3-50 : Akim Gara not far from Harar township. Dense graminea carpet. Some bushes in places. Slope : 10 percent and many outcroppings of the limestone in situ (Kebri Dahar limestone).

0 - 25 cm A1 : Very dark grey (10 YR 3/1) ; clay ; medium and coarse crumb structure with very well-developed granular trend ; very dense root system holding back earth aggregates ; dry ; friable and non-calcareous. Irregular and short transition to :

25 - 40 cm A1R : Mingled calcareous elements from 0,5 to 10 cm thick and fine clay earth ; dark brown (10 YR 3/3) ; fine granular structure ; still dense root system ; fine, non-calcareous earth ; dry and friable ; sudden transition to :

40 cm R : Sound limestone slab in situ.

This rendzina soil is considered as a calcic soil since a distinct decarbonation may be observed in horizon A1.

Physico-chemical properties

Soil group	Depth cm	Type of horizon	Texture	Structure	CO_3Ca	Organ. matter %	N ‰	C/N	pH	T me/100g	ExB me/100g	V percent	K + me/100g	Na + me/100 g	Total P_2O_5 ‰
25a brown calci soils	0-30	A11	C	gr.	0	6,1	1,7	21	6,9	45	44	97	0,5	0,1	1,0
	30-40	A12	C	abl	0	2,8	0,9	18	6,8	41	38	93	0,2	0,1	0,4
	40-170	(B)	C	abl	0	0,5	0,4	7	7,0	38	35	92	0,4	0,2	0,4
25b calci rend-zina	0-25	A1	C	gr	0	10,3	4,5	13	7,1	58	59	100	0,4	0,2	1,5
	25-40	A1R	C	gr	40,	4,4	2,0	13	8,1				0,1	0,1	0,7

These brown to brownish-black soils are clayey. For brown calcic soils, the structure is granular in the first 30 cm and becomes angular blocky in the depth. Rendzina soils present a granular structure throughout the profile. In both cases horizons A1 are friable.

There is no calcium carbonate except in horizon A1 of rendzina soils which in fact consist of fine non-calcareous earth mingled with small dissolution calcareous elements which pass into the fine earth when analysed.

The decarbonation of the profile results from very heavy rainfall- from 800 mm to 1000 mm combined with a high altitude determining a cool climate which is favourable to subsurface drainage and consequently to the washing away of calcium carbonate.

The content of organic matter is high with 6,1 percent from 0 to 30 cm in brown calcic soils and with 10,3 percent in horizon 0-25 cm of rendzina soils. The nitrogen percentage is high and C/N is medium to low.

pH is practically neutral except in rendzina soils where it is 8,1 in the weathering horizon of the limestone in situ. The exchangeable capacity is high and the saturation degree is approximately 100, which proves that the complex is base-saturated.

Exchangeable potassium content is medium.

Phosphorus content is high at the surface and medium in the depth.

The $\frac{\text{Total N}}{\text{Total } P_2O_5}$ ratio shows a nitrogen deficiency in the case of brown calcic soils. As regards calcic rendzina soils, the nutritional balance is correct.

Suitabilities of soils for crop-growing, pastures and afforestation.

- Calcic rendzina soils are unsuitable for agricultural purposes owing to their thinness. They are at the present time under cultivation using the method of low contour dry-stone walls in order to obtain an adequate thickness of soil, but the crop-yield is very poor. The area dedicated to crop-growing between two bunds is only about 2m wide. Consequently these areas are progressively deserted but could be used for forest production combined with livestock-breeding.

- Brown calcic soils are suitable for crop-growing since they are deep and organic matter is abundant. Their extension is small and they are only under cultivation in the Harar region (for instance : chatt and cereals). Nitrogen and potassium carriers would certainly largely increase the crop-yield.

26. Calcic rendzina soils derived from the basalt of plateaus and from volcanic tuff

These soils occupy the steep slopes of the canyons of rivers cutting the High Plateaus of Arussi (Wabi canyon downstream from the Malca Wacana falls, U-lul and Illi canyons in particular). and towards the slopes of the edge of the High Plateaus which fall very steeply towards the "Chola" (region of Suru and of Gassara) at an altitude from 1.500 to 2.000 m. They cover a total area of approximately 2.160 km2.

The slopes of plateaus form a regular geological section showing basalt outcroppings alternated with tuffs and usually abundant pumice. Soils are developed on these two mingled materials.

Morphology

The following profile type is frequently observed :

0 - 15 cm A11	: Dark brown (10 YR 3/2) ; loam ; granular with basalt gravels or non-calcareous pumice.
15 - 40 cm A12	: Brownish-grey (10 YR 5/2) ; loam ; granular and non-calcareous.
40 cm + R	: Horizon consisting of weathering basalt in situ or of tuff with abundant and often calcareous pumice.

Physico-chemical characteristics

These brown loam soils present a very well developed granular structure. They are usually shallow.

The presence of calcium carbonate is only distinct in the horizon with tuff or weathering basalt (up to 18 percent) but horizon A is always decarbonated.

The content of organic matter is high with 4,7 percent from 0 to 40 cm depth and so is the nitrogen content (3,6 ‰). The C/N ratio is very low (8 to 10) and shows that the humus of calcic type is well-developed.

Suitabilities for crop-growing and afforestation

These soils are wholly unsuitable for crop-growing or afforestation owing to the steepness of slopes.

In zones where the slopes of canyons are not so steep, reforestation is possible and would present two advantages :

- limit erosion which badly degrades the edge of the High Plateaus.
- economic development of regions which at the present time present no interest.

E. SOILS WITH A CALCAREOUS DIFFERENCIATION

This class includes soils the profile of which is characterized by a redistribution of limestone. It is divided into two sub-classes :

- with a melanic horizon
- with a pallid horizon

The sub-class with a melanic horizon includes soils the upper horizon of which presents the following features through at least 18 cm depth, namely :

- the soil-structure is well-developed and the horizon is never hard when dry.

- soil has a chroma less than 3,5 when wet and a darker "value" than 3,5 in the same condition or 5,5 when dry (Munsell Colour Chart).

- base-saturation is greater than 50 percent.

- organic matter represents at least 1 percent throughout the melanic profile.

These soils, with a dark surface horizon and a content of organic matter of at least 1 percent, exist in the Middle Belt zone and in Arussi where the pedoclimate is damp enough to allow a certain accumulation of humus of mull type.

The sub-class with a pallid horizon includes soils the upper horizon of which is too lightly coloured and presents a too low percentage of organic matter to be considered as "melanic". Organic matter generally represents less than 1 percent for a 20 cm depth. This sub-class corresponds to all the soils with a calcareous differenciation of the subarid zone of Lower Ogaden.

Calcareous differenciation is considered for the classification in soil-groups. Four types of differenciations are determined, i.e. :

- with powdery lime : lime is not visible in the profile but fine earth reacts with hydrochloric acid. Calcium carbonate averages 20 percent.

- with heaps and nodules : calcium carbonate is accumulated at a medium depth or lower in more or less hard heaps and nodules.

- with friable massive accumulation : only in the case of chernozem of the Guedeb plain and corresponding to the "soft powdery lime" as termed by F.A.O.

- with hard massive crust (nodule crust) : the calcareous accumulation horizon is thick and hard. It consists of calcareous nodules coated with a hard calcareous cement. The following sub-groups have been determined :

- for soils with powdery lime : a single modal sub-group ;

- for soils with calcareous heaps and nodules, three sub-groups :

  - carbonated sub-group,
  - vertic carbonated sub-group,
  - vertic calcic sub-group.

- for soils with friable massive calcareous accumulation : chernozem sub-group.

- for soils with a hard massive crust (nodule crust), three sub-groups :

  - carbonated sub-group,
  - calcic sub-group,
  - vertic calcic sub-group.

. carbonated sub-group : horizon A contains carbonate.

. calcic sub-group : horizon A contains no carbonate but is base-saturated.

. vertic carbonated sub-group : vertic features in the depth ; horizon A contains carbonate.

. vertic calcic sub-group : vertic teatures in the depth ; the horizon contains no carbonate but is base-saturated.

Sub-class of soils with a melanic horizon

Group with Powdery lime

27. Reddish-brown modal soils derived from the Kebri Dahar limestone

They are developed on reddish brown calcareous colluvial deposits on the lower glacis of the limestone plateaus of the Fik, Degah-Medo and Segeg region. They cover a total area of 1.431 km2.

Morphology : In the Segeg region the following profile is observed on the colluvial deposits of lower plateaus, with a "striped" vegetation of tall Acacia alternated with a dense thorny bush.

0 - 15 cm A11 : Reddish-brown (5 YR 5/3) ; silty loam ; very well-developed medium granular ; friable.

15 - 150 cm A12 : Reddish-brown (5 YR 5/3) ; silty clay loam ; granular to very well-developed medium angular blocky structure ; very friable.

150 cm R : Limestone slab in situ.

These soils are generally rich in coarse elements consisting of gravels or of worn limestone pebbles. Basalt "pseudo-pebbles"* may also be seen when basalt outcroppings exist nearby (Higher Valley of Walensi and Duri between Fick and Degah-Medo).

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* Basalt "pseudo-pebbles" are not linked to alluvial transportation but to the weathering in boulders characterizing this rock.

Physico-chemical characteristics

These soils are reddish-brown with silty loam at the surface and silty clay loam in the depth. The most important feature is the considerable development of the structure as in the case of chernozem soils but with differences which consist in :

- a considerably lower percentage of organic matter : 1,6 in A11 and 1 percent in A12.

- no decarbonation of the profile and no accumulation at the base. Lime remains powdery and represents a high percentage (32 to 36).

- pH varies from 8,2 to 8,4.

Suitabilities for crop-growing and afforestation

These soils are unsuitable for crop-growing owing to inadequate rainfall. Nevertheless, a natural vegetation with tall trees allows envisaging local reforestation on these types of soils near Fick, Degah-Medo and Segeg.

28. Brown modal soils derived from the basalt of Ogaden

These soils only occupy 340 km2 on the alluvial deposits derived from the basalt outcroppings of Fik and Degah-Medo. They are often associated with the brown vertisols of soil-family 11 which cover lower zones.

These are reddish-brown very well structured clay soils, presenting abundant coarse elements which mainly consist of basalt "pseudo-pebbles" of variable size and, in a smaller quantity, of worn limestone gravels and pebbles.

They are wholly unsuitable for crop-growing or forests.

29. Brown carbonated soils derived from Jijiga basalt.

These soils are only developed on the steep slopes of the basalt mountain-range of Cramara including Mount Merda which separates the catchment basin of the Fafen to the West, from that of the Jerer, to the East. They cover approximately 253 km2.

Morphology : The following profile is generally observed on the steep Caramara slopes (Jijiga mountain).

0 - 35 cm A1	: Very dark brown (10 TR 2/2) ; clay ; highly developed medium and coarse granular structure ; very friable.

35 - 70 cm : same type of horizon but with small calcareous mottles and
B ca concretions ; scarcely friable.

70 cm + : motley weathered basalt with a calcareous film coating the
C ca weathering elements.

Physico-chemical characteristics

- Soil is very dark brown and very clayey with a very well-developed granular structure. It is generally shallow owing to weathering on steep slopes.

- The calcium carbonate percentage : - 1,6 in horizon A1 is low in fine soil but it greatly increases in the weathered basalt horizon.

- Organic matter content is very high with 8,9 percent for 35 cm depth and soil is rich in nitrogen : 3,9 ‰ and C/N is 13.

- Soil is base-saturated and pH is approximately 8.0.

- Exchangeable potassium is medium with 0,4 me percent.

- The total phosphorus content is high with 1,7 ‰ in horizon A1 and 1,5 % in horizon B ca.

Suitabilities for crop-growing and afforestation

These soils are not arable because of slopes. However, their specific retention and their fertility, which is mainly linked to the high content of organic matter, are very favourable factors for reforestation in a region where wood is lacking.

30. Yellowish-Brown carbonated soils derived from basalt and volcanic tuff

These soils are developed on the alluvial and colluvial deposits of the gently rolling Asa Osmane region at the bottom of the canyon of U - Lul and of its tributaries. They only cover 75 km2 but are certainly very suitable for agricultural purposes.

These are calcareous soils throughout the profile, with calcareous concretions.

Morphology : in a coffee plantation in bad condition the following profile has been observed :

0 - 60 cm A1	:	Dark greyish-brown (10 YR 4/2) ; fine sandy clay ; granular to well-developed subangular blocky structure ; very friable.
60 cm + B ca	:	Yellowish-brown (10 YR 5/6) ; clay ; scarcely developed coarse angular blocky structure ; few friable calcareous nodules ; relatively compact.

Physico-chemical characteristics

These dark greyish-brown to yellowish-brown soils with a mostly clayey texture, present a well-developed structure in horizon 0 to 60 cm. But, in the depth, at the same level as calcareous concretions, soil becomes more compact.

- This soil is generally calcareous with 20 to 30 percent of calcium carbonate.

- Organic matter content is medium and less than 3 percent.

Cultural fitness

The dry climate at the bottom of the Asa Osmane canyon is compensated for by numerous small permanent streams which are affluents of the U-Lul river.

Altitude is relatively low (1.900m about) and this zone being protected against the high cold wind blowing on the plateau, tropical crops may be suitably cultivated under irrigation.

Hence, sugar-cane, bananas, papayas etc... are grown here for local consumption.

Coffee-plantations also existed but the remaining coffee-trees observed seem to be unfavourably affected by an excessive quantity of calcium carbonate in soil (chlorosis).

It is sure that rational irrigation would enable creating sizeable plantations for the production of bananas, sugar-cane and other tropical plants.

31. Reddish-Brown carbonated soils derived from Gesoma sandstone 31 a, 31 b, 31 c.

- Soils of Northern and Eastern Ginir - Shek - Hussien - Seru (31 a and 31 b)

They cover vast spreading zones of sandy weathered material from Gesoma sandstone at the foot of the High Plateaus to the East, on the one hand South of Seru, and on the other hand, between Ginir and the Wabi Shebelle. They occupy a total area of 9.620 km2.

These soils are deeply weathered, West of a line from Ginir to Haragura and present a very broken up topography (31 a), but they also cover very flat glacis which are scarcely cut by the rivers flowing down from the Aouatou mountains and the base of which consists of Kebri Dahar limestone to the North, and of main gypsum to the South (31 b).

The mean altitude varies from 1.200 m to 1.500 m and rainfall is more than 600 m. These two factors are favourable for the development of a relatively dense vegetation of tall Acacia with a thick graminea carpet. Tall Euphorbia stands are often seen. Numerous prickly-pear trees grow in the Sheik-Hussien region.

Soils of El Kere region : (31 c).

They occupy the long and gently sloping glacis on the colluvial deposits derived from the sandstone of the El Kere plateau. At a mean altitude of 600 m, these soils rest on a deep gypsum slab (main gypsum formation). Rainfall is distinctly less than in higher regions but the vegetation is relatively well-developed in some places and presents tall acacias.

Morphology : The following medium profile has been observed :

0 - 25 cm A11 : Dark reddish-brown (5 YR 3/3) ; fine sand ; single-grained ; loose.

25 - 70 cm A12 : Reddish-brown (5 YR 4/3) ; sandy loam to loam ; scarcely developed subangular blocky structure ; some lime concretions ; loose.

70 - 100 cm (B) ca : Reddish-brown (5 YR 4/4) ; fine sandy clay ; well-developed subangular blocky structure ; numerous lime concretions ; very friable.

100 cm R : limestone slab in situ (31 c and 31 b). gypsum slab in situ (31 c).

Physico-chemical characteristics

Soil group	Depth	Horizon type	Texture	Structure	CO_3Ca percent	Organ. matter %	N ‰	C/N	pH	K + me percent	Na + me percent	Total P_2O_5 ‰
31 b	0-25	A11	fs	sg-gr.	1,2	2,0	1,1	10	7,7	1,0	0,1	0,6
	25-70	A12	fs	sub.bloc	3,6	1,2	0,7	10	7,7	0,6	0,2	0,5
	70-90	(B) ca	fs C	sub.bloc	7,7	1,0	0,5	12	8,3	0,5	0,8	0,8

These dark reddish-brown to reddish-brown soils are distinctly sandy but become slightly more clayey in the depth. The single-grained to subangular blocky structure gives a general loose to friable consistency.

Calcium carbonate is present throughout this soil but the percentage increases in fine earth and with the depth from 1,2 to 7,7. This is in relation to the existence of an horizon with an accumulation of lime concretions between 70 and 90 cm depth which is developed just above the limestone slab and plays the role of a lime reservoir.

The content of organic matter is medium at the surface and slowly decreases with the depth. This often characterizes soils with dominant sand and in which organic matter is well distributed in the profile. The nitrogen content is medium and the low C/N reveals a calcic mull.

pH is neutral to basic in the depth at level B ca where calcareous nodules are accumulated.

Exchangeable potassium is abundant.

Phosphorus content is medium.

The $\frac{\text{Total N}}{\text{Total } P_2O_5}$ ratio is less than 2, hence a low nutritional nitrogen deficiency.

Suitability for crop-growing, pastures and afforestation

Northern and Eastern Ginir - Shek-Hussien-Seru (31 a and 31 b).

Zones located on either side of the Ginir Lege Hida track and between the Wabi and Errer rivers, on the large glacis at the foot of the High Plateaus and of the Aouatou mountains (31 b) could be cultivated using a network for soil erosion control consisting of small earth embankments to prevent a loss of water due to overland runoff. These soils would then be available to cultivate sorghum and also cashew trees in orchards.

As regards soil-fertility, nitrogen carriers are necessary but phosphorus should also be added.

Conversely, all the other areas, whether they are very steep or deeply affected by erosion (31 a) could be reforested usefully as rainfall is sufficient to ensure a suitable growth of selected species. This reforestation would be particularly favourable near the Aouatou mountains to the North-East of Ginir.

Pastoral possibilities are good in all this region during the rainy season.

El Kere region (31 c)

In this region these soils are not available for agricultural purposes but they are suitable pastures during the rainy season.

32. Reddish-brown carbonated vertic soils derived from the Kebri Dahar limestone

These soils were observed on the calcareous colluvial and alluvial deposits near the Dare temporary river which is located to the South of Hara - Gura. They only cover an area of 700 km2.

Morphology :

0 - 30 cm A11	: Dark brown (7.5 YR 4/4) ; silty loam ; single-grained ; friable.
30 - 80 cm A12	: Reddish-brown (5 YR 5/3) ; clayey ; medium angular structure becoming flat ; friable.
80 cm + (B) ca	: Dark brown (7.5 YR 4/4) ; clayey ; medium developed prismatic structure with scarcely distinct slickensides ; some lime concretions and gypsum crystals ; scarcely friable.

Physico-chemical characteristics :

These soils are brown to reddish-brown with silty loam at the surface and clay in the depth. Vertic features appear below 80 cm depth.

The calcium carbonate content is approximately 15 percent with no noticeable gradient.

The content of organic matter is 2,1 percent in A11 and gradually decreases with the depth to 1 percent in (B) ca.

The nitrogen content is 1.4 ‰.

pH is greater than 8.0.

The content of exchangeable potassium is high : 0.9 me/100 g. Phosphorus content is medium with 1.2 ‰.

The $\frac{\text{Total N}}{\text{Total } P_2O_5}$ ratio is approximately 1 and shows a distinct nitrogen deficiency.

The exchangeable sodium content increases with the depth to attain 5,6 me/100 g of soil with Na/T approximately 8,0.

Cultural fitness

Because of their high specific retention due to their clayey texture, these soils may be very suitable for the cultivation of sorghum providing that rain water is held back in the plots by small dykes. Nitrogen carriers such as ammonium sulphate are necessary to obtain satisfactory yields.

33. Reddish-brown vertic calcic soils derived from Gesoma sandstone and Kebri-Dahar limestone

These soils are developed on the calcareous and sandy colluvial deposits of large glacis spreading on either side of the Jerer between Kaho and Degahbour. They cover a total area of 1.538 km2. Rainfall is approximately 450 mm.

Physico-chemical characteristics

This brown to reddish-brown soil generally consists of fine sandy-clay at the surface and clay in the depth with pronounced vertic features.

Soil is scarcely calcareous.

The content of organic matter is approximately 2,5 percent and these soils present a large quantity both of exchangeable potassium and of phosphorus.

Cultural fitness

These soils form a zone where the cultivation of sorghum could be extended. The large and scarcely sloping glacis seem suitable for mechanized cultivation providing that :

- Field operations should be carried out at right angles to the natural direction of slope, in other words, by contouring for instance : contour ploughing in order :

- to limit erosion as much as possible,

- to facilitate specific retention and prevent a loss of water due to overland runoff (see chapter VI b).

Nitrogen carriers such as urea, ammonium nitrate and ammonium sulphate are recommended.

Group of soils with a massive friable accumulation

34. Chernozem derived from volcanic tuff

These soils are only represented in the Guedeb plain where they occupy the largest part covering 983 km2.

This "plain" is in fact a double gently sloping glacis where the Wabi in the centre occupies the lower part, and which joins on the outskirts the hills of Dodola and Adaba in the South, in the North the sides of the Kaka and Enkolo mountains, and in the West the rolling land of Kofele. Eastwards it becomes narrower and ends on the level of the Malka Wacana falls.

This plain has a volcanic origin ; the cross-section of the Assassa ford shows in fact a succession of usually calcareous tuff and ash with a ryolitic layer at an elevation of 30 m+ compared to the level of the Wabi. This formation rests on basalt (at present : bed-level of the Wabi).

The ryolitic layer is in a way the framework upholding the Guedeb plain. It is overlain with approximately 15 meters of andesitic ash resulting from eruptions of the Rift Valley.

This ash with abundant glass constitutes the base material of chernozem soils.

The climate is characterized by a mean annual rainfall of 800 mm, a pronounced dry period from November to January and a low mean annual temperature of approximately 13°.

The vegetation mainly consists of gramineae since this zone is under cultivation, and trees only remain in some small valleys.

Morphology : The following profile has been observed at 7,5 km away from Dodola on the Assassa track.

Vegetation mainly consisting of Pennisetum ; old fallow field.

0 - 7 cm A11	: Dark brown (7,5 YR 4/4) ; loam ; well-developed medium crumb structure ; dry and friable ; numerous rootlets ; distinct and uniform transition to :
7 - 35 cm A12	: Dark brown (7,5 YR 4/4) ; silty-loam ; well-developed medium granular structure ; dry and friable ; numerous rootlets ; gradual transition to :
35 - 75 cm A13	: Brown (7,5 YR 5/4) ; silty loam, subangular blocky structure with trend to well-developed granular ; friable ; many rootlets ; short and uniform transition to :
75 - 105 cm (B)	: Yellowish-brown (10 YR 5/6) ; sandy clay-loam ; scarcely developed coarse subangular blocky structure ; dry and friable ; some rootlets ; distinct transition to :

105 - 140 cm
C. Ca : Yellowish-white calcareous accumulation ; "soft powdery lime" with calcareous heaps and nodules (lime puppet). Gradual transition to :

150 cm +
R. : Greyish-yellow non-calcareous tuff with abundant pumice.

Horizon A is therefore considerable since it attains 75 cm thick. However, its thickness varies in relation to its position. The gentle folds of the Gedeb plain present a convex aspect and soils are thicker on the upper part of these folds but they are very thin at the foot of slopes.

Physico-chemical characteristics

Soil group	Depth cm	Horiz type	Texture	Structure	CO_3 Ca %	Organic matter percent	N ‰	C/N	pH	T me/100g	BE me/100g	V percent	K + me/100g	Na + me/100g	Total P_2O_5 ‰
	0-7	A11	L	Cr	0	6,2	2,8	12,7	6,6	24,0	20,6	86	2,25	0,10	0,90
	7-35	A12	L	Gr	0	2,7	1,3	12,1	6,6	25,0	23,6	94	1,90	0,17	0,80
	35-75	A13	SiL	sub.bl	0	1,9	0,72	15,0	7,3	27,0	28,6	100	2,51	0,27	0,75
	75-105	(B)		sub.bl	traces	1,0	0,64	9,3	7,6	30,0	29,3	98	2,84	0,72	0,80
	105-140	C.ca	L	-	15,6	0,4	0,28	7,1	9,0		-		3,60	2,10	0,80

Dark brown soils have a usually light texture : loam to silty loam . The clay percentage is very low unlike in the neighbouring vertisols formed on basalt.

Two features have been observed enabling to class these soils as chernozem, i.e. :

- the strongly-developed granular structure of a considerable thickness averaging 75 cm and becoming a subangular blocky structure deeper down.

- the presence of an horizon with calcareous accumulation (15,6 percent in the depth, in the form of soft powdery lime with a fluffy" consistency. Besides, big (50 cm) lime "puppets" may also be observed.

- horizons A and (B) are non-calcareous.

The content of organic matter is high and averages approximately 6 percent and steadily decreases with the depth. They give horizon A its brown colouring (melanic horizon). The nitrogen content is high at the surface and medium at a small depth.

C/N ratio is approximately 12 and indicates a calcic mull.

Organic matter which is linked to mineral matter is one of the favourable elements for the formation of a granular structure.

The exchangeable capacity is medium throughout the profile. The absorbing complex is weakly desaturated at the surface but is saturated below 35 cm depth.

The content of exchangeable potassium is high : approximately 2 me/100 g of soil.

Exchangeable sodium comparatively increases in the depth owing to the weathering of andesitic material.

Total phosphorus is medium.

The $\frac{\text{Total N}}{\text{Total } P_2O_5}$ ratio is approximately 3 which means that the nutritional balance between these two elements is correct.

Cultural fitness

These soils with a comparatively dry climate due to their very well-developed granular structure are particularly suitable for the cultivation of cereals. The Gedeb plain has been entirely under cultivation for the last thirty years using a traditional crop-growing system based on cereals wheat-barley alternating with long fallow-periods during which gramineae are used for grazing (Pennisetum).

The cereal-yield combined with livestock-breeding would considerably increase if :

- cultural practices were improved by using modern instruments for field work.

- more productive crop-varieties tested beforehand were grown.

- fallow land was replaced with a cultivated meadow.

- nitrogen carriers such as urea, ammonium sulphate and ammonium nitrate and phosphate carriers (lime superphosphate) were added in order to obtain a higher yield).

By planting wind-breaks, 400 m to 500 m apart and at right angles, the yield would be improved owing to an increase of the hydrological balance of soil (see ch VI c).

Group with hard massive crust (nodule crust)

35. Brown carbonated soils derived from Kebri Dahar limestone

These soils with a shallow calcareous crust occupy all the hillocks of the Jijiga plateau, the hills South of Shekum and of Borale in the North-

Eastern part of the Basin and a large zone with small hills stretching on either bank of the Dare-Ledae temporary river between Hara Gura and the Wabi, in the South-Western part of the Basin. They cover a total area of 1.852 km2 with poor grazing grounds.

Morphology : The following profile is generally observed :

0 - 20 cm A1 : Dark-brown (7,5 YR 4/4), loam to clay loam, developed fine and medium angular blocky structure.

20 - 90 cm B ca : Very hard limestone crust of nodule type.

90 cm C ca : Weak weathering of the limestone in situ.

Physico-chemical characteristics

These are dark brown soils with loam to clay loam and a well-developed structure in horizon A1 though its thickness is variable ; it is even sometimes completely eroded and the crust is visible at the surface.

This very hard limestone crust consists of light yellow nodules cloaked with grey cement. Though the age of this crust is not exactly known, the observation of an horizon resulting from the weathering of the limestone in situ (C ca) shows that pedoclimatic conditions are favourable in this zone for the present migration of calcium carbonate.

- The surface horizon has a high percentage of calcium carbonate (30 percent).

- The content of organic matter in horizon A1 is high and approximately 3 ‰.

Cultural fitness

These soils are unsuitable for crop-growing owing to the shallowness of the soil used by the roots of plants and they must be left as natural pastures.

36. Reddish-brown calcic soils derived from Gesoma sandstone

They occupy the large sandstone plateaus commanding the Degahbur basin to the East of the Jerer, and cover 1.070 km2.

These gently rolling plateaus present a not very dense savannah with tall acacias and a dense graminea carpet in slightly depressed zones. Rainfall is approximately 400 mm.

Morphology :

0 - 30 cm A1 : Dark reddish-brown (2,5 YR 3/2) ; coarse sand to fine sandy clay with numerous quartz gravels ; subangular blocky structure with a trend to single-grained structure.

30 cm + B ca : weakly calcareous hardpan ; very hard ; nodule type with small nodules.

Physico-chemical characteristics :

These dark reddish-brown soils are generally not very thick but in slightly depressed zones (colluvial zones of plateaus), they are sometimes 50 cm thick.

The hardpan consists of nodules including numerous quartz elements. The small (1 1/2 to 1cm) nodules are strongly cemented together with a calcareous cement but leave many spaces filled in with fine earth from the upper horizons as well as with the roots of trees and the rootlets of gramineae.

The calcareous crust is much weaker than in the former soil-family owing to the poor lime content in the original sandstone material to which is also due the lack of carbonates in the surface horizon.

The content of organic matter is approximately 2 percent in horizon A1, but is still 1,5 percent in the fine soil which occupies the spaces in the hardpan. Nitrogen has a medium content of 1,1 ‰ in horizon A1.

The exchangeable potassium content is medium : 0,4 me/100 g and the phosphorus content is low : 0,4 ‰ of total P_2O_5.

Cultural and pastoral fitness

These soils are unsuitable for crop-growing but the abundance of grass in slightly depressed zones makes them particularly fit as pastures during and after the rainy season.

37. Reddish-brown calcic vertic soils derived from Gesoma sandstone

These soils cover the sandstone plateaus, North of Degahbour, as well as the Gelelcha plateau and they represent a total area of 1.236 km2.

On these gently rolling plateaus grows a real wooded savannah with a predominance of tall acacias and a dense gramineae carpet. Consequently, the vegetation is far more considerable than on the same plateaus on the level of Degahbour-Aware (family 36), and is characteristic of an increasing rainfall which is probably higher than 500 mm.

Morphology :

0 - 30 cm A11	: Dark brown (7,5 YR 3/2) ; fine sandy clay ; very well-developed granular structure ; friable.
30 - 60 cm A12	: Dark brown (7,5 YR 3/2) ; clayey, well-developed angular with a vertic trend.
60 cm B ca	: calcareous hardpan.

Physico-chemical characteristics :

These dark brown fine sandy clay to clay soils have a well-developed granular structure at the surface and present vertic features in the depth.

The thickness of horizon A varies from 1 m in the lower part of an undulation to sometimes only a few centimeters on the upper parts.

The surface horizon is non calcareous.

The content of organic matter is approximately 3 percent in the upper horizon and the exchangeable potassium and phosphorus contents are medium.

Cultural and pastoral fitness

Except in the depressed areas of plateaus where crop-growing is possible since soil is thick enough, it would be more advisable to leave this zone as a wooded savannah. It constitutes excellent pastures most of the year. Besides, by controlling deforestation which might increase, owing to the growing needs of the towns of Jijiga and Degahbur, this zone is particularly recommended for the creation of a fauna reserve (see chap. VI 6).

Sub-class of soils with a pallid horizon

The upper horizon has a light colouring and the content of organic matter is 1 percent or even less for a 20 cm depth. This sub-class corresponds to soils with a calcareous differenciation in the arid zone of Lower Ogaden.

Group with powdery lime (38 a and b) Modal soils on yellowish-red to reddish-yellow alluvial deposits derived from Kebri Dahar and Mustahil limestone and from Gesoma sandstone.

These soils are developed on 3.000 km2 in the U-shaped and large bottomed valleys and on the detrital fans of the Fafen tributaries in the Shekosh, Kebri-Dahar region on the one hand, and in very deeply cut valleys of the temporary rivers of the El Kere region on the other hand. Rainfall is approximately 300 mm.

Morphology and physico-chemical characteristics

These soils are yellowish-red (5 YR 5/6) to reddish-yellow (5 YR 6/6) with a fine and medium sandy (Shekosh 38 a) or coarse sandy (El Kere 38 b) texture and a single-grained structure. The horizons are generally loose and consist of instratified layers with pebbles.

All the soil is calcareous with 20 percent of calcium carbonate in (38 a) but scarcely calcareous (2 to 3 percent) in (38 b). Carbonates remain powdery and are not individualized.

The content of organic matter is low : 1,2 percent at the surface.

The nitrogen content is only 0,6 ‰.

The exchangeable potassium content is medium to low : 0,1 to 0,3 me/100 g.

Phosphorus content is medium: 1,5 ‰ in (38 a) and low in (38 b).

The $\frac{\text{Total N}}{\text{Total } P_2O_5}$ ratio is approximately 1 in (38 b) and reveals a nutritional unbalance detrimental to nitrogen.

Cultural fitness

In the Shekosh Kebri-Dahar region (38 a) these soils are unsuitable for agricultural purposes and are but poor grazing grounds during the rainy season.

Conversely, in the El Kere region (38 b) in spite of a sandy texture, these soils are certainly fit for agricultural purposes. The considerable floods of temporary rivers draining rain-water from the sandstone plateaus of the El Kere region are very favourable for a good sorghum yield. In another case, the presence of a permanent ground water table near the surface also allows the cultivation of sorghum though the soil texture is very coarse ("Ashawa Bota" : El Kere track).

Complete mineral dressing with nitrogen, phosphorus and potash is necessary in order to obtain higher yields (ammonium sulphate, superphosphate and potassium chloride).

Group with calcareous heaps and nodules. 39 (a.b.c.d.e.)*
Yellowish-red soils derived from Kebri Dahar, Mustahil and Belet Uen limestone.

These soils cover, South of the Basin, the vast characteristic tabular limestone plateaus which stand out at a 50 m height against the horizon representing one of the most specific features of the Ogadenian landscape. These plateaus consist of different geological formations according to the region :

Kebri Dahar limestone : North of a line : Korahe-Hamaro Hadad.

Mustahil limestone : approximately South of a line : El Kere - Dalad - Burkur.

Belet-Uen limestone : represented only to the North of Ferfer

These plateaus have a medium extension on the Mustahil and Belet Uen limestone (39.c.d.e.). They are jagged owing to the action of rivers in the Kebri Dahar - Shekosh - Maleiko region (39 a.). Conversely, they form a vast and absolutely flat zone without a single river, from the North of Maleiko to Bulul and Daketa (39 b).

In other cases, and this is particularly true for Mustahil limestone, they often form isolated hills in the large "gypseous plain" : Goja, Menelik Tarara, Galue mountains etc....(39 c). No proper hydrographic system exists (39 d) on the vast gently sloping glacis with a limestone substratum (Mustahil limestone) of the Lola Shilavo region, which is commanded to the East by the weathered bluff of Gesoma sandstone, and which disappears Westwards at the limit of the Dobowein depression.

The climate of these plateaus is hot and dry and rainfall is less than 300 mm and sometimes under 150 mm.

The density of the vegetation is surprising in such an arid climate. It consists of a dense bush with Boscia minimifolia and Delonix elata, averaging 3 to 4 m high and it is often difficult to drive through this vegetation.

This important vegetation on the plateaus is due - apart from the fact that the plants are adapted - to the following reasons :

- There are two rainy seasons in the year and the dry seasons never last very long.
- These zones are not much frequented by herds, hence they are scarcely degraded.

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* Letters : a.b.c.d.e. concern the soil classification on the map at 1/250.000. Details are given in the following pages of this report.

- the most important factor is probably the fact that the limestone slabs are deeply cracked and that the roots of shrubs can draw profit from the humid pedoclimatic conditions long after rainfall since they can reach down to the limestone depths.

The vegetation often presents a very distinct striped-bush pattern especially when flat zones are vast enough as, for instance, the Maleiko, and South-Segag zone and the large plateaus to the West of Gode.

These soils cover a total area of approximately 24792 km2.

Morphology : The following medium profile is observed :

Profile 6 - 117, approximately 30 km to the East of Gode on a limestone plateau.

0 - 10 cm A11	: Reddish-yellow (5 YR 6/8) ; silty loam ; subangular blocky with single-grained trend ; very friable ; numerous fine angular limestone gravels ; numerous rootlets ; short and uniform transition to :
10 - 30 cm (B) ca	: Light-yellowish red (5 YR 5/8) ; silty loam ; subangular blocky structure with single-grained trend ; dry and friable ; numerous very round, 2 cm in diameter calcareous nodules consisting of hard limestone coated with concentric dark reddish layers ; some nodules are cemented together forming calcareous heaps, the size of a fist ; numerous angular limestone pebbles ; still numerous rootlets ; sudden and irregular transition to :
30 cm + R =	: Fine whitish-grey limestone slab in situ.

This profile characterizes shallow soils in situ.

In weakly depressed zones on large plateaus, colluvial deposits may be observed on the lower areas and soils are deeper. This was mostly observed in the Hamaro - Maan - Degah - Medo regions and East of Shilavo. They are in fact very visible on aerial photographs owing to the fine striped pattern of the vegetation. On the vast Degah - Medo - Maleiko plateau on the Degah - Medo - Segeg track, the following profile may be seen :

0 - 30 cm A11	: Yellowish-brown (10 YR 5/8) ; sandy clay loam ; fine granular with single-grained trend.
30 - 90 cm A12	: Reddish-yellow (5 YR 6/8) ; sandy clay loam ; fine subangular blocky with single-grained trend.

90 - 120 cm B ca	: Yellowish-red (5 YR 5/8) ; fine sandy clay ; scarcely developed fine subangular blocky structure ; 60 percent of 1 cm diameter, medium very hard, calcareous nodules which are not cemented together.
120 cm + R.	: Limestone slab in situ.

This profile characterizes colluvial soils on plateaus.

Conversely, in other zones, mainly in regions where the drainage pattern is dense, plateaus are narrow and soil is usually eroded so that the slabs in situ become apparent.

These soils were differenciated at a scale of 1/250.000 by combining factors such as : type of parent-rock, morphology of plateaus, importance of colluvial deposits on the plateaus, i.e.

39 a. shallow soils in situ on the broken-up plateaus of Kebri Dahar limestone.

39 b. colluvial soils predominant on plateau + shallow soils in situ on the vast plateaus of Kebri Dahar limestone ; with striped bush pattern.

39 c. shallow soils in situ on the Mustahil limestone plateaus.

39 d. colluvial soils predominant on plateaus + shallow soils of plateaus on Mustahil and Belet Uen limestone. Vegetation of a striped-bush pattern.

39 e. shallow soils in situ on broken up plateaus, on Belet Uen limestone.

On the map at 1/1.000.000, all these types of soils are grouped together with the reference N° 39.

Morphology and origin of nodules :

Round calcareous nodules are always numerous above the limestone slab in situ. They are very hard and consist of a central core with the same "texture" as the limestone slab, and they are coated with a series of concentric, more or less dark brownish-red calcareous layers. It is difficult to know whether they result from the present dynamics of limestone or whether they are the remnants of a more humid previously existing pedoclimate. One may believe that these nodules were formed very slowly, either in the present climatic conditions, or in a climate more favourable to the movement of calcium carbonate, for instance a mediterranean climate.

We prefer the second assumption which has already been favoured as regards limestone pebble-deposits in the ancient detrital fans of the Gode region.

Physico-chemical characteristics

Soil group	Depth cm	Type of horizon	Tex-ture	Struc ture	CO_3Ca %	O.M. %	N ‰	C/N	pH	Conductivity of saturation ext. mmhos/cm	K^+ me/ 100g	Na+ me/ 100g	Total P_2O_5 ‰
39	0-10	A1	SIL L	s-gr	30	1,1	0,60	11	8,2	1,0	0,7	0,1	0,8
	10-30	B ca	L	s-gr sub-bl.	31	0,8	0,33	14	8,3	1,0	0,6	0,1	0,7

These soils are reddish-yellow to yellowish-red but sometimes yellowish-brown at the surface in colluvial zones on plateaus.

The texture is usually slightly clayey and of a silty loam to loam type.

The fine earth of this soil is very calcareous.

The content of organic matter is low at the surface : 1,1 percent but scarcely varies with the depth : 0-8 percent. Nitrogen content is low and C/N reveals a mull of calcic type and a fast mineralized humus. This deficiency of organic matter in soils is not at variance with the importance of the above described vegetation. In fact, the species have a short vegetative cycle and provide but little leaf mold.

pH is greater than 8,0 which is in relation to the presence of a large quantity of calcium carbonate.

Conductivity of the saturation extract is very weak. The calcareous materials provide but very small quantities of chlorides and sulphates.

The exchangeable potassium content is high.

Phosphorus content is medium.

Cultural and pastoral fitness

These soils are unsuitable for agricultural purposes owing to the dry climate and to the thinness of the soils.

The limestone plateaus of Ogaden are often used for the movement of livestock during the rainy season. In depressed and colluvial zones on the plateaus, the accumulation of rain-water is favourable to the development of pastures which are frequented by nomads and their herds. Nevertheless, and even from a pastoral point of view, the limestone plateaus present but a very weak economic interest especially on account of the remoteness of water points. These vast regions could be integrated in a game reserve though they lack the interest of the gypsum zones.

40. Red carbonated soils derived from zoogenous sandstone

They are developed on a layer of zoogeneous sandstone of the main gypsum formation which outcrops North of Imi on either side of the Wabi and they form small 20 m high tabular hills with jagged edges.

The mapped area corresponds to 370 km2 plus one fifth of the Northern Imi association, thus totalizing 970 km2.

Soil is red (2,5 YR 5/8) and presents a loam texture and a structure with single-grained trend. Horizon B ca is often rich in calcareous nodules and fine earth has a high calcium carbonate percentage.

These soils are unsuitable for crop-growing or pastures but the corresponding zone will eventually be integrated in a fauna reserve, North of Imi (See Chapter VI G).

41. Carbonated soils on Reddish-Brown alluvial deposits of the Jerer

These soils are developed on the alluvial deposits of the Jerer, from the North of Kaho to the South of Bulale on an area of 370 km2.

These yellowish-red (5 YR 6/6) to reddish-brown (5 YR 5/4) soils consist of clay loam and medium sandy clay and are characterized by the presence at the base of the profile of numerous friable lime concretions.

These soils are calcareous with 16 percent of calcium carbonate at the surface and 30 percent in the depth.

The content of organic matter is low : 1 percent at the surface.

The conductivity of the saturation extract amounts to 66 mmhos/cm in the depth owing to the influence of the salt-loaded water of the Jerer during flood periods.

The cultural fitness of these soils is inexistent.

Pastoral fitness is very poor.

42. Carbonated soils on the Yellowish-Red alluvial deposits derived from Gesoma sandstone

They are developed on the alluvial deposits of the temporary rivers flowing down from the Duhun sandstone plateaus and occupy one fifth of the Duhun soil-association (no IV) or 430 km2.

Morphology :

0 - 10 cm A11	: Reddish-yellow (5 YR 6/6) ; medium sand ; single-grained ; very friable.
10 - 60 cm A12	: Yellowish-red (5 YR 4/6) ; medium sandy clay ; medium subangular blocky ; friable.
60 cm + Bca	: Yellowish-red (R YR 4/6) ; medium sandy clay ; medium and fine angular blocky ; numerous friable lime concretions ; relatively friable.

Physico-chemical characteristics

These reddish-yellow to yellowish-red soils have a mainly medium sandy texture and are loose to friable.

Calcareous accumulation generally below 60 cm depth in the form of scarcely consolidated or friable nodules.

Calcium carbonate exists throughout this soil but the gradient increases with the depth and in fine earth the content varies from 5,0 percent in horizon A11 to 14,6 percent in horizon B ca.

The content of organic matter is always low and approximately 0,4 percent throughout the profile.

The nitrogen content is also very low.

pH averages 8,3.

The exchangeable potassium content is high : 0,6 me/100 g.

Phosphorus content is medium : 0,7 ‰.

The $\frac{\text{Total N}}{\text{Total } P_2O_5}$ ratio is distinctly less than 1 and indicates a nitrogen deficiency.

Cultural and pastoral fitness :

Some of these soils are cropped to sorghum near Duhun. The valleys of temporary rivers could be equipped in order to increase the efficiency of flooding by water from the plateaus (see chapter VI G). Nitrogen carriers such as ammonitrate and ammonia sulphate are recommended.

These soils are of very moderate value for pastures. They are nevertheless much frequented by livestock during the rainy season.

43. Red carbonated soils on alluvial and eolian complex

They are associated with vertic powdery gypsum soils (family 52) in the large spreading basins of Dobowein and of North Danan. They cover the upper part of the gentle folds characterizing the topography of this region and correspond to a total area of approximately 800 km2.

The vegetation consists of very dense groups of gramineae the stubbles of which remain as tufts during the dry season. The lower areas of these basins are often marked by rows of tall acacias (North Danan) or shrubs (Dobowein). Rainfall is less than 200 mm but the basins are partly affected by the floods of temporary rivers during the rainy season (North Danan), or by Fafen floods (Dobowein).

Morphology :

0 - 30 cm A11	: Yellowish-red (5 YR 4/6 ; coarse and fine sands ; single-grained ; friable.
30 - 70 cm A12	: Red (2,5 YR 4/8) ; coarse and find sands, fine subangular blocky ; some calcareous spots ; friable.
70 cm+ B ca	: Red (2,5 YR 4/8) ; fine sandy clay ; medium to fine subangular blocky ; 40 percent of very friable, irregular calcareous nodules ; relatively friable.

This soil presents abundant small angular quartz gravels and dark brown limestone gravels.

On the soil surface, quartz gravels are numerous. Wind has blown away the fine particles leaving the coarser quartz elements. These appear on aerial photographies in characteristic white patches which must not be mistaken for saline efflorescences.

Physico-chemical characteristics :

In these yellowish-red to red soils the texture is mostly coarse sandy which reveals the sandstone nature of the original material. The structure is single-grained at the surface and becomes subangular blocky in the depth and the whole profile is loose to friable.

The carbonate content in fine earth, increases with the depth (from 17 to 28 percent).

The calcareous accumulation appears in the form of small irregular and very friable nodules giving a white powder.

The content of organic matter is low : 1,2 percent at the surface and very gradually decreases in the depth (still 0,9 percent in B ca).

The nitrogen content is low and less than 0,5 ‰.

The conductivity of the saturation extract is low : from 1 mmhos/cm at the surface to 2 mmhos in the depth.

Exchangeable potassium is medium with : 0,3 me/100 g.

Phosphorus content is low : 0,45 ‰.

Cultural and pastoral fitness

As these soils are located on the upper part of the gentle undulations of the plain, they only receive rain water in very small quantities and consequently, are unsuitable for crop-growing.

The tall dry graminea tufts are very poor grazing as they are ligneous and hardly edible.

Conversely, these zones could be turned into a game reserve since antilopes are particularly numerous there (see chapter VI G).

44. Red calcic soils derived from Gesoma sandstone

These soils are developed on the bright-red sandy weathered material derived from the ferrugineous Gesoma sandstone, on a vast area of 5.450 km2, in the farthest North-Eastern part of the Basin in the Shilavo region.

The ferrugineous Gesoma sandstone is very coarse-grained and easily disaggregated, thus providing a considerable quantity of weathered sandy material which covers the whole landscape. It rests directly on limestone with nodules (Belet Uen limestone), forming small steps leading up Eastwards and separated by large sills covered with the weathered sandstone layer. The sandstone bluff is seen 18 km to the North-East of Shilavo on the Warder road. It is only 4 m high and consists of very brown and very ferrugineous sandstone. Small residual hills preceding the bluff present motley weathered sandstone facies. On the plateau, these small steps consisting here of hard sandstone may also be seen with vast sills disappearing under the bright red sandy material.

These plateaus form an entity in Lower Ogaden and must be considered completely apart from the rest of this region owing to their three specific features, as follows :

- There is no regular drainage system on account of the great permeability of sandstone. However, small depressions with grey soils which might be deferrated zones may be observed. Wells have been dug in these depressions the mean diameter of which is not more than 500 m. They are located on the Shilavo-Mustahil track and in the Bulaye and Gembari region.

- Numerous very bright red termitaries, often more than 4 m high, present a particular shape : the base is in fact narrower than the top which gives them the aspect of a cone standing upside down.

- The vegetation consists of a thicket of Gardenieae and Cordia gharaf which is approximately 4 m high and not very dense near Warder but which becomes an impenetrable bush North of Shilavo. Unlike the striped-bush pattern of limestone plateaus, here the vegetation is uniformly distributed and presents a fine light grey dotted pattern on aerial photographs.

Morphology : 5 km to the North East of Shilavo the following profile may be observed under a dense vegetation of Gardeniea and Cordia Gharaf ; the undulated nature of ground is due to the action of wind.

0 - 15 cm A11	: Red (2,5 YR 5/8) ; coarse and fine sands ; single-grained ; loose ; dense root system ; gradual transition to :
15 - 120 cm A12	: Bright red (2,5 YR 5/8) ; coarse and fine sands ; single-grained ; loose ; rootlets and numerous small roots ; some big roots ; gradual transition to :
120 cm + B ca	: Red, coarse and fine sands (2,5 YR 5/8) with numerous 1 to 4 mm friable concretionary masses consisting of sand cemented with a white calcareous cement ; single-grained structure ; friable ; still numerous rootlets.

The thickness of soil depends on the thickness of the weathered sandstone layer. For instance the thickness of soils decreases as one draws near the sandstone or limestone steps above-described.

The profile is hardly differenciated. A calcareous accumulation of very small concretionary masses consisting of sands cemented with carbonates may be observed in the depth. Besides, small (1 to 2 mm diameter) round ferrugineous elements previously existing in the base-rock may also be noted.

Physico-chemical characteristics

These soils are immediately identified in the field owing to their characteristic red to bright red colour. They are very sandy with a predominance of coarse sands. The structure is single-grained. These soils are very friable to loose but a very slightly increasing compacity may be observed in the horizon with a nodule accumulation.

Fine earth is non-calcareous which is linked to the lack of carbonates in sandstone. The formation of nodules seems in relation to the fluctuations of the water-table which is loaded with carbonates when in contact with the sub-jacent limestone formations.

The content of organic matter is very low and approximately 0.4 percent throughout the profile.

pH is approximately 8 .

The absorbing complex is base-saturated.

The exchangeable potassium and total phosphorus contents are weak.

Cultural and pastoral fitness

These soils are either scarcely or not at all suitable for crop-growing. Nevertheless, a very considerable volume of soil is available to the root system which accounts for the developed shrub vegetation. Furthermore, coarse sand is a specific retention factor owing to the absence of capillarity, hence fruit-trees could be adapted in these conditions.

In sandy soils the quality of pastures is poor even during the rainy season.

In these red sandy zones exists a specific and diversified wild life which is usually not seen in the other regions of Ogaden hence this region should constitute a reserve for wild animals (see chapter VI G).

45 (a-b) - Red calcic soils derived from Gesoma sandstone

These soils are developed on the red sandstone alluvial (45 b) and colluvial (45 a) deposits which spread at the foot of the scarp of sandstone plateaus, from the East of Degahbour to the Jerer temporary river. They correspond to what is usually called "the Degahbour basin" and their surface is approximately 2.700 km2.

The red alluvial and colluvial deposits are approximately 7 m thick in Degahbour plain. They rest directly on the Kebri Dahar limestone in situ. In this zone, Gesoma sandstone is transgressive on this formation.

The natural vegetation is considerably degraded by cultivation near Degahbour, and mainly consists of a dense savannah with tall Acacias and a discontinuous gramineae carpet. Rainfall is approximately 400 mm. During the dry season, a strong eastern wind blows to which is due the deep eolian erosion in the plain.

Morphology : 3 km to the East of Degahbour.- Grazed gramineae.

0 - 40 cm A11	: Red (2,5 YR 4/6) ; coarse sand ; friable medium subangular blocky fragments giving a single-grained structure ; loose to friable ; dry ; few rootlets ; distinct and uniform transition to :

40 - 90 cm A12 : red (2,5 YR 3/6); coarse sandy clay ; friable subangular blocky fragments giving a subangular blocky structure with trend to single-grained structure; small very white calcareous myceliums; dry and friable ; some rootlets ; gradual and uniform transition to :

90 - 300 cm and + B ca : Red (2,5 YR 4/6) ; coarse sandy clay ; flat medium fragments giving a medium subangular blocky structure with single-grained trend ; small very hard concretionary sandstone masses cemented together with lime, and weathered sandstone pebbles, the average thickness of the whole being 0,5 cm ; humid, scarcely friable; no rootlets.

These soils are deep and calcareous accumulation is progressive. Small myceliums are already observed at a 40 cm depth. Below 90 cm depth, an horizon with abundant small lime concretions is present. The individualization of carbonates is surely linked to the fluctuations of the temporary ground water table which is located in the break between the alluvial and colluvial layer of weathered sandstone and the subjacent Kebri Dahar limestone during the rainy season.

Physico-chemical characteristics :

Soils of the Degahbour basin

Soil group	Depth cm	Type of horiz.	Texture	Structure	CO_3Ca %	Organic matter %	N ‰	C/N	pH	sat.ext conduct. mmhos/cm	K + me/ 100g	Na + me/ 100g	Total P_2O_5 ‰
45(a & b)	0-40	A11	cS	s-gr	0	0,9	0,7	8,5	8,5	1,0	0,4	0,1	0,7
	40-90	A12	cS withC	sub. bl.	3,4	0,8	0,3	15	8,4	1,0	0,5	0,1	0,5
	90 +	B ca	cS withC	sub.bl	8,1	0,4	0,2	11	8,9	2,0	0,5	1,0	0,4

These red soils with dominant coarse sands become more clayey in the depth but the structure remains scarcely-developed and the soils are usually friable down to the depth.

The calcium carbonate percentage of fine earth is negligible from 0 to 40 cm depth and though it progressively increases with the depth it remains weak.

The content of organic matter is very low and gradually decreases with the depth. The same occurs in the case of nitrogen.

pH is high, being greater than 8,4, but :onductivity of the saturation extract shows that soil solutions ·ly loaded with salt and that sodium fixed on the absorbing comple: weak.

The exchangeable potassium content var: medium to high.

The phosphorus content is low.

The $\frac{\text{Total N}}{\text{Total } P_2O_5}$ ratio is approximately :s. The nitrogen deficiency is very distinct.

Cultural and pastoral fitness

The Degahbour plain is already largely to sorghum. Considerable extensions to the North and South are possibl ır the plateaus, the existence of many runoff ravines prevents agı l development. However, the sorghum plantations are at the present ti :ed by regular "sand-winds" due to wind erosion itself, as well as strong mechanical actions and intense evapotranspiration condit :h considerably limit the crop-yield in a region where rainfall is

Consequently, it is absolutely necess ınt wind-screens in all the Degahbour plain if sorghum, which is alr ivated in limit conditions, is to give a suitable yield. These wind-scre consist of Tamarix (already existing locally) or any other speci ·ing dry periods and with a rapid growth. They should be placed e m at right angles, one side facing dominant winds (see chapter VI C)

Nitrogen carriers such as ammonium su ould be added.

Mechanized cultivation may also be look on these large flat zones with no coarse elements in the soil but it m ·rried out carefully in order to avoid before sowing the wind eros andy surface horizons.

46. Reddish-brown carbonated vertic so ıved from Kebri Dahar limestone.

These soils are developed on the coll ›osits and in thalwegs between the small round limestone hills with slopes of the Sesebene-Degahbour region to the East of the Jerer, a › Degah Medo-Gelelcha region to the East of the Fafan.

They cover a total area of 1.300 km2.

Morphology :

On the Degahbour-Sesebene track, the ng profile may be observed.

0 - 20 cm A11 : Dark reddish-brown (5 YR 4/4) ; loam ; medium subangular blocky structure ; loose.

20 - 60 cm A12 : Dark reddish-brown (5 YR 4/4) ; clay angular blocky fragments tending to prismatic giving a medium to coarse angular blocky structure ; dry and firm.

60 - 235 cm B ca : Dark reddish-brown (5 YR 4/4) ; clay with 1 to 4 mm broad shrinkage cracks ; prismatic fragments with distinct slickensides in the depth ; Many gypsum crystals ; numerous (especially at the base) friable lime concretions ; humid and compact.

235 cm + : Limestone slab in situ.

Physico-chemical characteristics :

These dark reddish-brown soils have a loamy texture in the upper horizon and are clayey in the depth.

A calcareous accumulation appears in the form of friable concretionary masses at the base of the profile above the limestone slab. Many gypsum crystals also exist at this level.

Calcium carbonate represents a medium percentage and averages 26 percent in fine earth.

The content of organic matter is low but well distributed : 1,1 percent in A1 and 0,5 percent in Bca.

The nitrogen content is medium with 1,4 ‰ at the surface.

pH is approximately 8,5 and the conductivity of the saturation extract is high in the depth : 14 mmhos/cm in Bca. Soluble salts are abundant in the depth of these soils, in particular sodium chloride and gypsum.

The exchangeable potassium ratio is high with 0,7 me/100 g.

Total phosphorus represents 0,8 ‰.

Cultural and pastoral fitness

These soils being cut by many ravines are not arable but nevertheless constitute during the rainy season suitable pasture lands for livestock.

Group with hard massive calcareous crust. (nodular)

47. Light brown carbonated soils derived from Kebri Dahar limestone

These soils are developed in the same zone as the soils of the preceding family, but on limestone hills. They cover a total area of 3.900 km2.

Morphology :

The following medium profile may be observed :

0 - 25 cm A1 : Light brown (10 YR 6/4) ; silty loam ; 70 to 90 percent of scarcely worn (or not at all) limestone pebbles.

25 - 35 cm B ca : Calcareous conglomeratic crust consisting of yellowish-grey calcareous elements of nodule type coated with a light red ribboned lime cement.

35 - 90 cm R : Limestone slab with in places a beginning of weathering giving white chalky elements.

Physico-chemical properties

These light brown soils with a silty loam texture present, at a very small depth, a very hard and well-developed calcareous crust with a conglomeratic aspect. The beginning of a weathering process often appears on the base-rock.

Fine earth is rich in calcium carbonate with 42 percent in horizon A1.

The content of organic matter is low with approximately 1,0 percent in A1. This is also true for the nitrogen content (0,8 ‰) in the lower horizon.

pH is 8,4. Conductivity of the saturated paste is low 2 mmhos/cm.

Exchangeable potassium and phosphorus contents are medium and low with respectively 0,3 me/100 g and 0,3 me/100 g and 0,30 ‰

Cultural and pastoral fitness

These soils are unsuitable for crop-growing and only constitute poor grazing grounds during the rainy season.

F. SOILS WITH A GYPSEOUS DIFFERENCIATION

This class includes soils the profile of which is only characterized by a redistribution of gypsum. It is represented only in the South of the Basin, that is to say, in the climatic zone of Ogadenian type which is unfavourable for calcareous migration and accumulation.

All the soils belong to the sub-class with a pallid horizon. In fact, the color of the upper horizon is always pale and the content of organic matter is very weak. No soils with a melanic horizon have been observed. This sub-class has been differenciated in two groups :

- group with powdery gypsum : a gypsum accumulation of small translucent crystals, generally more abundant at the base of profiles but never cemented together,is observed.

- group with a crust : the gypsum crystals cluster and form a gypsum crust sometimes several meters thick in the banks of temporary rivers the water of which transports large quantities of gypsum during the rainy season. However, the gypsum crust is always relatively friable with many empty spaces which differenciates it from the much harder calcareous crust. These gypsum crusts are frequent on red colluvial and alluvial deposits in all the zone where the main gypsum series outcrops.

Within each group, the following sub-groups have been determined :

- for soils with powdery gypsum, two sub-groups :
  - modal sub-group
  - vertic sub-group
- for soils with crust, a single sub-group :
  - modal sub-group

Sub-Class of soils with a pallid horizon

Group with powdery gypsum

48. Brown to Reddish-Brown modal soils derived from the main gypsum formation, from the Mustahil limestone and from the Gesoma sandstone

These soils are developed on the vast glacis surrounding the sandstone plateaus of Duhun. They are included in the map of the soil association.: IV Duhun where they cover approximately 1.700 km2.

On the geological map, the following succession may be observed :

- At the base, the main gypsum formation which is at present the base level of the drainage system.

- Above, the Mustahil limestone which only remains here and there forming low (10 to 20 m high) tabular hills, these being thicker at Duhun as they are protected by the overlaying sandstone.

- The whole is crowned with Gesoma sandstone which attains 110 m heigt on the Duhun plateaus. The latter are in facts remnants left by erosion.

Consequently, the original materiel of the colluvial deposits of the lower zones is a complex mixed weathered material derived from these three geological formations.

A generally dense vegetation of tall acacias with a continued gramineae carpet is observed especially near the sandstone plateaus. Farther, the vegetation becomes sparse and is replaced with an open "bush" where small thorny plants are dominant.

Morphology : 2 km to the North of Duhun, on the Duhun-Segeg track, the following profile may be observed, n° 3-22. Position : at the base of slopes below the gypsum hills - Dense vegetation with tall thorny bushes and gramineae in some places.

0 - 7 cm A11	: Yellowish-brown (10 YR 5/6) ; silty loam ; medium to fine well-developed subangular blocky structure ; friable and dry ; numerous rootlets.
7 - 40 cm A12	: Dark greyish-brown (10 YR 4/2) ; clay loam ; some small gypsum crystals ; friable and dry ; rootlets and numerous small roots ; distinct and uniform transition to :
40 cm + B gy	: Dark brown (7,5 YR 3/2) ; clay ; relatively friable angular fragments giving a coarse, well-developed angular blocky structure ; some not very distinct slickensides in some places and some shrinkage cracks ; numerous small whitish gypsum crystals giving a white powder ; compact, slightly humid ; some rootlets.

Some gypsum crystals are also observed in horizon A12 but the accumulation is only distinct below 40 cm depth in horizon B gy.

Physico-chemical characteristics

These yellowish-brown to dark brown soils with silty loam at the surface become clayey in the depth. The structure is well-developed, of granular type down to 40 cm. But in the depth weakly-developed vertic features appear.

The whole soil is calcareous with calcium carbonate averaging 25 percent.

The content of organic matter is 1,9 percent in horizon A1 from 0 to 40 cm depth and decreases very slowly in the depth. In horizon Bgy it is still 1,5 percent.

Nitrogen content is low : 0,8 ‰ in A1.

- pH is 8,0

- content of exchangeable potassium is high : 2,2 me/100 g in horizon A1.

- The phosphorus content is medium with 1 ‰.

Cultural and pastoral fitness

The climatic conditions are unfavourable for crop-growing on this type of soil which nevertheless constitute suitable pastures during the rainy season.

49 a and b. Modal soils on Yellowish-Brown to Brown alluvial deposits of the Wabi Shebelle and of the Fafen

These soils include all the soils formed on alluvial deposits, except vertisols and hydromorphic soils, in the Valley of the Wabi Shebelle between Imi and Burkur (49 a) and in the Fafen Valley between Northern Kebri Dahar and Korahe (49 b).

They cover approximately : - 1.300 km2 in the valley of the Wabi Shebelle.

- 560 km2 in the Fafen Valley

The vegetation generally consists of a meadow with very small gramineae but in many areas a sparse bush with thorny shrubs (2 to 3 m high) or a real savannah with tall acacias may also be observed (Fanad plain North of Kebri Dahar).

Morphology :

This soil family associates two soil series corresponding to two types of alluvial deposits.

- a series with dominant sand on yellowish brown alluvial deposits.

- a series with a medium texture (sand and clay stratifications) on Brown alluvial deposits.

The series with dominant sand is especially developed on the ancient or recent natural levees of the Wabi and Fafan. The gypsum accumulation in the depth is generally very weak and is limited to some gypsum crystals. The structure is single-grained and the whole profile is very friable.

A detail study of these soils may be found in the reports : "Study and reclamation of the soils of the Lower Valley of the Wabi Shebelle"

- "Note on the soil map of the Lower Valley of the Fafen".

The series with a medium texture is developed in an intermediate topographic position between the series with dominant sand and vertisols located in depressed areas. The gypsum accumulation is more considerable : gypsum crystals appear distinctly in the clay stratifications. The structure is single-grained in the loose sandy layers. On the other hand, it is prismatic or fine cubic in the friable clay stratifications.

Physico-chemical characteristics

Complete physico-chemical characteristics may be found in the more detailed surveys carried out in the Valleys of the Wabi Shebelle and of the Fafen.

However, some chemical characteristics for both series are given below, i.e. :

The calcium carbonate represents approximately 18 percent with no noticeable gradient with the depth. Lime is powdery in the form of carbonate particles and silt sized.

The low content of organic matter averages 1 percent in the upper horizon and gradually decreases with the depth to 0,5 percent.

The nitrogen content is less than 0,5 ‰.

pH is approximately 8,2 but conductivity of the saturation extract increases from 2 mmhos/cm at the surface to 7 mmhos/cm below 1 m depth. Soils are slightly saline in the depth, the two main salts being sodium chloride and calcium sulphate (gypsum).

The content of exchangeable potassium is high in the series with dominant sand (more than 3 me/100 g of soil).

The phosphorus content is also high and averages 1,5 ‰.

Cultural and Pastoral fitness

In the Valley of the Wabi Shebelle (49 a) these soils are included in class I, hence they are very favourable for irrigation and their crop-growing suitability depends on the soil texture.

But in the Fafen Valley (49 b) where practically no irrigation possibilities exist, these soils are scarcely suitable for agricultural purposes. They are sometimes cropped to sorghum with variable results, North of Korahe. Nevertheless they constitute good temporary pastures during the rainy season.

50. Vertic soils on Red alluvial deposits derived from the Kebri Dahar limestone, from the main gypsum formation and from the Mustahil limestone.

They occupy the small depressions scattered in Lower-Ogaden, and mainly the gypseous zones, these depression often being formed in the wider part of some valleys of temporary rivers or downstream from alluvial fans. Filled in with alluvial deposits derived from limestone and gypsum, these depressions present a real economic interest in this region since they are suitable for crop-growing. In fact, they are periodically flooded but less than the soils of family 12 which are mainly represented in the Danan depression, and this also accounts for less pronounced vertic features. They cover a total area of approximately 700 km2.

The vegetation usually consists of small greyish thorny plants with a very dense gramineae cover.

Morphology :

The following profile has been observed 4 km to the South-West of Kelafo. Rough micro-relief with broad shrinkage cracks.

0 - 20 cm A11 : Reddish-yellow-brown (7,5 YR 5/6) ; silty loam ; medium to fine relatively well-developed subangular blocky structure ; unstable aggregates ; powdery ; numerous small shrinkage cracks ; friable ; short and uniform transition to :

20 - 100 cm A12 : Reddish-yellow (5 YR 6/8) ; silty clay loam ; large and 1 to 3 cm wide subvertical shrinkage cracks delimiting big friable subangular fragments giving a single-grained structure ; the whole is compact ; some gypsum crystals ; still some rootlets ; gradual transition to :

100 cm + B gy : Yellowish-red (5 YR 5/8) ; clay ; small shrinkage cracks ; small flat angular fragments ; massive and very compact ; numerous small gypsum crystals ; few rootlets.

Physico-chemical characteristics

Soil group	Depth	Type of Horiz.	Texture	Structure	CO_3Ca %	Organic matter %	N ‰	C/N	pH	Conductivity of sat. ext. mmhos/cm	K + me/ 100g	Na+ me/ 100g	Total P_2O_5 ‰
	0-10	A11	SiL	sub. bl.sg	32	0,6	0,30		8,2	1,0	0,9	0,1	1,9
	10-60	A12	CL	sub. bl.sg	32	0,5			8,2	0,5	0,5	0,1	1,7
	60 +	B gy	C	ang. bl. prism.	27	0,4			8,1	28,0	0,5	2,6	1,7

The reddish-yellow to yellowish-red soils has a silty loam to silty clay loam texture in the first 60 cm and becomes clayey in the depth.

The structure is characterized by a general cracking of the profile when dry with shrinkage cracks in all directions in horizon A1.

In the depth, the structure becomes massive with a prismatic trend but slickensides are seldom observed.

The gypsum accumulation appears below 60 cm depth in the clay horizon but always in a powdery form (separate crystals).

These are very calcareous soils owing to the origin of alluvial deposits derived from limestone or gypsum.

The content of organic matter is weak despite the considerable vegetative cover. In fact, vegetation is active only during a short part of the year and humus is soon mineralized.

The nitrogen content is low.

pH is approximately 8,2 and conductivity of the saturation extract greatly increases with the depth. There is a considerable accumulation of sodium chloride which represents approximately 6,3g/1000 g of soil in the profiles analysed.

The exchangeable potassium content is high.

The phosphorus content is also high.

The $\frac{\text{Total N}}{\text{Total } P_2O_5}$ shows a very distinct nitrogen deficiency.

Cultural and Pastoral fitness

In the arid context of Ogaden, these depressions constitute interesting cultivation zones but owing to soil salinity in the depth, only some salt-tolerant plants such as certain varieties of sorghum may be considered. Some of these depressions are periodically or episodically under cultivation. They are determined more accurately on the map at 1/250.000.

A noticeable improvement of crop-yields could be achieved through a combination of the flood effects of temporary rivers and of rainfall : in this end, it would be advisable :

- to improve the efficaciousness of floods, the latter being distributed homogeneously in the depressions.

- to prevent a loss of rain-water through runoff by a system of small contour earth dykes compelling rain-water to seep on the spot into the soil (see chapter VI D).

Nitrogen carriers such as ammonium sulphate and lime nitrate at the end of the rainy season, are absolutely necessary in order to obtain suitable crop-yields.

51. Vertic soils on dark brown alluvial deposits of the Daketa and its tributaries

They stretch on the large alluvial zones of the Daketa, of the Sulul and of their tributaries, North of Segeg and cover approximately 915 km2. The vegetation consists of small scattered thorny shrubs with some gramineae tufts here and there.

Morphology : In the plain of the Daketa on the Fik-Degah Medo track the following profile may be observed :

0 - 30 cm A11	: Dark brown (10 YR 5/4) ; silty loam ; medium granular ; small shrinkage cracks in all directions ; friable.
30 - 120 cm A12	: Dark brown (7,5 YR 4/4) ; silty loam ; medium angular blocky ; small vertical shrinkage cracks.
120 cm (B gy)	: Dark brown (7,5 YR 4/4) ; clay loam ; angular fragments with distinct slickensides in some places, firm ; some gypsum crystals.

Physico-chemical properties

Soil is reddish-brown to brown silty loam soil at the surface and turns to clay loam in the depth. The texture is still light with abundant silt.

Soil is considerably affected by small cracks in all directions and giving a granular structure at the surface, but in the depth, vertic features appear.

The undulated nature of ground leads to believe that swelling processes occur in the depth when the ground water table rises owing to the floods of temporary rivers.

The gypsum accumulation is very weak in the depth.

Soils have a high calcium carbonate content averaging 30 percent.

The content of organic matter is low but, from the surface down to 120 cm depth it is 1,1 percent and still 0,9 percent lower down. This stability is probably due to the cracks allowing decomposed plant elements to sink from the surface into the depth.

The nitrogen content is low throughout the profile : from 0,4 to 0,5 ‰.

pH is approximately 8,1 but conductivity is high throughout the profile (between 8 and 11 mmhos/cm of the saturation extract).

Sodium chloride in soil corresponds to approximately 2 g/1000.

Exchangeable potassium content is high : 0,9 me/100 g.

The total phosphorus content is medium : ‰.

The $\frac{\text{Total N}}{\text{Total } P_2O_5}$ ratio distinctly less than 1 shows a considerable nitrogen deficiency.

Cultural and pastoral fitness

Despite their relatively high salinity, these soils could be cropped to sorghum for instance, using the flood waters of the Daketa and of the Sulul. Unfortunately both these temporary rivers are often deeply embanked in their alluvial deposits : at an approximate 4 m depth for the Daketa and 7 m for the Sulul at Segeg.

The violent and sudden character of the floods especially of the Daketa, is a problem as regards the installation of a diversion dam to flood the plain in the downstream part. A network for the control of soil erosion with small earth ridges could be considered in some zones.

When crop-growing is possible, nitrogen carriers such as ammonium sulphate should be added.

These zones are scarcely suitable for crop-growing and even grazing possibilities are poor during the rainy season.

52. Red vertic soils on alluvial and wind-blown material

These soils occupy the hollows of the gentle undulations of large spreading basins of Dobowein and Northern Danan. They are mapped together with soils with a calcareous differenciation of family 43 in association V (Dobowein, Northern Danan), and represent half of the surface or approximately 780 km2

A very dense gramineae carpet with closely growing gramineae tufts covers the ground. This considerable development of gramineae is due to the relatively low position of these soils which allows them to drain the overland runoff water flowing from slightly more elevated areas where on the contrary gramineae are not so dense (see soil family 43). In some places, acacias may be seen. The very pronounced gilgai microrelief at the surface makes it very difficult to move about.

Morphology : In the Dobowein spreading basin, the following medium profile may be observed.

0 - 40 cm : Yellowish-red (5 YR 4/8) ; well-developed granular ; very
A11 friable.

40 - 120 cm : Red (2,5 YR 4/8) ; clay ; scarcely friable angular fragments
A12 with some slickensides ; scarcely friable.

120 cm : Accumulation of gypsum crystals in a medium sandy clay matrix,
B gy the whole with a motley grey and red colouring ; compact.

The gypsum accumulation is very distinct in the form of crystals. In some profiles a gypsum crust tends to appear but this is not usually the case.

Physico-chemical characteristics

These reddish-yellow to red soils present a clay dominance but with medium sand. The structure is granular down to 40 cm depth but becomes larger in the depth where vertic features appear.

All this soil presents a high content of calcium carbonate : 30 percent.

The content of organic matter is relatively high for the region in horizon A11 with 1,5 percent. In horizon A12 it is but 0,9 percent.

pH is approximately 7,8 and conductivity of the saturation extract is weak : 1 mmhos/cm in horizons A11 and A12.

Cultural and pastoral fitness

These soils could eventually be cropped to sorghum but with variable results depending on rainfall. In the Dobowein plain and on these types of soils in the West, several formerly cultivated lands are now abandonned.

It seems that a network for soil erosion control with earth ridges should improve the growth conditions of sorghum (see ch. VI C) in these relatively low zones. Nitrogen carriers such as ammonium sulphate is also recommendable.

The zone located North of Danan is a good pasture during and after the rainy season. It may be used as a reserve for wild animals. The Dobowein spreading basin could play the same role (see ch. VI 6).

Group with crust

53. Modal soils on red alluvial deposits, derived from the Gesoma sandstone and Mustahil limestone.

These soils occupy the South-Eastern end of the Basin on the red alluvial deposits of a pattern of temporary rivers flowing down from the Western limestone plateaus and from the Eastern sandstone plateaus (El Habred region) ending in a large saline alluvial fan between Burkur and Ferfer. They cover a total area of approximately 642 km2.

The reddish-yellow to red soils,(5 YR 4/8) to (2,5 YR 4/8), have a fine to medium sandy texture. The crust at a small or medium depth is usually discontinuous and in this case, alluvial deposits with abundant gypsum crystals may be observed resting directly on the gypsum slab in situ (Bargun region).

These soils are wholly unsuitable for crop-growing and only constitute poor pastures during the rainy season.

54. Reddish-yellow to yellowish-red soils, derived from the main gypsum formation and from the Mustahil limestone

These soils cover all the colluvial or alluvial zones of the gypsum formation of Lower-Ogaden. They are mapped, in the soil-association with eroded soils in early stage of development of the gypsum hills (family 3), in association I (Lower Ogaden) where they occupy more than half of the area or 21.000 km2, in association with soils with a calcareous differenciation of the small zoogeneous sandstone plateaus North of Imi (family 40), and in association III where they cover 4/5 of the area or approximately 2.400 km2.

The total surface occupied by these soils is correspondingly 23.400 km2 which is considerable (more than 1/9 of the total surface of the Basin).

The erosion of the retreating slopes of plateaus of which very often only remnants are left (for instance the Duhun sandstone plateaus and Goja hills North of Imi) as well as the erosion of gypsum, provided a considerable quantity of weathered material, the latter being transported downstream by temporary rivers.

Alluvial deposits scarcely exist in the upstream part of temporary rivers finding their way with difficulty between gypsum hills which are yet hardly eroded. But, in downstream, the landscape widens and alluvial deposits are more extended. The limit between alluvial deposits and the gypsum formations in situ is usually very distinctly seen on the field owing to a diffence in the colouring : yellowish-red alluvial deposits and soils on yellowish-grey gypsum. The temporary river ends in an alluvial fan the size of which varies according to the size of the river.

In the alluvial part along the temporary river or on the alluvial fan, depressed areas are covered with vertisols (family 12) or vertic soils with powdery gypsum (family 48) which are suitable for agricultural purposes.

This soil family also includes vast colluvial zones stretching on almost flat areas with, in some places only, small limestone or gypsum remnants.

The vegetation consists of a sparse bush with thorny (or not) shrubs approximately 2 m high, and a plant association with dominant Gyrocarpus habebensis. Along the bed of temporary streams generally grows a line of tall trees of acacia type. The gramineae undergrowth is not dense and is only developed during the rainy season.

On colluvial zones, bare areas may be observed on the field, alternated with zones presenting a dense vegetation with a "striped-bush" pattern seen on aerial photographs (South of Dalad for instance).

Morphology :-on alluvial deposits (Gode region)

0 - 30 cm : Reddish-yellow (7,5 YR 6/6) ; clay loam ; subangular blocky ;
A11 single-grained trend.

30 - 80 cm : Yellowish-red (5 YR 5/8) ; clay ; subangular blocky.
A12

80 - 120 cm : Dark yellowish-red (5 YR 5/8) ; clay ; compact.
A13

120 cm + : Friable gypsum crust.
B gy

- on colluvial deposits (Northern Danan)

0 - 20 cm : Reddish-yellow (7,5 YR 6/8) ; silty loam ; scarcely developed
A11 crumb structure.

20 - 50 cm : Yellowish-red (5 YR 5/8) ; clay loam ; friable angular
A12 fragments.

50 - 70 cm : Reddish gypsum crust
B gy

70 cm + : Gypsum slab in situ.
R

The forming-process of the gypsum crust is different in alluvial deposits and in colluvial deposits.

The alluvial deposits are usually very thick and the formation of the gypsum crust is due to the pulsation effect of the ground water table caused by variations of the hydrological conditions of temporary rivers.

On the other hand, colluvial deposits are not very thick and usually overlay a shallow gypsum slab. The latter plays the role of an imperviou**s**horizon which is favourable to the permanent existence of a small perched water table with abundant gypsum during the rainy season, and to the gradual formation of a gypsum crust.

In alluvial deposits, gypsum crusts are sometimes very thick and seem to depend on the importance of the height of bank dampened by flood waters which are practically always loaded with gypsum. Thus, for the Bu-Y temporary river (West of Danan) the level of which may vary from 0m to 8m, a 6,5 cm thick gypsum crusts may be observed as well as considerable saline efflorescences.

In the alluvial fans of temporary rivers, the accumulation is often much weaker, approximately 20 to 50 cm thick, and sometimes in a powdery form.

In colluvial deposits, the gypsum shell is always thin and is often limited to discontinued gypsum heaps.

Physico-chemical characteristics

These reddish-yellow to yellowish-red soils present a silty loam to clay loam texture at the surface and are usually clayey in the depth.

The structure is generally scarcely developed ; surface horizons are very friable and powdery when dry, whereas in the depth above the gypsum accumulation, soil becomes compact. The gypsum crust remains friable.

The calcium carbonate content is 25 to 35 percent.

The content of organic matter is weak and approximately 0,9 percent in horizon A11 and 0,6 percent in horizon A12.

The nitrogen content is low to medium (0,5 to 1,2 ‰).

pH is approximately 8,1 but the low conductivity in horizon A1 (2mmhos/cm) greatly increases in the gypsum crust (24 mmhos/cm). It shows a considerable increase of the sodium chloride content at this level which corresponds approximately to 5,6/1.000 g of soil. This seems normal when one knows that gypsum accumulation is frequently accompanied by a sodium chloride accumulation. No alkalinization process may be observed owing to the presence of gypsum and calcium carbonate which prevents any considerable fixation of sodium on the absorbing complex.

The exchangeable potasium content is high, from 0,6 to 1,1 me/100 g of soil.

The phosphorus content is medium to high : 0,9 to 1,6 ‰.

The analysis of the soils of Gode region show a high content of available boron approximately 75 ppm, which is a very toxic concentration grade for most cultivated plants.

Cultural and pastoral fitness

These soils are unsuitable for crop-growing. Apart from depressed areas, the alluvial and colluvial zones are nevertheless good pastures during the rainy season.

Many antilopes and other animals live in these vast zones which may constitute interesting reserves for wild animals (see chapter VI G).

G. CLASS OF "BROWN AND BRUNIFIED SOILS"

These soils are developed in the Basin of the Wabi Shebelle in a Humid and temperate climate with rainfall approximately 900 mm and an altitude above 2.000 m, on the gentle or steep slopes of basalt mountains (Chercher) or on ash formations (Arussi). They are characterized by their brown colouring, the lack of calcium carbonate in the profile and, in the weathered material, a neutral or acid pH with a base-saturation grade close to or less than 100 and a high content of organic matter in the upper horizon. These soils present no vertic features in the depth. Two groups have been determined :

Group of brown eutrophic soils with a neutral pH with two sub-groups :

- modal sub-group
- scarcely developed organic sub-group.

Group of brown mesotrophic soils with a pH 6,5 with a single sub-group:

- hydromorphic sub-group.

Group of brown eutrophic soils

55. Association of brown modal soils (55 a) and developed organic soils (55 b), derived from basalt of plateaus and of mountain-ranges

These soils are developed on the slopes and flat parts of the basalt mountain masses of Chercher (Kurfachele, Deder, Burka region) and farther West, on the slopes of Mount Gugomana, Gugu and Meto. They also stretch along the canyons of the Magna and Ilili and cover a total area of approximately 2.824 km2.

Apart from the Magna and Ilili canyons, all these regions are largely under cultivation on gentle slopes, and deforested and turned into pastures on steep slopes. Accordingly, the natural forest with Juniperus procera (Tid) and Podocarpus gracilor (Zigba) only remains on very steep slopes or in some talweg heads.

The association on the map at 1/1.000.00 consists of two sub-groups :

- modal sub-group on gentle slopes where soil is deep and largely cultivated
- scarcely developed organic sub-group on steep slopes with shallow soils used only as grazing grounds.

These two sub-groups are separate on the map at 1/250.000 and are represented by the symbols 55 a and 55 b.

Morphology

Brown modal soils (55 a). On the Girawa-Kurfachele track, at 14 km from Girawa, the following profile may be observed on a gentle slope :

0 - 30 cm A11	: Dark reddish-brown (5 YR 2/2) ; loam ; subangular blocky to fine granular structure ; very friable.
30 - 90 cm A12	: Dark brown (10 YR 4/3) ; heavy clay ; medium angular fragments ; scarcely compact.
90 - 160 cm B	: Motley red and dark brown ; heavy clay ; medium angular blocky structure ; friable.
160 cm + R	: Weathered basalt.

In horizon B, the motley greyish-red and dark brown colouring has probably been left by the weathering of basaltic material, which seems to be confirmed by the friable character of this horizon.

Organic weakly developed brown soils (55 b) in the same zone as further above but on the steep slcpe of a basalt hill.

0 - 15 cm A11	: Very dark greyish-brown (10 YR 3/2) ; loam ; subangular blocky with single-grained trend ; loose.
15 cm + A12 R	: Very dark greyish-brown (10 YR 3/2) ; friable weathered basalt gravels mixed with fine earth ; loam ; subangular blocky with single-grained trend ; very friable.

Physico-chemical characteristics

Soil group	Depth cm	Type of horiz.	Tex ture	Struc ture	CO_3Ca %	org. mat. %	N ‰	C/N	pH	T me/ 100g	Exch. Bases me/100g	V per-cent	K+ me/ 100g	Total P_2O_5 ‰
55a	0-30	A11	L	sub.bl	0	8,3	4,2	11	7,1	25,0	27,0	100	0,7	0,86
	30-90	A12	C	ang. bl	0	1,4	0,6	12	7,2	21,0	22,5	100	1,0	0,55
	90-160	B	C	ang. bl	0	0,6	0,3	10	7,1	24,0	24,0	100	0,8	0,50
55b	0-15	A11	L	s.gr	0	13,8	6,0	13	7,1	30,8	28,1	90	2,4	1,59
	15+	A12 R	L	s.gr	0	12,2	5,3	18	7,2	25,5	26,0	100	0,8	1,58

Brown modal soils (55 a)

These soils present a loam texture at the surface and become clayey with depth. The structure is subangular blocky or angular blocky giving the horizons down to the base of the profile a very friable character

No vertic features are observed since soil drainage is facilitated by two factors : the general gradient of land occasioning a lateral drainage of runoff or infiltration water, and the existence of a parent-rock consisting of basaltic colonnades the large vertical permeability of which is considerable.

The content of organic matter is high at the surface as well as the nitrogen content but they soon decrease below 30 cm depth.

C/N is low and characteristic of a soon mineralized humus.

pH is neutral and the soil is not calcareous.

The absorbing complex is base-saturated.

The content of exchangeable potassium is high.

However, the phosphorus percentage is low.

The $\frac{\text{Total N}}{\text{Total } P_2O_5}$ ratio is approximately 5 and shows a slight unbalance detrimental to phosphorus.

Organic weakly developed brown soil (55 b)

They present a loam texture and a structure tending to single-grained. These soils are not thick in horizon A11, but the weathering of basalt is considerable and horizon A12 is thick since it consists of fine earth mixed with weathered basalt. This feature differenciates these soils from the organic eroded soils in early stage of development of family 9 (Shek-Hussien) where the organic horizon rests directly on non-weathered material.

The content of organic matter is high, down to 40 cm when horizon A1 is thick enough.

This is also true for nitrogen. The low C/N characterizes a quickly mineralized humus.

pH is practically neutral.

At the surface, the complex is very weakly desaturated.

The content of exchangeable potassium is very high at the surface.

The phosphorus content is also high.

The $\frac{\text{Total N}}{\text{Total } P_2O_5}$ ratio is approximately 4 and shows a slight unbalance detrimental to phosphorus.

Cultural, pastoral and afforestation suitabilities

Brown modal soils are everywhere largely cropped to cereals, peas, lentils, in fact to all the necessary food-crops for local consumption. The general lie of the land with its slopes makes mechanized cultivation difficult. The technique of contour beds is recommended (see chapter VI B), and phosphate carriers such as lime superphosphate should be added.

Brown organic soils are under cultivation in some places despite the steep slopes but, in most cases, they are covered with a very dense gramineaecarpet grazed by livestock. If the increase in the population was not so considerable, these uneven zones would be highly suitable for afforestation in "garden forest" : Coniferous grow particularly well in these misty zones which also seem very fit for intensive livestock-breeding after improving the flora of pastures and the soil fertility (addition of phosphate carriers).

Group of brown mesotrophic soils

56. Brown mesotrophic hydromorphic soils derived from grey volcanic ash.

These soils stretch at the Western end of the Basin in the Kore, Kofele and Ibano (sources of the Wabi) regions and cover approximately 1.270 km2 .

They are developed on ash formations at a medium altitude of 2.700 m and commanding the Gedeb plain (chernozem zone) 200 m below. The weathering in ravines of this soft material has given a very characteristic landscape.

with round hills deeply cut by valleys. On the hillsides, thin (from 50 to 100 cm) trachytic layers outcrop and are intercalated in ash material. At this level, appear many sources of small tributaries flowing down to the Wabi which is here but a small river.

This region has a Tichean climate. The Kofele hills, the first barriers to the East wind bringing rain, have a high rainfall : approximately 1.000 mm. Owing to the high altitude and to the rainfall, temperatures are low all year round, the maximum seldom being higher than 20° and hoar-frost being relatively frequent during the coolest months.

The vegetation consists of an overgrazed gramineaē carpet with dominant Pennisetum and scutch-grass. Forest remnants with Juniperus procera (Tid) may be still seen between Kelafo and Kore and in the Ibano and Hogiso regions.

On the other hand, the regions of Kore and Sire with red ferrallitic soils (studied further below) and protected against the East wind, present considerably milder climatic conditions and instead of pastures, cereals are grown under a thin forest (Tids and wild olive-trees).

Morphology : 2,7 km from Kofele on the Dodola track, on a gentle slope, the following profile may be observed :

0 - 10 cm A11 : Brown ; coarse sand ; crumb structure with a single-grained trend ; humid and friable ; numerous rootlets ; distinct transition to :

10 - 40 cm A12 : Light brown ; coarse sand ; medium to fine subangular blocky structure with single-grained trend ; humid and friable ; many rootlets ; gradual transition to :

40 - 90 cm A13 : Yellowish-brown to light reddish-brown ; loam ; well-developed fine subangular blocky structure ; humid and friable ; still some rootlets ; distinct transition to :

90 - 165 cm B Fe Mn : Brownish-yellowish-grey concretionary horizon ; coarse sandy clay with some rusty spots and numerous small brown friable and round concretions ; usually hard horizon in places ; distinct transition to :

165 cm + gley : motley grey and reddish-yellow ; coarse sandy clay ; hydromorphic.

Small glass fragments are visible throughout the profile. The differenciation with the hillslopes is usually small, however, soil tends to be lighter in horizon A12. Furthermore, complex profiles in relation to the presence of thin trachytic layers interstratified with ash, may be observed on the slopes.

Physico-chemical characteristics

Soil roup	Depth cm	Type of horiz.	Tex ture	Struc ture	CO_3Ca %	Org. mat. %	N ‰	C/N	pH	T me/ 100g	Exch. bases me/ 100g	V per- cent	Ca++ me/ 100g	Mg++ me/ 100g	K+ me/ 100g	Total P_2O_5 %
	0-10	A11	cS	s.gr	0	19,6	5,9	13	5,9	88	31,4	35,6	16,2	13,8	0,5	2,15
56	10-40	A12	cS	s.gr	0	3,9	1,7	12	6,0	58	16,9	29,3	6,6	9,6	0,6	1,67
	40-90	A13	L	sub. bl	0	1,3	0,8	9	6,1	23	12,8	55,6	5,7	6,3	0,7	1,74
	90-165	BFeMn	cSC	-	0	0,25			6,1	25	12,8	51,2	5,7	6,3	0,7	1,42
	165+	gley	cSC	mas-sive	0	0,18			6,5	35	9,70	27,7	4,8	4,2	0,6	1,42

These brown mesotrophic soils are characterized by a texture with dominant coarse sand in the upper horizons and loam layers. Clay increases in the depth. Coarse sand is practically only represented by glass which is unsuitable for a good permeability even of the upper layers since the fine ash particles have a soil-clogging effect unfavourable to water penetration.

The accumulation of organic matter is considerable in horizon A11. The content is much weaker in horizon 10-40 cm but shows that organic matter penetrates very deeply.

The nitrogen content is very high in horizon A11 and is still high in horizon A12. Nitrogen mainly consists of organic nitrogen.

The C/N ratio taking the pH into account, characterizes a slowly mineralized acidic humus.

pH is acid and increases slightly in the depth. These soils are, with andosols, the only soils of the Basin with an acid reaction.

The base saturation grade is low compared to other soil families and varies from 30 to 56 percent.

The $\frac{Ca}{Mg}$ ratio is approximately 1 or less which might block the assimilation by plants of calcium or potassium. Hence, the calcium content must be increased.

The content of phosphorus is high and very high at the surface.

The $\frac{\text{Total N}}{\text{Total } P_2O_5}$ ratio is approximately 2,5 at the surface and only 1 at a small depth and characterizes a nitrogen deficiency.

The specific physico-chemical characteristics of these soils are due to very wet and cool climatic conditions and to a generally unsuitable drainage in relation to :

- the inadequate permeability of fine ash which soon clogs the soil.
- the presence, sometimes at a small depth, of impervious trachytic layers.

But unlike what has been observed for the vertisols and chernozems of neighbouring regions, the temporary clogging of the lower layers do not lead to an individualization of lime. Lime if it previously existed in the parent-rock has been completely eliminated, the solution has been acidified thus facilitating the migration of iron and manganese and the manifestation of hydromorphic features.

Ferrugineous and manganesiferous concretions are generally very abundant and sometimes form real ironpan blocks as seen on the Kofele-Kore track.

Cultural and pastoral fitness

The climatic conditions are unsuitable for agriculture : only "ensete" (Musa ensete) is cultivated here and there near houses.

This zone is suitable for livestock breeding but pastures are poor. The soil acidity and the Ca^{++}/Mg unbalance should be corrected with lime amendments and the quality of pastures could be improved with more suitable fodder plants for livestock.

Nitrogen carriers are absolutely necessary in order to obtain a large production of grass. If lime amendments cannot be added to the soil, lime-nitrate may be used, the latter being a nitrogen carrier which contains 1/4 of its weight in time. Urea is also advisable for these soils with a high organic content. It is also recommendable to plant wind-screens in order to improve the usually very cold local micro-climates (see chapter VI C).

H. FERSIALLITIC SOIL-CLASS

Fersiallitic soils exist in the North of the Basin in the Harar-Babile region on sandy-granitic colluvial deposits, in the Gebiba region in situ on the parent-rock and in the South of the Basin on the sandstone plateaus of Duhun, El Kere and of North-Eastern Ginir. Rainfall is 400 to 800 mm.

All of them belong to the sub-class of saturated fersiallitic soils. The main morphological and physo-chemical features allowing to class them as fersiallitic soils are :

- a not very thick profile, on a zone either flat or with a small slope.

- The soil has a bright reddish-brown to red in B horizon.

- Horizons A and B are decarbonated but base-saturated.

- on the other hand, in horizon C, traces of calcium carbonate may be observed in weathered granite.

The type of clay varies function of the parent-rock (see table further below).

Illite is dominant in soils developing on granite.

Soils on limestone present a dominant metahalloysite fraction with open illite.

Conversely, soils on sandstone present a dominance of kaolinite or "fire clay" inherited from the parent-rock.

Type horizon	On granite (Babile)	On limestone (Gebiba)	On sandstone (Duhun)
A1	illite kaolinite or fire-clay traces of mont-morillonite. traces of haematite	metahalloysite traces of open illite abundant haematite	Kaolinite or fire clay abundant haematite gibbsite trace of goethite
B	illite kaolinite or fire-clay some montmorillonite traces of haematite	metahalloysite open illite abundant haematite	Kaolinite or fire-clay very abundant haema-tite some gibbsite traces of goethite
C weathering	illite montmorillonite kaolinite or fire-clay traces of haematite		
R	montmorillonite Kaolinite or fine-clay illite trace of haematite		Kaolinite

The various mineral fractions are given in the order of decreasing importance.

-horizon B still often presents numerous minerals at weathering stage (in the case of granite). They mainly consist of feldspar (plagioclase and andesite).

The sub-class of saturated soils consists of 1 group :

The type group with two sub-groups :

- modal sub-group with a weathered horizon C at 80 cm depth at least.

- a scarcely-developed sub-group with an horizon C at less than 80 cm depth.

57. Reddish-brown modal soil-types, derived from Adigrat granite and sandstone.

These soils are developed in the region of Harar, Babile-Fugnanbira, on rolling plateaus and on slopes where the weathering of granite or the colluvia derived from sandstone and granite are the most considerable. They are easily known owing to their reddish-brown to red colouring contrasting with the light grey of soils in early stage of development on granite. On these plateaus, isolated granite outcroppings are frequently seen. West of the Harar-Dire Dawa road they also exist on relatively steep slopes the top of which consists of limestone remnants with brown calcic soils. They cover a 1.470 km2.

Morphology : on the Babile plateau the following profile may be observed.

0 - 40 cm A1	: Brown (7,5 YR 5/4) ; coarse sand ; medium and fine crumb structure ; friable.
40 - 100 cm B	: Reddish-brown (5 YR 5/4) ; fine sandy clay ; subangular blocky ; stone-line of scarcely worn quartz gravels ; abundant yellow mica ; friable.
100 - 180 cm C	: deeply weathered granite in situ ; motley white and red with some pockets of red clayey earth ; friable.
180 cm + R	: decayed granite with black mica ; friable.

Variations are mostly observed in horizon A1. Very frequently, owing to weathering, the stone-line of horizon B is very near the surface (Hadow region, Fugnanbira track).

<u>Physico-chemical characteristics</u>

Soil group	Depth cm	horiz type	Texture	Structure	CO_3 Ca %	Org.mat %	N ‰	C/N	pH	T me/ 100g	Exch bases me/ 100g	V per-cent	Ca++ me/ 100g	Mg++ me/ 100g	K + me/ 100g	Total P_2O_5 ‰
	0-40	A1	cS	s.gr	0	2,1	1,2	10	7,7	10	11,8	100	7,1	4,0	0,54	0,6
57	40-100	B	cSC	sub. bl.	0	1,2	0,8	9	7,5	18	18,4	100	11,8	6,0	0,34	0,4
	100-180	C	CS	-	0,8	0,6	0,5	8	8,0						0,30	0,4

These reddish-brown and red soils are very sandy at the surface (coarse sand) and more clayey at a small depth.

In the weathered granite horizon (C) some traces of calcium carbonate may be observed.

The content of organic matter is medium to low as well as the nitrogen content. C/N is very low and shows that humus is quickly mineralized.

The absorbing complex is saturated but the exchangeable capacity is very weak owing to the scarcely clayey soil-texture.

- The Ca/Mg ratio is correct.

- The content of exchangeable potassium is medium to low.

- The phosphorus content is medium.

- The $\frac{\text{Total N}}{\text{Total } P_2O_5}$ ratio is approximately 2 and indicates a nutritional unbalance detrimental to nitrogen.

Yet, the medium contents of the three main elements : NPK must be increased for intensive crop-growing.

<u>Cultural fitness</u>

Soils are generally largely cropped in Harar owing to the density of population and there are practically no fallow lands. On this type of soils the main crops are sorghum, groundnuts and sweet potatoes as well as vegetables. Chat (Catha edulis) is grown on the terraces built on steep slopes.

Though the farmers regularly add manure to the soil, the latter is very poor in nitrogen as well as in potassium and phosphorus. The nitrogen deficiency is easily observed on sorghum and chatt. The addition of a complete mineral fertilizer : NPK before cultivating the land and a fractional adding of nitrogen during the vegetative cycle would considerably increase the crop-yield. However, as on the one hand the soil is very well-drained and on the other hand it has a very weak exchangeable capacity hence a low retention of fertilizers, the fractional addings of nitrogen carriers should be calculated judiciously in order to avoid losses due to leaching.

The preferential carriers to be added are, i.e. :

- nitrogen : urea, ammonium lime nitrate and ammonium sulphate.
- phosphorus : superphosphate.
- potash : potassium chloride.

The problem concerning erosion which is particularly alarming in Harar will be studied in the paragraph on ferralitic soils (family 60).

58. Dark Reddish-Brown modal soil-types, derived from Kebri-Dahar limestone

These reddish-brown to red soils are developed on the very gently rolling tabular limestone plateaus, mainly :

- Boke-Midagola plateau representing approximately 500 km2 at a mean altitude of 1.800 m.
- Gebiba plateau between the Omashivo and Sekota rivers and another plateau between the Sekota and Ungwata rivers, the total surface of which is approximately 600 km2 at a mean altitude of 1.600 m.

Morphology :

The following profile may be observed in the Gebiba region with a vegetation of gramineae and bush with acacias.

0 - 20 cm A11 : Dark reddish-brown (5 YR 3/3) ; silty clay loam ; granular ; friable.

20 - 80 cm A12 : Dark reddish-brown (5 YR 3/4) ; silty clay to clay ; medium angular blocky ; firm.

80 cm + B : Dark red (5 YR 3/6) ; clay ; "platy" fragments ; very compact.

The limestone slab is located at about 2 m depth.

Physico-chemical characteristics

Soil group	Depth cm	Horiz type	Texture	Structure	CO_3Ca %	Org. mat. %	N ‰	C/N	pH	T me/ 100g	Exch Bases me/ 100g	V per-cent	Ca++ me/ 100g	Mg++ me/ 100g	K+ me/ 100g	Total P_2O_5 ‰
58	0-20	A11	SiCl	gra.	0	7,6	3,4	13	7,5	50	44,2	88	28,0	10,0	6,2	0,63
	10-80	A12	SiC C	ang. bl.	0	2,5	1,2	11	7,3	33	38,3	95	22,5	7,0	1,5	0,56
	80 +	(B)	C	ang. bl.	0	1,5	1,0	9	7,5	28	26	92	18,0	7,0	0,5	0,48

The dark reddish-brown to dark red soil has a silty clay loam to clay texture. The granular structure at the surface becomes angular blocky at a medium depth. This soil is friable to firm and can easily be tilled.

No traces of calcium carbonate in the soil. The content of organic matter is very high in horizon 0 - 20 cm and decreases progressively in the depth but is still 1,5 percent in horizon B. This is also true for the nitrogen content which is high at the surface and medium between 20 and 80 cm depth.

- The C/N ratio is low and characterizes a soon mineralized humus.

- The pH is approximately 7,4 and the absorbing complex is practically saturated.

- The Ca/Mg ratio is normal.

- The exchangeable potassium content is high at the surface and high in the depth.

The phosphorus content is medium. The N/total-P_2O_5 ratio is unbalanced in horizons A11 and A12 and proves detrimental to phosphorus, hence the necessity of using phosphate fertilizers.

Cultural fitness

When rainfall conditions are suitable, these soils present distinctly better crop-growing possibilities than in the case of the soils previously studied since, to their clayey texture is due a far more considerable specific retention.

- In the Boke Fadis region, these soils are cropped to maize, sorghum, chatt and vegetables (mostly onions).

- on the large plateaus, mechanized cultivation is possible and is now in progress (see chapter VI E).

In the case of soil already under cultivation over a long period, phosphate fertilization must be completed with nitrogen fertilization as the content of organic matter is often much lower than was indicated above (fallow-lan

- on the plateaus to the South-West of Gebiba and Soddu, the extension of dry farming cultivation seems possible once the phosphorus deficiency of soil is corrected.

59 (a and b) Association of red modal soil-types (59 a) and scarcely developed soil-types (59 b), derived from the Gesoma sandstone.

These red soils are extended on the large sandstone plateaus located on the one hand between the Labu and the Wabi Shebelle and on the other hand, Southwards on a series of plateaus (remnants) with a variable extension, namely :

- Duhun and El Kere plateaus on considerable areas.
- Aouatou Mountains (North-East of Ginir) and several smaller plateaus between the Madiso and the Gelmiye temporary river (North-East Imi).
- These plateaus correspond to a total area of approximately 1.530 km2

In the El Kere region a scarcely-developed soil-group on small weathered plateaus is mapped on the map at 1/250.000 and is associated in a typical group on the map at 1/1.000.000.

Morphology :

On the Duhun sandstone plateaus under a dense gramineae vegetation with tall trees, the following profile may be observed :

0 - 20 cm A1	: Red (2,5 YR 4/6) ; fine sandy clay ; scarcely friable fragments giving a single-grained and medium subangular blocky structure ; relatively firm when dry ; gradual and uniform transition to :
20 - 80 cm (B)	: Dark red (2,5 YR 3/6) ; fine sandy clay ; friable angular blocky fragments giving a well-developed medium subangular blocky structure ; just humid, friable ; numerous rootlets ; sudden transition to :
80 cm + R	: Very hard sandstone slab in situ.

Type modal soils (59 a) are usually deeper : For instance, in the profiles observed in the El Kere region, the sandstone slab is at 130 cm depth and on the plateaus to the North of the Wabi it is below 150 cm depth.

Conversely, the scarcely-developed type modal soils (59 b) stretching on the narrow weathered plateaus in the El Kere region present a sandstone slab very near the surface.

Physico-chemical characteristics

Soil group	Depth cm	Type of horiz.	Texture	Structure	CO_3Ca %	Org.mat. %	N ‰	C/N	pH	T me/ 100g	Exch bases me/ 100g	V per-cent	Ca++ me/ 100g	Mg++ me/ 100g	K+	Na^+	Total P_2O_5 ‰
59 a	0-20	A1	sC	sub. bl.	0	1,5	0,9	10	7,7	15,0	11,0	73	9,0	1,2	0,4	0,4	0,40
	20-80	(B)	sC	sub. bl.	0	1,1	0,6	11	7,5	16,0	14,0	87	13,2	0,6	0,1	0,1	0,40

These red to dark red soils generally consist of fine sandy clay but they are clayey on the Labu plateaus. Soil remains friable in fine earth.

There is no calcium carbonate.

The content of organic matter is low but decreases slowly in the depth. This is also true for nitrogen. The C/N ratio is low and indicates a soon mineralized type of humus.

The exchangeable capacity is generally weak but it is more considerable on the Labu plateaus owing to the high clay content.

The Ca/Mg ratio is very high. The content of exchangeable potassium is medium and low at Duhun and El Kere and higher on the Labu plateaus.

The phosphorus content is medium.

Cultural and pastoral fitness

Fersiallitic modal soil-types (59 a) on sandstone may be very suitable for agro-pastoral development.

- It is certainly possible to extend dry-farming cultivation on the Labu plateaus.

In Lower Ogaden, the plateaus on sandstone are the only plateau-zones where fresh water may be found. In fact, the suspended water table rests on the subjacent Mustahil limestone.

To this ground water table are due many permanent springs in the El Kere region and it is said that wells have been dug on the Duhun plateaus. The vegetation of these sandstone plateaus is far more developed and often quite different from the vegetation of the neighbouring gypseous zones.

They constitute very good pastures practically all year round but nevertheless could probably be largely ameliorated. Knowing the possibilities of the suspended ground water table is essential for any attempt at agro-pastoral development.

In the case of crop-growing, and even for an improvement of pastures, the soil fertility must be ameliorated as regards the three major elements : NPK and carriers should be added, for instance :

- nitrogen : lime nitrate, ammonium, ammonium sulphate and eventually, urea.

- phosphorus : lime superphosphate

- potash : potassium chloride.

The scarcely developed fersiallitic soil-types (59 b) on steep slopes and eroded zones are favourable for reforestation in the region of the Aouatou mountains as well as in the El Kere region.

I - FERRALLITIC SOIL CLASS

Ferrallitic soils are developed in the Basin only in well drained areas, at an altitude between 2.500 m and 3.500 m with rainfall approximately 1.000 mm or more. They correspond to the red and reddish-brown or yellowish-brown well-drained soils (at the surface and within), on small hills and mountain-slopes in contrast with the dark grey vertisols of the underdrained flat zones of the plain.

All the ferrallitic soils of the Basin of the Wabi are included in the sub-class of weakly desaturated or saturated ferrallitic soils. They are characterized :

- by a very thick profile presenting no traces of limestone.

- by a subangular to angular blocky structure throughout the profile. This soil being very friable is easily known on the field.

- by a clay fraction with a dominance of metahalloysite or of kaolinite and with some illite to which is due the high exchangeable capacity of soil.

Foot note - The classification presented here for ferrallitic soils is provisional and tentative. These soils can be considered as transitional between ferrallitic and fersiallitic. Further studies are likely to modify the present classification.

- by the presence, in the deeper horizons consisting of weathered material, of montmorillonite on soil derived from a complex material (colluvial limestone, sandstone and granite deposits).

- by a generally considerable haematite content (see table).

- by the colouring of soil (horizon B) from red to reddish-brown with various hues, for instance yellowish-brown for some soils on sandstone.

	Original material		
Type horizon	On limestone + granite (Harar) colluvial deposits	On basaltic colluvial deposits (Kuni)	On sandstone (Micheta) colluvial deposits
A1	Metahalloysite Illite Abundant haematite	Metahalloysite open illite Abundant haematite	Kaolinite open illite traces of goethite
B	Metahalloysite Illite Abundant haematite	Metahalloysite	Kaolinite open illite some goethite
C weathered			Kaolinite open illite some goethite

The different mineral fractions are represented in the order of decreasing qualitative importance.

In the sandy fraction,minerals which can be affected by weathering still exist in particular feldspar (on basalt material).

It is therefore obvious that fersiallitic and ferralitic soils are not clearly differenciated from the mineralogical as well as from the physico-chemical points of view. However, the morphological characteristics of the profile (thickness, structure, friable character, type of base-rock weathering) are those usually observed in ferrallitic soils.

The ferrallitic soil sub-class, either desaturated or saturated, includes two groups :

- the type group with two sub-groups :

  - a thick modal sub-group with a weathered horizon C below 1,5 m depth,

- a scarcely developed sub-group with a weathered horizon C at less than 1,5 m depth. This sub-group presents an organic facies with a content of organic matter varying from 3 to 7 percent.

- the humic group with a content of organic matter greater than 7 percent for a 20 cm depth, and a single sub-group :

- scarcely developed sub-group with a weathered horizon C at less than 1,5 m depth.

60. Red modal soil type, derived from the Kebri Dahar limestone, from Adigrat sandstone and from granite.

These soils are developed on the slopes and colluvial deposits at the base of slopes of the hilly landscape of Harar, in the triangle formed by Harar-Adelle-Melkerafu. They cover approximately 375 km2. The colluvial deposits are complex and include weathering material derived from :

- limestone of tabular hills commanding the landscape (Akim-Gara-Kondudo etc...)
- subjacent but not very thick Adigrat sandstone.
- granite of the base which outcrops on large areas, Southwards and near Kersa in the North.

Morphology :

Leaving Harar, to the North, on a natural section due to weathering, the following profile may be observed under a graminea cover :

0 - 50 cm A1 : Dark reddish-brown (2,5 YR 3/4) ; clay ; very well-developed crumb to granular structure ;

50 - 470 cm B : Dark red (10 YR 3/3) ; clay ; small horizontal and vertical cracks delimiting shining prisms ; the latter are very friable and provide material with a very well-developed medium angular blocky structure including shining aggregates ; friable.

470 - 800 cm C : Reddish-brown weathered sandstone.

The friable nature of horizon B as well as the weathering in the depth characterize ferrallitic soils.

The most remarkable feature is the glossy aspect - as if they were varnished - of the structural elements of horizon B. This is probably due to the presence of halloysite dominant in the clayey fraction.

The nature of the weathered material in C depends on its position on the slope, for instance :

- in the upper part and in the middle of the slope, soil usually rests on weathered sandstone material.

- in the Lower part of the slope, the weathered material is derived from granite.

In the Alemaya and Adele regions, the upper horizon is brown to dark brown. This is not due to a greater content of organic matter but to the presence, higher up, of limestone remnants providing brown weathered material overlaying the slopes in the form of colluvial deposits. In the upper parts of hills the weathering of limestone produces the brown calcic and calcic rendzina soils described previously (family 25).

<u>Physico-chemical characteristics</u>

Soil roup	Depth cm	Horiz type	Texture	Structure	CO_3Ca %	Org.mat %	N ‰	C/N	pH	T me/100g	Exch bases me/100g	V percent	Ca++ me/100g	Mg++ me/100g	K+ me/100g	Na+ me/100g	Total P_2O_5 ‰
	0-50	A1	C	gr.	0	2,7	1,2	12	7,0	26,0	26,3	100	16,6	9,3	0,30	0,1	0,5
60	50-470	B	C	ang. blo.	0	0,3			6,7	17,6	17,9	100	10,0	7,6	0,20	0,1	0,4
	470+	C		-	0				6,5	5,0							0,4

This soil is dark reddish-brown at the surface and dark red in the depth and presents a clayey texture. It is very thick with a granular structure in horizon A1 turning into a very well-developed medium angular blocky structure in the depth. The whole profile is very friable.

Soil is not calcareous.

The content of organic matter is medium down to a 50 cm depth.

The nitrogen content is also medium at the surface.

C/N is low and characterizes a soon mineralized humus.

pH is neutral at the surface and slightly acid in the depth.

The absorbing complex is base-saturated.

The Ca/Mg ratio is correct.

The content of exchangeable potassium is medium to low.

The $\frac{\text{Total N}}{\text{Total } P_2O_5}$ is approximately 2 and reveals a nutritional unbalance detrimental to nitrogen.

Cultural fitness :

These soils are largely cropped mainly to maize, sorghum and chatt (Catha edulis) which is a "cash-crop". Beans, sweet potatoes and various other vegetables (potatoes, onions, tomatoes) are also produced in large quantities.

The fertility level of these soils is medium as regards phosphorus and potash but is very poor as regards nitrogen.

Consequently, it is necessary to add nitrogen carriers in order to increase in a considerable proportion the yield of chatt plantations and of annual crops.

Besides, since the contents of phosphorus and potash are medium, adding phosphate and potassium carriers seems advisable if the economic conditions of cultivation make it possible.

The carriers to be added are as follows :

- nitrogen : urea, lime nitrate, ammonium nitrate, ammonium sulphate.
- phosphorus : lime superphosphate
- potash : potassium chloride.

The most urgent measure to be taken is erosion control. All the Harar region is affected by a very serious headwater erosion resulting in the formation of very deeply eroded gullies, and very often of "lavakas" 3 to 5 m deep quickly going up the hillslopes.

Therefore, erosion control consists in limiting overland runoff on slopes and also in warping the erosion gullies.

Control of water erosion

- On the steep slopes(representing more than 8 percent), farmers have built terraces especially for the cultivation of chatt. These sometimes consist of low dry-stone walls but usually of earth ridges. The flat part of the terrace is also divided perpendicularly which is a suitable technique for erosion control on steep slopes.

It is nevertheless necessary to extend the erosion control system to smaller slopes :

- for slopes from 3,5 to 8 percent, contour bed-ploughing should be adopted (see chapter VI B).

- for slopes less than 3,5 percent, the technique of contour ploughing should be applied (see chapter VI B).

Besides, these techniques would allow improving in a considerable way the hydrologic balance of soil (see chapter VI C).

Stabilization of erosion gullies

It consists in controlling the swiftness of water flow in gullies by means of small pile weirs, gabions and wire or even masonry dams in the "lavakas", these installations also being useful for wraping with erosion material and for a progressive growth of a natural vegetation (see details in chapter VI B).

61. Humic ferrallitic soil types on Reddish-Brown material derived from the basalt of plateaus

These soils are developed at an altitude from 1.600 m to 2.000 m with rainfall approximately 1.000 mm or more. The stretch on the one hand, on the colluvial deposits on slopes and on the base of slopes of the rounded basalt hills of Chercher which constitute the counterfort of basalt chains encircling the basin in the North and North West, in the Kuni, Gelemso and Minne regions.

- on the other hand, on the undulations of basalt plateaus in Northern Ginir bordering the Shek Hussien mountains.

These soils cover a total area of 1.270 km2.

Morphology : Description of a road trench observed on the Kuni-Bedessa track 4 km from Karakurkura.

0 - 30 cm A11 : Dark reddish-brown (5 YR 3/3) ; clay ; medium granular ; friable.

30 - 90 cm A12 : Dark reddish-brown (2 YR 2/4) ; clay ; well-developed fine angular blocky ; friable.

90 - 600 cm (B) : Dark reddish-brown (2 YR 2/4) ; clay ; scarcely-developed medium to coarse angular blocky ; friable ; some friable manganese concretions at the base.

600 cm C : Much weathered basalt in small motley-coloured nodules with flakes due to weathering ; non-calcareous.

Throughout the profile the presence of a large quantity of magnetite gives the soil a dark colour.

The profile is not always so well-developed and its thickness varies locally in relation to the importance of the colluvial process.

Physico-chemical characteristics

Soil group	Depth cm	Horiz type	Texture	Structure	CO_3Ca %	Org.mat %	N ‰	C/N	pH	T me/100g	Exch bases me/100g	V percent	Ca++ me/100g	Mg++ me/100g	K+ me/100g	Na+ me/100g	Tot P_2O_5 %
61	0-30	A11	C	gr.	0	4,1	2,5	9	6,9	56	29	50	18,0	10,0	0,7	0,3	1,1
	30-90	A12	C	ang. blo.	0	1,9	1,6	7	6,8	37	28	80	17,0	10,0	0,6	0,3	0,9
	90-600	(B)	C	ang. blo.	0				7,1	36	26	80	15,0	9,0	0,6	0,4	0,7

These dark reddish-brown soils have a very clayey texture (more than 65 percent), but the considerable development of the angular blocky structure gives the horizons a very friable character and a good permeability.

The external and internal drainage of these soils is very good. As soon as one reaches the underdrained areas at the foot of hills, brown vertisols may be observed.

The soil is non-calcareous and no traces of carbonates exist in weathered basalt.

The content of organic matter is high in horizon A11 and a certain amount penetrates into horizon A12.

The nitrogen content is high in horizon A11 and is medium below.

The C/N ratio is very low showing that humus is intensely mineralized.

pH is slightly acidic in the horizons containing organic matter and is neutral in horizon (B).

The exchangeable capacity is high but the saturation degree is medium in the organic horizon and though it is higher deeper down, the absorbing complex is never completely saturated.

Conversely, the soils of Northern Ginir are practically base-saturated right from the surface where the saturation degree is 94 percent, and it increases to 100 percent in the depth.

The Ca/Mg ratio is correct.

The content of exchangeable potassium is high as well as the phosphorus content.

The $\frac{\text{Total N}}{\text{Total } P_2O_5}$ ratio is approximately 2 and shows a relatively pronounced nitrogen deficiency.

Cultural fitness

These soils are highly suitable for the plantation of trees and orchards owing to their considerable thickness, their good internal and external drainage and the possibility for roots to penetrate into the depth. They are also adequate for most annual crops, in particular because of their suitable specific retention.

- In Chercher, climatic conditions are favourable to many temperate and tropical crops. On the red ferrallitic soils of slopes, terraces have been built on which coffee-trees and chatt are usually well-grown. These soils are also intensely cropped to maize, sorghum and sweet potatoes.

--In the regions of the Northern-Ginir plateaus, climatic conditions are not so good since temperatures are cooler. Nevertheless, coffee-tree plantations can be largely extended to this zone.

As regards fertility, these soils have suitable contents of phosphorus and potassium, but owing to the intense mineralization of humus, a nitrogen poverty may be observed, compared with total phosphorus.

Adding nitrogen carriers would highly increase the yields (urea, lime nitrate, ammonium and ammonium sulphate).

62. Yellowish-brown organic ferrallitic soil-types, derived from Gesoma sandstone.

These soils occupy the flat areas and gentle slopes of the Shek Hussien mountains. They cover approximately 140 km2 and are associated on the map with organic lithic soils on steep slopes (family 9) in association n° VI - Shek Hussien.

Morphology : On the Shek Hussien-Djara track at 20 km from Shek Hussien, the following profile is observed :

0 - 20 cm A1	: Brown ; humic ; sandy and medium sandy ; single-grained ; loose.
20 - 180 cm: B	Light red ; not humic ; sandy to medium and fine sandy with some pockets with more abundant humus ; single-grained ; loose.
180 - 300cm: C	Motley yellowish-red and whitish weathered sandstone ; friable.

Cultural and afforestation suitabilities

On these soils may be seen a fine Tid forest. In some places recent land-clearing was carried out in order to grow coffee-trees and maize. But owing to their sandy texture, these soils will probably be soon eroded.

These soils are naturally suitable for forests (see comments on the fitness of soil family n° 9).

63. Association of yellowish-brown modal soil types (63 a) and scarcely developed soils (63 b), derived from Gesoma sandstone

These soils are developed on the plateaus and on the hills of the Gesoma sandstone formation which outcrops on a large area in the regions of Debre Salam, Ejerso and Belbeletti. As regards altitude, these plateaus are located below the basalt massifs and their colluvial deposits which cover these soils in the Minne and Micheta regions, and above the limestone formation outcropping in the South (near Dara Gudo)for instance.

The mean altitude of these plateaus and hills varies from 1.300 m to 2.000 m. This is the Woina-Dega zone where the climate is already warm but where rainfall is sufficient for tropical crops.

These soils cover approximately 1.770 km2

Morphology :

Modal soil-type : profile observed at 15 km from Micheta on the Dara-Gudo track ; slope : 6 percent.

0 - 30 cm A11	:	Dark brown (7,5 YR 4/4) ; fine sandy ; single-grained ; friable.
30 - 60 cm A12	:	Dark brown (7,5 YR 4/4) ; fine sandy ; scarcely-developed subangular blocky ; friable.
60 - 180 cm (B)	:	Dark brown (7,5 YR 5/6) ; fine sandy clay ; scarcely developed subangular blocky ; friable ; some ferrugineous concretions.
180 cm R	:	Yellow sandstone in situ ; friable.

Scarcely developed soils : profile observed at 61 km from Debore-Selam near Micheta ; slope : 3 percent.

0 - 15 cm A1	:	Dark brown (10 YR 4/3) ; fine sandy ; single-grained ; friable.
15 - 45 cm (B)	:	Pale yellow (2,5 YR 8/4) ; coarse sandy ; single-grained ; friable.
45 cm + R	:	Yellow sandstone in situ ; friable.

The modal soil-types are deep whereas in scarcely-developed soils, the weathered material is near the surface. The relative distribution of these two types of soils is not easily determined in relation to the topography since the sandstone outcroppings are either near the surface on gentle slopes or in the depth on steep slopes.

Physico-chemical characteristics

Results are only given for soil-types

Soil group	Depth cm	Horiz type	Texture	Structure	CO_3Ca %	Org.mat. %	N ‰	C/N	pH	T me/ 100g	Exch. bases me/ 100g	V per-cent	Ca++ me/ 100g	Mg++ Me/ 100g	K+ me/ 100g	Na+ me/ 100g	Tota[l] P_2O_5 ‰
	0-30	A11	fs	s.gr.	0	1,8	1,0	10	6,6	20	11,1	55	6,0	4,2	0,8	0,1	0,32
63	30-60	A12	fsC	sub-blo.	0	1,2	0,7	9	6,4	17	9,0	53	4,9	3,3	0,7	0,1	0,24
	60-180	(B)	fsC	sub-blo.	0	0,5			6,4								

Ferrallitic soils on sandstone present various colourings from yellow to red in the deeper horizons but the surface horizons are practically always brown to dark brown.

These are very sandy to fine sandy soils. In thick soils (63 a) the clay content increases in the depth. The soil consistency is from friable to loose.

Soils are never calcareous.

The contents of organic matter and nitrogen are low.

pH is slightly acid.

The exchangeable capacity is weak and the soil saturation degree is low.

The exchangeable calcium and magnesium contents are low and the Ca/Mg ratio is not balanced and proves detrimental to calcium.

Conversely, the content of exchangeable potassium is suitable.

The phosphorus content is medium to low.

Cultural fitness

These zones are largely cultivated especially to the East of their extension zone. The warm and comparatively humid climate is favourable to many crops such as maize, sorghum, fruit-trees, vegetables but the two main crops are coffee and chatt.

These zones are deeply affected by erosion but on most hills terraces have been cleverly built. In the case of more level zones, contour bed ploughing may be envisaged.

Despite the fact that manure is usually added when possible by farmers, the nitrogen and phosphorus contents of soils are low. Conversely, the potassium content is high.

The yield of coffee trees and chatt would be highly improved by adding nitrogen and phosphate fertilizers, for instance :

nitrogen : lime nitrate, ammonium, urea.

phosphorus : lime superphosphate

64. Association of reddish-brown scarcely-developed "humiferous" ferrallitic soils (64 a) and scarcely-developed "humic" soil-types (64 b), derived from the basalt of mountains.

These soils are developed on the slopes of high mountains and their counterforts, encircling the farthest Western part of the Basin in the provinces of Arussi and Northern Bale at an altitude between 2.500 m and 3.400 m. They cover a total area of approximately 2.040 km2.

The scarcely developed "humiferous" soils are brown at the surface and reddish-brown to red in depth and present a content of organic matter greater than 7 percent down to 20 cm depth. They may be observed on the steep slope of mountains at an altitude from 2.800 m to 3.400 m, i.e. :

- In the South, on the slopes of the Korduro, Somkaru, Beranta, Gara Arewa mountains:

- In the North, on the slopes of the Kakka, Enkolo, Galama, Boraluku, Erosa, Bada and Gugu mountains.

Climatic conditions are intermediate between the "Tichean" and "Boraluku" climates, with a mean annual temperature approximately 12°, and rainfall at least 1.500 mm.

Natural vegetation consists of a fine forest with mainly : Juniperus procera (Tids) and also in some places : Podicarpus gracilor (Zigbas).

On the slopes of the Boraluku, many epiphytes hang from the trees.

The scarcely developed "humic" soil-types, reddish-brown to red, with a content of organic matter varying from 3 to 7 percent, are developed on small basalt hills at the foot of mountains at an altitude between 2.500 m and 2.800 m :

- In the South, on the hills of the back-country of Dodola and Adaba.

- In the North, on the counterforts of the Kakka mounts : region of Kore, Sire, Meraro and on the small Ticho hills in the back-country of Ido, Gobessa and Dixis.

The "Tichean" climate-type is characterized by a mean annual temperature of approximately 13° and rainfall between 1.500 and 1.700 mm.

The original vegetation consisting of a forest of Juniperus and Podocarpus has practically completely disappeared to be replaced with crops and pastures.

Morphology :

Scarcely developed "humiferous" soils ; profile observed on the slopes of Mount Boraluku 6 km to the West of Ticho ; Juniperus forest ; altitude : 2.800 m.

0 - 15 cm A11 : Dark reddish-brown (5 YR 3/2) ; organic fine sand ; very well-developed medium to fine crumb structure ; very friable.

15 - 60 cm A12 : Reddish-brown (5 YR 3/4) ; relatively organic silty loam well-developed ; fine subangular blocky ; friable.

60 - 300 cm (B) C : Dark red (2,5 YR 3/6) ; silty loam ; well-developed fine and medium angular blocky ; numerous basalt fragments weathered in boulders some of which are very friable ; generally friable.

Scarcely developed "humic" soil-type : profile observed on a hill 4 km to the East of Ticho, Robi track, graminea vegetation.

0 - 50 cm A1 : Reddish-brown (5 YR 4/4) ; medium organic ; clay, medium to fine subangular blocky ; well-developed ; friable.

50 - 100 cm (B) : Red (2,5 YR 4/6) clay ; well-developed angular blocky ; friable.

100 cm + C-R : Motley weathering in boulders of the basalt in situ.

In both cases, if soil presents morphological characteristics typical of ferrallitic soils, such as friability of horizons B and deep weathering of the base-rock, one may note that the weathered material is high in the profile : 60 cm depth in the first case and 100 cm in the second. The profile is rejuvenated by erosion.

On slopes and hills near Mount Gugu, horizon B is usually rich in ferrugineous and mangaseniferous concretions.

Physico-chemical characteristics

Soil group	Depth cm	Type of horizon	Texture	Structure	CO_3Ca %	org. matt. %	N ‰	C/N	pH.	T me/100 g	BE me/100 g	V percent	Ca^{++} me/100 g	Mg^{++} me/100 g	K^+ me/100 g	Organic matter percent	Na^+me/100 g	Total P_2O_5 ‰
64 a	0-15	A11	fs	cr	0	8,7	3,6	14	6,5	43,0	44,7	100	35,5	6,5	2,6	8,7	0,15	1,42
	15-60	A12	SIL	sub bl	0	6,4	2,9	13	6,6	25,0	21,5	94	16,5	4,5	2,4	6,4	0,06	0,92
	60^+	(B) C	C	ang. bl.	0	0,7	0,4	12	6,4	21,0	20,2	98	11,0	7,0	2,8	0,7	0,12	1,10
64 b	0-50	A1	C	ang bl.	0	4,6	2,5	11	6,0	35,0	35,6	100	25,2	9,0	1,2	4,6	0,25	1,13
	50-100	(B)	C	ang bl	0	1,7	1,0	10	6,3	31,0	22,6	75	14,0	8,0	0,6	1,7	0,05	0,7
	100^+	C.R		-					6,6		-							0,7

Scarcely developed "humiferous" soils have a lighter texture than scarcely developed "humic" soils which are clayey at the surface. The structure is very well developed in both cases and the horizons are very friable.

These soils are non-calcareous.

Organic matter penetrates in the profile down to a 50 or 60 cm depth. The content is high in scarcely developed "humiferous" soils to which is due their brown colouring at the surface. The content is still considerable in scarcely developed "humic" soils the upper profile of which is reddish-brown.

The nitrogen content is high in both types of soil.

C/N is relatively low and characterizes a quickly mineralized humus.

pH is slightly acid and more distinctly acid in the upper horizon of rejuvenated "humic" soils.

The exchangeable capacity remains high partly owing to the abundance of organic matter.

The absorbing complex is saturated or weakly desaturated.

The Ca/Mg ratio is correct.

The content of exchangeable potassium is very high in humiferous soils and high in humic soils.

The phosphorus content is high in the first type of soil and medium in the second.

However, in the humic type (64 b) the $\frac{\text{TotalN}}{\text{Total } P_2O_5}$ ratio hardly different from 2) shows a nutritional unbalance detrimental to nitrogen.

Cultural, pastoral and afforestation suitabilities

On the scarcely-developed "humiferous" soils (64 a) of mountain slopes the natural forest still exists on steep slopes but in flat areas, they are under cultivation or constitute pastures.

The scarcely-developed "humic" soils (64 b) stretch on hills at the base of mountains and are used for crop-growing and pastures. Both these types of soils are mainly cropped to wheat, barley, peas and lentils. Conversely, teff does not grow well and the climatic conditions are unsuitable for coffee-trees and other tropical plants.

This zone of hills and mountain slopes is naturally fit for livestock breeding which should become intensive breeding.

Coniferous forests should also be planted on the steeper slopes (64 b).

The soil fertility level is generally good but nitrogen carriers such as urea, lime nitrate, ammonium should be added to the scarcely-developed humic soils (64 b).

J. HYDROMORPHIC SOIL-CLASS

This class includes soils the evolution of which is mostly affected by an excess of water due to temporary or permanent waterlogging of part or whole of the profile. This class has a small extension in the Basin.

Two sub-classes are distinguished, i.e. :

- a medium organic sub-class with a content of organic matter greater than 8 percent down to at least 20 cm depth.

It includes a single humic gley group that is to say with a permanent shallow water-table.

- a sub-class of mineral hydromorphic soils with a content of organic matter less than 8 percent down to 20 cm depth.

It includes a single pseudo-gley group, that is to say with a shallow ground water table only during a shorter part of the year.

These two groups may be divided into three sub-groups, namely :

- a sub-group with powdery lime,
- a sub-group with calcareous heaps and nodules,
- a calcic sub-group : non-calcareous but base-saturated.

Sub-Class of medium organic soils

65 a and b : Humic gley soils with powdery lime on brown alluvial deposits of the Wabi Shebelle and Fafen

These soils are developed in Lower Ogaden,

- on the easily flooded alluvial deposits of the Wabi Shebelle, downstream from Kelafo in the Shebelle plain and in the Mustahil plain where they extend on 100 km2 (65 a).

- on the easily flooded alluvial deposits of the Fafen, in the Korahe-Maharato plain where they cover approximately 50 km2 (65 b).

These soils owing to their very high content (for the region) of organic matter : 10 percent down to 10 cm depth in the Shebelle plain and 5 percent in the Maharato plain, and because of their silty-clay texture are particularly suitable for :

- hydro-agricultural development in the Valley of the Wabi Shebelle*
- pastures in the Fafen Valley*

See* "Report on the soils of the Lower Valley of the Wabi Shebelle and "Note on the soils of the Lower Valley of the Fafen.

66. Humic calcic gley soils on the brown alluvial deposits of the Harar lakes

The extension of these soils is small and haloe-shaped around the lakes of Alemaya, Adele and Kersa and they can only be mapped at 1/250.000

Their texture is mostly clayey and the content of organic matter is high. These soils are flooded during the rainy season owing to the higher level of lakes and is still influenced by the presence of a high(at about 50 cm depth) ground water table during the dry season.

Sub-Class of mineral hydromorphic soils

67. Pseudo-gley soils with powdery lime on the light brown sandy alluvial deposits of the Wabi Shebelle and of its tributaries

They occupy the bottom of the deeply cut Valley of the Wabi Shebelle, from the Malka Uacana falls, to the North of Imi where the river flows out of its canyon, as well as the bottom of the canyons of the tributaries of the Wabi Shebelle upstream from its junction with the Errer. These soils cover a total area of 1.830 km2.

Morphology :

At the bottom of the Lagehida canyon, 800 m lower than the level of the plateau, and covered with a dense shrubby vegetation, the following profile may be observed :

0 - 30 cm : Light-brown (7,5 YR 5/4) ; fine sand ; single-grained ; friable and dry.

30 - 110 cm : Light brown (7,5 YR 5/4) ; loam ; single-grained ; friable and dry.

110 - 260 cm: Light brown (7,5 YR 5/4) ; silty loam with small calcareous spots, friable, humid.

260 cm + : Light brown (7,5 YR 5/4) ; fine sand ; single-grained ; humid and friable.

Physico-chemical characteristics

These light brown soils present a fine sandy texture. Their very friable character is linked to their single-grained texture.

The usual hydromorphic manifestations (iron oxyde stains) may not be observed as soil is slightly calcareous (between 4 and 7 percent). The only visible hydromorphic features consist of calcareous spots at the usual fluctuation level of the ground water table in relation to the level of the nearby Wabi Shebelle.

The content of organic matter is medium to low as well as the nitrogen content.

pH is distinctly alkaline : 8,3 to 8,8 and the conductivity of the saturation extract distinctly increases in the depth.

The content of sodium chloride in horizon 110-260 cm is 0,3 g for 100 g of soil but the profile is not alkalinized.

The content of exchangeable potassium is high, from 1,3 to 2,9 me/100 g.

The phosphorus content is also high.

The $\frac{\text{Total N}}{\text{Total } P_2O_5}$ ratio is distinctly less than 2 and shows a nutritional nitrogen deficiency.

Cultural fitness

The alluvial deposits at the bottom of the canyons of the Wabi Shebelle and of its tributaries extend on a small area and are usually not more than 50 meters wide. They are covered with a dense fringing forest with acacias in the direction of the High Plateaus and with a predomiance of many-headed palm trees with several heads (*Hyphaene thebaïca*) to the South East.

Though these zones are not easily accessible, they are nonetheless cropped in some places to sorghum in the regions of Lageida and of Shek Hussien by "fishermen-farmers" coming from Imi and following the canyons. Adding nitrogen carriers would highly improve the crop-yields (ammonium sulphate and nitrate).

68. Greyish pseudo-gley soils with calcareous heaps and nodules, derived from the Gesoma sandstone

These greyish soils are developed in the small depressions of sandstone plateaus in the Shilavo Gembari region. They can only be mapped at 1/250.000.

The grey colouring of these soils contrasts deeply with the bright red of the soils of sandy plateaus only a few meters higher (family 44).

These soils have a medium silty loam texture and are slightly calcareous at the surface (8 percent) and medium calcareous in the depth (15 percent).

A progressive accumulation of calcareous nodules may be observed and is the most considerable below 80 cm depth. Soil also contains numerous red gravels coated with sandstone.

It seems that the red material of sandstone colluvial deposits has been deferrated through the effects of the ground water table. However, ferrugineous stains or concretions are never observed.

Presence of shallow water-tables

The absence of an organized superficial drainage system in this zone of plateaus and sandstone deposits has already been mentioned in the survey of the red soils of the Shilavo region (family 44).

Shallow water tables only exist in depressed areas. The ground water table rests on the impervious subjacent limestone or gypsum beds. Wells have been dug especially at Shilavo, but apparently all the possibilities of the water table are not used.

A systematical prospection of these depressions by shallow drilling should on the one hand improve the conditions of living of people and livestock and on the other hand be favourable to the development of the particularly characteristic wild life of these vast red zones in view of creating a fauna reserve.

69. Calcic pseudo-gley soils on Yellowish Brown sandy alluvial deposits of the Errer, of its tributaries and of the Daketa

These soils are developed :

- on the one hand, in the high and not deeply cut valley of the Errer and Daketa.

- on the other hand, at the bottom of the canyons of the Gobele and of the middle valley of the Errer.

These soils only cover approximately 438 km2.

They are very sandy, with coarse and medium sands, are non-calcareous and present at the usual pulsation level of the ground water table, small reddish ferrugineous stains.

Their economic interest is small.

These soils are inundated by the floods of the Errer and of the Daketa and are only used as pastures in the upper valleys of both these rivers.

At the bottom of the canyons of the Gobele and Errer, a relatively dense fringing forest may be observed but the latter does not occupy all the alluvial zone.

K. SODIC SOIL CLASS

This class, the evolution of which is commanded by the presence of soluble salts such as chlorides,sulphates etc... is only represented in the Basin by a single sub-class with a small extension : the sub-class of soils with a non-deteriorated structure indicating that soil is not alkalinized.

This sub-class presents a single group : the group of saline soils with a single sub-group, also with saline efflorescences.

70. Saline soils with saline efflorescences on complex red alluvial deposits, derived from Gesoma sandstone, Belet Uen limestone and Ferfer gypsum.*

These soils are extended on approximately 136 km^2 to the North of Ferfer on the red alluvial deposits resulting from the convergence of several temporary rivers forming a vast alluvial fan. Annual rainfall is approximately 150 mm.

Vegetation wholly consits of halophyte species, and saline efflorescences are very frequently seen on the ground.

Physico-chemical characteristics

The soil consisting of a red loam to clay layer of alluvial deposits rests on a gypsum slab (gypsum in situ) and is very saline ; the mean content of the saturation extract of 1 : 2 of soil is more than 2,9 of sodium chloride for 100 of soil.

In some places, the beginning of an alkalinization process may be obser with a soil compacity which considerably increases at the surface for approximately 10 centimeters. But this is always a limited process as soils present abundant gypsum and lime. This is confirmed by the fact that pH is approximately 8,0 and that saturation of the absorbing complex by sodium is never more than 5 per cent.

Cultural and pastoral fitness

These soils when dry are unsuitable for crop growing and constitute poor grazing grounds though they are appreciated by livestock and wild animals because of their salinity.

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* See more complete study in the report on soils and soil reclamation in the Lower Valley of the Wabi Shebelle.

VI. IMPROVING AGRICULTURAL, PASTORAL AND AFFORESTATION POSSIBILITIES IN THE BASIN OF THE WABI SHEBELLE - CREATION OF FAUNA RESERVES. *

Agriculture in the Basin of the Wabi Shebelle is mainly concentrated in the North of the Basin on the High Plateaus at an altitude between 1 600 m and 3 200 m. Climatic conditions are favourable for many temperate crops between 2 500 and 3 200 m and for tropical crops from 1 600 to 2 500 m.

Above 3 200 m, the cold temperature is a limiting factor, but these zones are not largely extended and are located at the Western end of the Basin on mountains at the same level as the Alchemilla spp and Ericacea (andosol zone) belts.

Below 1 600 m, the dry climate is the limiting factor, however two different zones may be considered, ie :

- the plateau zone from 1 000 m to 1 600 m also called the Middle Belt where dry conditions are not yet too serious and where the cultivation of plants requiring little water may be envisaged on suitable types of soil.

- the zone stretching from 200 m to 1 000 m in Lower Ogaden, where the climate only allows crop-growing under the following conditions :

  - by irrigation in the Lower Valley of the Wabi Shebelle.
  - by flooding in some areas of the Fafen Valley.
  - by concentrating the water collected by some temporary rivers in small depressions scattered throughout Lower Ogaden and mainly in the gypsum zone.

A. FERTILITY OF SOILS

The main factors of soil fertility are : organic matter, nitrogen, phosphorus, potassium, sulphur (major elements) and trace elements (minor elements).

Organic matter

The percentage of organic matter is mostly linked to the climatic conditions.

In cool and humid zones on the High Plateaus above 2 500 m with rainfall greater than 700 mm, the content of organic matter is generally more than 3 percent.

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*Part of this chapter is a summary of the paragraphs on "Cultural, pastoral and afforestation suitabilities" followed by the description and physico-chemical characteristies of each soil family, which may usefully be referred to. All the data concerning this chapter are given in table 2.

In the Middle Belt zone between 1 000 and 2 500 m in a warmer climate with rainfall greater than 400 mm, organic matter represents 1,5 to 3 per cent.

In the Southern part of the Basin, below 1 000 m and generally at approximately 300 m in a subarid and warm climate with rainfall less than 400 mm, the content of organic matter is less than 1,5 per cent and often less than 1 per cent. Nevertheless, an accumulation of organic matter corresponding to more than 7 per cent may be observed in easily flooded zones (West of the Korahe plain, Shebelle plain).

In fact, this humus is quickly mineralized and disappears if plant elements are not abundant enough.

Now, humus besides its protective role against erosion and its favourable effect on the hydrological balance of soils, constitutes a storage of easily available major elements for the growth of plants, as well as of trace elements. This is particularly true in the case of nitrogen and phosphorus. Accordingly, the existent humus content should be preserved as much as possible in the soils under cultivation of the High Plateaus and of the Middle Belts. As to the irrigable zones of the Lower Valley of the Wabi Shebelle, the humus percentage should be increased in order to attain 2 per cent , by returning to the soil crop residues, temporary pastures etc...

The levels of organic matter are classed as follows :

- Content of organic matter	Level
. Less than 1,5 per cent........................	low
. From 1,5 per cent to 3 per cent..............	medium
. More than 3 per cent..........................	high

- Nitrogen

The nitrogen contents of surface horizons are correlated to the content of organic matter in the Basin of the Wabi Shebelle. Hence, they are :

. high on the High Plateaus

. medium in the Middle Belt

. low in Lower Ogaden

As will be said further on, the contents present but a comparative value and must be compared to the contents of total phosphorous in order to determine whether the nutritional balance between both these elements is compatible with a suitable growth of plants.

Thus one may note that in most soils of the Basin, the element limiting fertility is nitrogen (see table 2). It is therefore necessary to increase the nitrogen content by an addition of nitrogen carriers.

The fertility scale adopted concerning nitrogen is as follows, ie :

Nitrogen content	Fertility level
. less than 1 ‰	low
. from 1 ‰ to 1,5 ‰	medium
. more than 1,5 ‰	high

- Phosphorus

The proportioning of total phosphorus is useful to know the content of phosphorus in the soil. Only the part of this phosphorus is used by plants : this is available phosphorus.

- In calcareous and low organic soils (Middle Belt and Lower Ogaden), it is often difficult to know the quantity of available phosphorus. Most of the phosphorus is in fact in a tricalcic form scarcely soluble in soil solutions. However, the content of total phosphorus is always high in the calcareous soils of the Basin. Besides, lime appears as fine particles of the size of silt. It is therefore possible, especially under irrigation, to obtain a weak but regular solubilization of tricalcic phosphorus for the use of plants. The available phosphorus for plants is estimated to be 1/20 of the total phosphorus in soils when the lime content is approximately 20 percent.

- In non calcareous but base-saturated and slightly acid soils (High Plateaus) with more abundant organic matter, total phosphorus includes a greater quantity of soluble phosphorus in the soil solution. In this case, available phosphorus for plants corresponds to 1/10 of the total phosphorus content.

The fertility scale adopted concerning phosphorus is as follows : (P_2O_5 in ‰) :

Non-calcareous soils	Calcareous soils (averaging 20 percent)	Fertility scale
- pH approximately or less than 7	- pH greater than 7	
- less than 0,25 ‰	- less than 0,50 ‰	- low
- from 0,25 to 0,75 ‰	- from 0,50 to 1,50 ‰	- medium
- greater than 0,75 ‰	- greater than 1,50 ‰	- high

On the whole, in the Basin of the Wabi Shebelle, sois are well provided with phosphorus and the latter is a factor limiting fertility only in several cases (see table 2).

- Potassium

Potassium exists in soils in three forms, i.e. :

. a complex form localized between the layers of certain minerals (muscovite, biotite) and to be found only in illite and in no other clay mineral. A certain quantity exists in the fersiallitic and ferrallitic soils of the Harar, Chercher and Arrusi.

. a fixed form concerning potassium which tends, particularly in montmorillonite, to migrate from the external face to the internal face of the clay layers. This process is known as retrogression of potassium which in this case is only scarcely exchangeable. The fixed form is mostly observed in the calcic vertisols of the High Plateaus or in the calcareous vertisols of the Middle Belt and of Lower Ogaden.

. an exchangeable form scarcely retained on the external face of layers is directly available to plants.

A balance exists between these three forms, the two preceding forms constituting the potassium storage in soil.

Most of the soils of the Basin are well supplied with exchangeable potassium.

The fertility scale adopted concerning potassium is as follows :

K in me/100 g of soil	Fertility level
less than 0,2	low
from 0,2 to 0,4	medium
greater than 0,4	high

$$\text{Utilization ratio} = \frac{\text{total N ‰}}{\text{total } P_2O_5 \text{ ‰}}$$

This ratio gives indications as to the nutritional balance between nitrogen and phosphorus concerning plants.

It was used for the first time on acidic soils or on soils with a neutral pH in West Africa (DABIN, 1964). In soils with a medium lime content (20 percent) one may consider that the efficiency of total phosphorus is reduced by half.

The following ratios are then utilized :

. non-calcareous soils : pH approximately 7 or less

$N/P_2O_5 > 5$: considerable phosphorus deficiency in soil.

$N/P_2O_5 < 2$: soil well-supplied with phosphorus but presenting a nitrogen deficiency.

. calcareous soils : (20 percent of total lime)

$N/P_2O_5 > 2,5$: considerable phosphorus deficiency in soil.

$N/P_2O_5 < 1$: soil is well supplied with phosphorus but a nitrogen deficiency may be observed.

In the case when the value of the ratio is intermediate between the extreme values, the nutritional balance is good but then, the needs of plants are dependent on the amount of each of these elements in the soil.

In most soils there is no nutritional balance since a nitrogen deficiency may be observed.

. $\frac{Ca^{++}}{Mg^{++}}$ Ratio :

Ions Ca^{++} and Mg^{++} are fixed on the absorbing complex and participate directly in the growth of plants. Though magnesium is not really toxic, it is unfavourable to the absorption of calcium, especially when the Ca^{++}/Mg^{++} ratio is equal to 1 or less on the complex.

- In most cases, the calcium and magnesium percentages are high, but the Ca^{++}/Mg^{++} ratio is far greater than 1 which is a very favourable element as regards the availability of both these ions.

- In only two cases, this Ca^{++}/Mg^{++} ratio is approximately 1 with respectively low contents (soils developed on ash, family 19 and 56) and an pH approximately 6,0. Lime should then be added in order to correct acidity and inverse the calcium and magnesium proportions in soils to the advantage of calcium, or to add a nitrogenous fertilizer with abundant calcium such as lime nitrate containing 1/4 of its weight in lime which allows at the same time correcting the nitrogen deficiency.

Sulphur.

- In the calcareous soils of the Middle Belt and of Lower Ogaden, a sulphur deficiency is not to be feared since these soils contain considerable quantities of gypsum (SO_4Ca, 2 H_2O).

- In the non-calcareous soils of the High Plateaus, an eventual sulphur deficiency could be corrected together with the nitrogen or phosphorus deficiencies, with ammonium sulphate or lime super-phosphate.

Trace-elements

Trace-elements are absolutely necessary for plants as diastase or vitamin "catalysers" but the needs are very small and the toxicity level is soon reached.

This is true for the red alluvial soils surrounding the Lower Valley of the Wabi Shebelle and probably for all the red to yellowish-red soils of the depressions of Lower-Ogaden (mainly soil families 12 and 50) where a considerable quantity of available boron may be observed and which is greater than 75 ppm in the Gode region. This value is distinctly higher than the toxicity level tolerated by many cultivated plants.

Types of fertilizers suggested in order to correct the factors limiting fertility

The main factors limiting the fertility of the soils of the Basin are, besides organic matter in the irrigable zones of the Lower Valley of the Wabi Shebelle, nitrogen, and less frequently, phosphorus and potassium and sometimes these three elements together. The improvement of the fertility potential is therefore related to the utilization of fertilizers in order to increase its level : nitrogen, phosphate and potassium carriers.

Nitrogen carriers

Urea is very useful owing to its high concentration and as it can be easily preserved it is a particularly valuable fertilizer in zones not easily accessible. However, it presents the following inconvenients :

As long as it is not hydrolysed, urea sinks into the soil like nitrate and is not fixed by the absorbing complex.

Its hydrolysis is facilitated by a suitable microbian activity, in particular in soils where the humus content is high enough. It then acts as a nitrogen fertilizer.

The utilization of urea to obtain good results and in order to avoid losing large quantities through leaching, requires a suitable amount of organic matter in the soil. It must consequently be used especially in the calcareous or calcic soils of the Middle Belt and of the High Plateaus.

- Ammonium sulphate : This fertilizer presents the advantage of acidifying the soil and may therefore be used favourably in the calcareous soils of the Middle Belt and in all the irrigable or easily flooded zones of Lower-Ogaden. Besides, it provides large quantities of sulphur and a sulphur deficiency may thus be avoided in the non-calcareous soils of the High-Plateaus.

- Ammonitrate or ammonium nitrate : this is a good fertilizer on all types of soils but concentrated formulas should be used. Besides, some precautions must be taken as regards storage.

- Calcium nitrate : lime represents one fourth of the weight of this nitrogenous fertilizer. It is highly hygroscopic and its preservation is difficult. Nevertheless it may suitably be recommended :

- for acid soils (mainly soils derived from ashes on the High Plateaus, family 19 and 56).

- for the calcareous soils of the Middle Belt under dry cultivation. In fact, owing to its hydrospicity, lime nitrate is the fertilizer most quickly absorbed by plants during dry periods.

To summarize : The utilization of fertilizers may be distributed as follows :

High Plateaus :- urea, ammonium sulphate, ammonium nitrate (calcic soils)

- urea, lime nitrate, ammonium nitrate (acid soils).

Middle Belt : - urea, ammonium sulphate (before and during rainfall), lime nitrate (after rainfall)

Lower Ogaden: - Irrigable zones of the Lower Valley of the Wabi Shebelle : ammonium sulphate.

- urea (if the percentage of organic matter is approximately 2 or greater).

- easily flooded zones (spreading basins) ammonium sulphate.

eventually, lime nitrate after rainfall.

Two methods may be used for nitrogen carriers :

- basal dressing before a cultural cycle.

- fractional additions in proportion to the needs of plants.

Fertilizers must always be buried at a small depth (10 to 15 cm for dry cultivation) in order to avoid losses of ammoniacal nitrogen in the atmosphere.

In the case of irrigated crops, irrigation will soon follow the spreading of fertilizers.

Phosphate carriers

In soils presenting a phosphorus deficiency, lime-superphosphate as a basal dressing is recommended. This fertilizer does not sink easily into the ground and should be mixed deep enough by ploughing two or three weeks before sowing, and together with potassium carriers if the latter are required.

Potassium carriers :

If potassium is insufficient in the soils of the High Plateaus, potassium chloride should be added and deeply mixed by ploughing, two or three weeks before cultivating the soil.

When potash is necessary in the irrigated soils of the Lower Valley of the Wabi, the best is to use potassium sulphate since potassium chloride contains a certain proportion of sodium chloride, a toxic element for plants, and is already abundant enough in the soils of the Lower Valley of the Wabi and of Lower Ogaden. It must be buried by light ploughing before sowing.

B. SOIL CONSERVATION AND EROSION CONTROL

1. Erosion in the Basin of the Wabi Shebelle

1.1. Water erosion (runoff) : This type of erosion is very important in the entire Basin but is most active in the middle and upper parts of the Basin.

It is related to two geographical causes which are not independent from each other, namely :

- The considerable difference of altitude between zones with a common drainage pattern, from 4.139 m at Mount Bada in the West, to 150 m at Ferfer, which represents a considerable grade of slope of 5,7 ‰.

- The drainage pattern has not recovered its equilibrium profile and to this fact are due the falls and rapids on the Wabi and the deep canyons ending upstream in cirques. Consequently a considerable recurrence of erosion may be observed on all the Central and Northern plateaus of the Basin.

During the rainy season, rivers transport a considerable quantity of solid debris and at Gode, 70 kg of silt per 1 m3 of water was observed in the flood waters of the Wabi.

Besides these two geographical causes, the action of man tends to accelerate this process.

As it happens, the surface of the High Plateaus is precariously balanced as regards erosion. When the forest cover was dense enough, erosion was weak and of the geographical type, hence relatively slow.

Practically complete deforestation, cultivation and overgrazing produced an acceleration of erosion processes.

The most frequently observed form of erosion in the Basin is gully erosion. During the rainy season when soil is waterlogged and sub-soil drainage is inadequate, which is the case for the vertisols on the High Plateaus, runoff in the fields cuts the soil and forms small erosion incisions. These incisions meet, the rivulets become larger and cut their beds like miniature torrents. Gullies are formed, going down the slopes at right angles to contours. They are usually observed on tracks used by animals and vehicles and in the rainy season, a track on a gentle hill-slope in the direction of the steeper slope may become a 2 to 3 m deep gully.

In the Harar region a slightly different form of headward erosion of Lavaka type (1) may be observed on the fersiallitic and ferralitic soils. It is in fact a gully ending like glove fingers with vertical sides sometimes more than 10 m high.

These gullies or lavakas progress very quickly upstream, often several meters a year.

When no protection structures exist, the evolution of a gully proceeds in four phases :

- channel scouring
- headward erosion and deepening of the gully, down to an horizon not affected by erosion.
- healing and growth of a natural vegetation.
- stabilization.

The two last phases concerning the ageing of the gully usually only take place when all the neighbouring soil has disappeared.

The depth of the gully is in direct relation to the thickness of soil or of loose material. In fact, the base level of the gully always consists of hard geological material in situ such as basalt, sandstone or limestone. This depth varies from 2 to 3 m and sometimes more than 15 to 20 m in Harar.

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(1) Lavaka : a madagascan word for this type of erosion.

In North America, gullies are classified as follows :

Gullies	Depth in cm	Drained surface in hectares
Small	<0,90	<2
Medium	0,9 to 4,5	2 to 20
Large	>4,5	>20

On the High Plateaus, the two last cases are practically always observed : the considerable surfaces drained by gullies require measures of erosion control on a large scale.

1.2. Wind erosion

is particularly intense in all Lower Ogaden and on part of the Middle-Belt where it mainly affects soils with a sandy texture. It is characterized by the formation of not very dangerous whirlwinds as regards the removal of soil, but especially by real sand-winds mainly blowing on the Shilavo and Degahbour regions on sandy soils formed on sandstone colluvial deposits. Control of wind-erosion in the arable areas of these zones is identical to the method to be used for an improvement of the hydrological balance, and consisting in planting wind-screens (see paragraph C).

2. Water erosion control and soil conservation

Soil conservation in the Basin presents two aspects :

- control of erosion due to runoff, for the Basin in general
- control of erosion due to runoff for the crop growing zone.

2.1. Water erosion control for the Basin in general

The problèm consists in controlling geographical erosion which means reducing the swiftness of runoff in the Basin as well as reducing the quantity of runoff water per time unit.

This may consist in saving or planting forests on all the steep slopes of the Basin and especially at a high altitude : mountain slopes in the

West and North of the Basin, but also, when possible, in the canyons of rivers, particularly in the vicinity of the High Plateaus of Arussi, Chercher and Harar. As vegetation play the role of a sponge it can considerably reduce erosion and also limit runoff by ameliorating the stability of the hydrological balance of rivers.

2.2. Water erosion-control in the crop growing zone

Water erosion is already particularly important on the High Plateaus. It might get worse owing to the inevitable and progressive extension of mechanized cultivation if measures for soil conversation are not taken in due time.

Soil conservation consists in :

- limiting runoff on the surface of cultivated soils.

- stabilizing erosion gullies.

2.2.1. Limiting runoff on the surface of soil :

The technique used depends on the steepness of slopes. Contour ploughing or contouring is efficient on slopes less than 3 to 3,5 percent which is the most frequent case in the vertisol zones of the High Plateaus and of the Middle Belt. Contour ploughing enables to retain water between the furrows and thus avoid runoff. To simplify this task from one year to the next, it is advisable to place 2 to 3 m wide contour-strips planted to grass, for instance every 200 m, these strips being also useful as line-marks for ploughing and other cultural practices (seed rows).

Contour bed ploughing is recommended for slopes from 3,5 to 8 percent which is the case of many regions in Chercher and Harar. Bed ploughing may be mechanized or not : the beds will be approximately 25 cm high and 1 m apart. Grass contour-strips are not so interesting here since the beds are still visible from one year to the next.

Terraces are used on slopes more than 8 percent and many already exist in the zones of Harar where they are well built with earth ridges or low dry-earth walls and divided at right angles.

It must be noted that the difference between contour bed ploughing and terraces is that in the first case, the soil surface between two furrows still slopes, whereas in the second case, the soil surface is horizontal.

2.2.2. Stabilizing erosion gullies (see fig. 5)

The natural drainage waterways formed by erosion gullies must be disposed so as to reduce the general slope of the latter. This consists in installing weirs to slow down runoff and allow the deposition of sediments. The gully is progressively filled-in and vegetation appears thus consolidating the bottom and the banks of the gully.

Accordingly, gabion dams, wire or pile fascines will be built. If slopes are too steep, stone-masonry dams deeply anchored in the banks might be necessary.

3. Conclusion

The serious problem concerning water erosion on the High Plateaus would become alarming if, for instance, mechanized cultivation was not carried out in a suitable way, thus causing a decrease in the upper horizons of the supply of organic matter which plays a well-known role against erosion. Besides, installing an anti-erosion system often disturbs the farmers of plots and their work-methods and is finally expensive. It would nevertheless be unforgivable not to take advantage of an evolution from manual agriculture or with draft animals to mechanized cultivation in order to introduce anti-erosion methods.

C. IMPROVING THE HYDROLOGICAL BALANCE OF SOILS

Improving the hydrological balance of soils is one of the main conditions in order to increase the farm production in already cultivated zones (High Plateaus) or to develop farming in the drier zones of the Middle Belt or in the basins of Lower Ogaden.

The improvement of the hydrological balance of soil consists in :

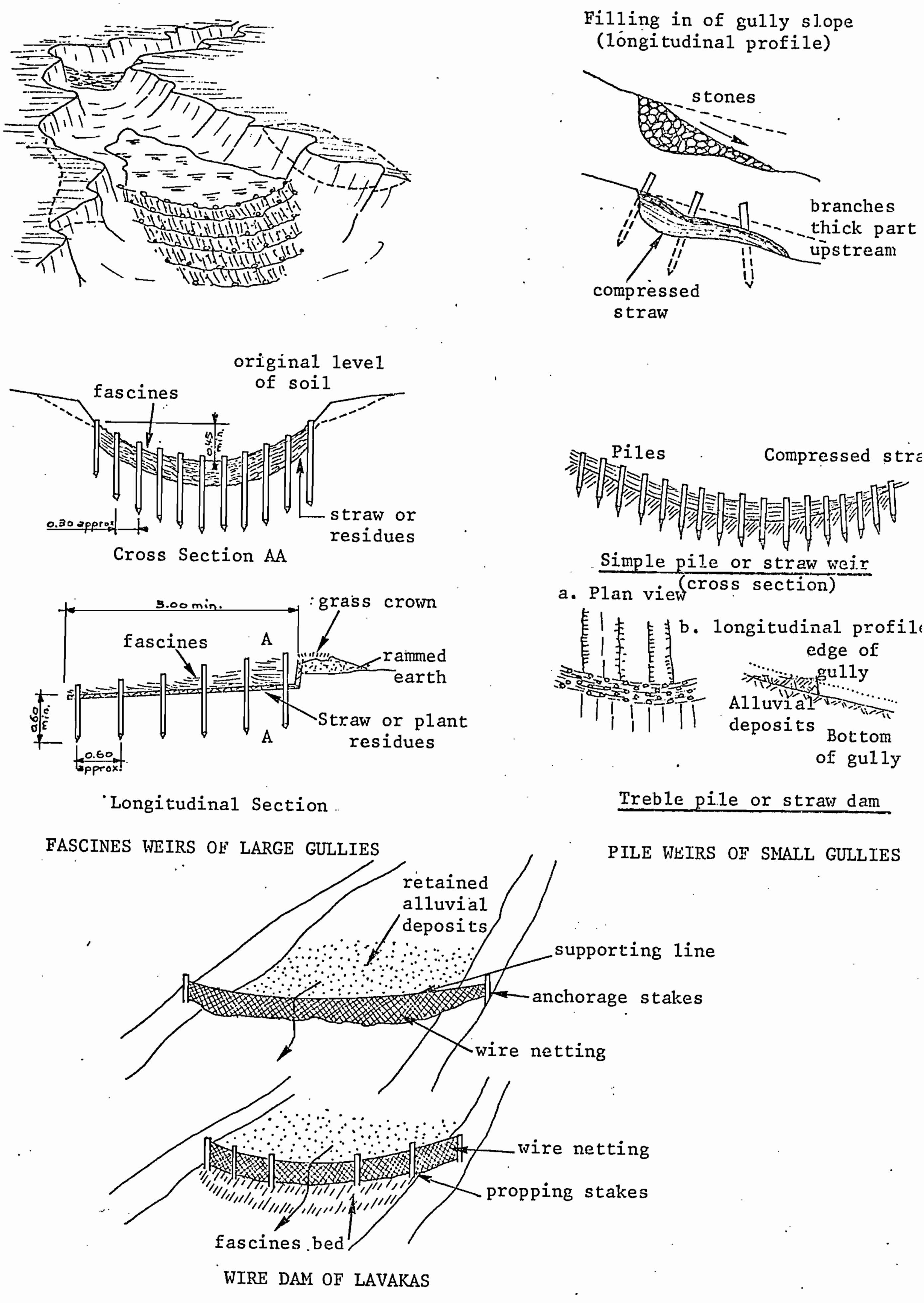
- reducing the percentage of runoff water
- reducing evaporation.

1. Reducing the percentage of runoff water

The previously described anti-erosion methods, by limiting runoff and consequently increasing the percentage of seepage water, is one of the essential factors for an increase of the hydrological balance of soil.

Hence, contour ploughing should be particularly profitable as regards crop-yields in all the large extension zones eventually suitable for dry-farming in the Middle Belt (soil family n° 15-16-17-18). This is also probably true in the Babile Harar regions, contour-ploughing being here combined with contour bed-ploughing and with terraces according to the grade of slopes.

Fig. 5 - Several methods to prevent gully erosion by TONDEUR and quoted in the "Techniques rurales en Afrique) n° 12 (Centre technique forestier tropical).



2. Reducing evaporation by using wind-screens

Dry wind is an important evaporation factor in soils, not only owing to its direct effect on the soil but because it increases evaporation on the stoma of cultivated plants.

- on the High-Plateaus of Arussi (Robi plateau, Kofele, Adaba and Dodola regions) and especially in the Gedeb plain where the climate is cool but relatively dry, not very thick curtains of trees (3 rows of Eucalyptus pruned at different dates in order to obtain a continued curtain from the lower part to the top) should be planted at right angles every 400 - 500 m, and would alter very favourably the micro-climate of crops as well as the livestock breeding conditions.

- in the Middle Belt and in Lower Ogaden (depressions), a frequent high wind is physiologically and physically damageable to crops thus considerably reducing the yields. In the Degahbour and Danan region for instance, sorghum plantations are often affected by a real sand-wind. Planting wind-screens would considerably limit these drawbacks, minimize evaporation-losses and increase crop-yields.

Wind-screens should be placed at right angles, one side of the square facing the prevailing wind, at a maximum distance of 200 m. They must present two main qualities, namely :

- consist in hardy species such as Tamarix* in the Dagahbour region and in Lower Ogaden, and Eucalyptus farther North,

- and not be a too strong obstacle against wind but play the role of a screen preventing whirlwinds and violent movements of air which might damage the crops.

D. SMALL HYDRO-AGRICULTURAL STRUCTURES IN LOWER OGADEN

Three types of agricultural possibilities exist in Lower Ogaden :

- Cultivation under irrigation in the Valley of the Wabi which is by far the most suitable possibility for hydro-agricultural development in this region. This is the subject of a complete study in another report.

- Cultivation by flooding from the Fafen in the Maharato region, with crop-growing of sorghum and maize but leaving the priority to pastures.

- Cultivation by flooding from the small temporary rivers of Lower Ogaden and upon which our attention is especially drawn. Lower Ogaden is scattered with basins the surface of which always represents more than 100 hectares : for instance, the depressed zones in the gypsum formations filled with alluvial material left by the temporary rivers flowing through the Danan spreading basin (soil families 12 and 50). Some of these depressions are cropped to sorghum but all of them are grazed and even overgrazed by nomadic herds. The U-shaped valleys of the El Kere region are also flooded and cropped to sorghum.

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* given as an example

The agricultural potential of these depressions and U-shaped valleys can be greatly ameliorated by controlling and modulating the distribution of water in order to protract flooding and extend the rationally flooded areas. The sheme outline could include :

- upstream, a structure with regulating gates for the control of the flood discharge of the temporary river ("reduction"of peak flow) in order to supply and distribute water in the zone to be flooded.

- pennate gullies supplying plots surrounded with contour embankments and successively closed, once they are full, by an earth plug. In this way flood-water can be distributed homogoneously. Besides, this system allows to collect practically all the rain-water which cannot flow outside the plots.

- Downstream, the depression can be closed by a small earth dyke and crops would be grown in the upstream part of the small dyke, using the water left in plots.

This technique may only be used on small temporary rivers with unimportant floods. As it happens, as soon as the temporary river is large enough, floods are too sudden and violent to be controlled even momentarily. This is the case for the Madiso and the Daketa and for several large temporary rivers of the Duhun-Danan region.

In the Shekosh region, the alluvial fans of the temporary rivers flowing from the East are cropped to sorghum.

Cultivation could also be ameliorated there merely by installing every 100 m small earth contour ridges from which the flood level could easily be controlled.

The network for erosion control with contour earth ridges may also be envisaged in certain depressions or in practically flat zones only in order to retain rain-water.

E. MECHANIZED CULTIVATION

Mechanization is an important factor as regards an increase of crop-yields.

The traditional type of agriculture using animals does not produce an adequate tillage of land. In fact, the swing-plough drawn by animals only scarifies the superficial soil horizons to a 15 cm depth at most with two unfavourable results :

- the thickness of loose soil inadequate for a suitable growth of crops.
- the difficulty in destroying perennial weeds. However, cuts due to erosion are not very deep.

Manual cultivation as it is carried out in Harar and Chercher is very efficient as regards tilling of land as well as for erosion control.

Prior zones for mechanized cultivation

Mechanized cultivation in the Basin must be carried out first in zones where it may cover large areas and this in order to absorb the expense made for costly equipment and also to obtain an adequate local concentration ensuring the possibility of creating repair shops and storing spare parts.

In a general plan for the modernization of agriculture

Effort as regards mechanization should bear on zones presenting the following characteristics :

- a large proportion of arable land.
- gentle slopes in order to avoid erosion
- deep soils (more than 50 cm) with no coarse elements at the surface, to facilitate the tilling of land and the movement of harvest machines (combine-harvester for instance).

These conditions exist in the following regions (see table I).

Table I

Vast mechanization zones in the frame of a modernization of agriculture on a regional scale

Zone	Location	Soil family
High Plateaus	Gedeb plain (Arussi)	34
	Robi plateau (Arussi)	18
	Sebre Dollo plateau (Ginir)	17
	Plateaus of Boke (Harar) and Gebiba (Chercher)	58
Middle Belt	Jijiga plain, plateaus of Babile-Fik, Midegalola South Godane, Soddu, North Dara-Gudo, Gobelle-Mojo	15
	Lagehida and Dara Gudo plateaus	17
	Lagehida region	16
	Degahbour basin	45 (c and b)
Lower Ogaden	Irrigable zones in the Lower Valley of the Wabi Shebelle	13 - 49 a
	eventually flooded zone of the Korahe plain	65 b
	eventually flooded depressions of Lower Ogaden	12 and 50

Type of useful agricultural equipment

The traction equipment (tractors) must include a large range of powers suited to the various cultural techniques but mainly heavy tractors.

This is justified, on the one hand, by the large extent of land concerned, and on the other hand, by the heavy texture of the soils on the High Plateaus (vertisols and ferrallitic soils on limestone) and in the Middle Belt (vertisols). Tractors with four driving-wheels seem to have the best performance.

However, in the Degahbour plain (soils with dominant sand) and in the Valley of the Wabi Shebelle (soils with dominant sand), lighter tractors would be wholly suitable.

As for cultural practises properly, using disk ploughing machines and clod-crusher machines is advisable.

Mechanized cultivation and soil conservation

It has already been said that if mechanized cultivation was not carefully undertaken, erosion processes might become disastrous. It is therefore absolutely necessary to turn to the following methods i.e. :

- Contour ploughing in zones where the slopes are less than 3,5 percent.

- Contour bed-ploughing in zones where slopes are 3 to 8 percent. We have already mentioned the interest presented by such techniques for an improvement of the hydrological balance of soils in regions where rainfall is limited as regards crop-growing.

Important remark

Apart from the regions above-described, in numerous small zones mechanization possibilities exist but only on small areas and consequently it is not evident that the equipment would turn profitable. This is the case in the regions of Harar, Babile, Hirna,Bedessa,South Adaba, Dodola.

F. USING SELECTED CROP-VARIETIES IS AN IMPORTANT CONDITION FOR AN AMELIORATION OF THE AGRICULTURAL, PASTORAL AND FOREST POTENTIAL.

Agriculture

Improving soil fertility and cultural techniques would be a failure from the economic point of view if the crops under cultivation were not fit to produce a greater yield justifying the expense and efforts made.

Therefore, it is necessary to :

1. introduce more recent and more productive varieties of wheat, barley and maize on the High Plateaus. The Middle Belt as well as the depressions of Lower Ogaden must be cropped to sorghum-varieties tolerant to salt and dryness and tested beforehand.

2. ameliorate the quality of plants traditionally cultivated in Ethiopa such as teff which is the staple-food and should produce a greater yield, and coffee, the production of which is far behind its renown. In this particular case, improving the cultivation conditions (pruning and fertilisation) would already be a considerable step leading to a larger production.

In the lower Valley of the Wabi Shebelle, these problems lose some of their importance since plants are tested at the Gode experimental farm before being introduced into the cultural cycle.

Pastures

The first step to be taken before selecting breeds for meat and milk production, is to improve the quality of pastures bringing about an increase of the number of fodder units per hectare.

Most of the pastures already existing in the Higher Basin are natural pastures consisting of fallow-lands in the cultivated zones, or permanent natural meadows in the regions where either climate or soil are unsuitable for agriculture.

Forage gramineae and legumes plants are recommended after being tested in the local conditions together with the following measures :

- suppression of fallow-lands in cultivated areas replaced with temporary meadows providing a high forage yield.

- amelioration of permanent pastures in uncultivated zones by progressively changing the flora through superficial practices (scarification for instance) and sowing with plants producing a greater quantity of forage once the soil fertility is improved (especially on the plateaus of Kofele and Adele).

Forests

1. The natural forest provides timber with a low sale-value owing to the defects of wood and could progressively be replaced with coniferous on the slopes of largely forested mountains. Unfortunately, the determination of suitable species is a long and exacting task.

We may remark on this subject that good-quality wood already exists in the Shek Hussien mountains (Tid variety) but the lack of communication media raises some problems.

2. Reforestation with the joint purpose of erosion-control and local use (building material and wood for household needs) could be envisaged on the steep slopes of the river canyons of the High Plateaus and also North of Ginir in the Aouatou Mountains.

G. CREATION OF GAME RESERVES

The variety and abundance of fauna in the Basin of the Wabi Shebelle and especially in Lower Ogaden may gradually decrease once one penetrates more deeply into these zones. It will therefore be necessary within a more or less short period to protect the fauna of these regions. We suggest two types of actions :

1. Creation of National Parks in zones near towns, with hotels and access facilities as well as possibilities of improving the living conditions of the fauna.

2. Creation of Entirely Protected Fauna Reserves in zones farther from important urban centres but presenting a considerable interest as regards the variety and abundance of wild life. These reserves could be turned into national parks as a function of future installations such as communication media, hotels etc...

1. Creation of National Parks (see map at 1/250 000 on utilization of soils).

1.1. Harar National Park :

A zone covering approximately 3 000 km^2 located at 70 km to the South East of Dire Dawa and 20 km to the East of Harar is recommended, as both these towns have the basic touristic commodities as well as access facilities, either by road to the capital or through the Dire Dawa international airport.

The boundaries of the park would be, as follows :

- to the North, the Harar-Jijiga road.
- to the South, parallel 8° 40' along approximately 70 km.
- to the East, the Fafen river along approximately 60 km.
- to the West, the Errer river along approximately 60 km.

In this zone elephants already exist along the Errer as well as lions, leopards, different species of gazelles, dikdiks, big kudus, oryxes, fores, jackals, porcupines, cheetahs, karkaros, various bird species, small mammals of numerous species, various types of monkeys etc....

The communication media from North to South can easily be created or improved (Babile-Fik and Borale Gelelcha track) this zone consisting of plateaus forming strips in a North-Southerly direction. Conversely, in the West-Easterly direction, the presence of deeply cut valleys as compared to the plateaus raises difficult problems.

During the dry season, the watering of animals may be a problem. Tank-trucks temporarily ensure the watering of the elephants of the Errer Valley. It will consequently be necessary to multiply open cisterns on the plateaus and to install drinking troughs supplied by pumping from the ground water table, in particular in the Errer and Fafen Valleys.

1.2. National Park of Arussi

This national park should be created on the mountain tops culminating approximately at 3 000 m in the Western part of the Basin, and mainly for the protection of Nyalas. It will be divided into two geographical zones :

The Arussi mountain-range with the Kakka, Enkolo, Galama, Erosa and Bada mountains.

The mountain-ranges of Arena, to the South and West of Dodola, including the Korduro, Somkaru, Beranta, Gara Arewa mountains.

Development of communication media in these mountainous zones is a difficult task, nevertheless :

- in the Arena zone, secondary roads may be built starting from the main Shashemene-Ginir road on the same line Dodola-Abada and at the pass bordering the Basin of the Wabi towards Ginir.

- for the Arussi zone, the Sagure-Ticho track passing on the Boraluku mountain can be improved and another track could be built starting from this mountain and leading Northwards (Mount Bada) and Southwards (Mount Galama) to join the Bokodji-Assela main road to the West.

2. Creation of Entirely Protected Reserves (see map at 1/250 000 on soil utilization).

In the Middle Belt and Lower Ogaden many animals of all kinds may be seen. Accordingly, the creation of entirely protected reserves is suggested in zones where animals are most numerous and when the latter present specific features or when modifications of the natural conditions (creation of dam lake) may be favourable to an increase and a diversification of this fauna. Bearing these factors in mind, three zones have been chosen :

2.1. Entirely Protected Reserve of the Wabi Shebelle

It presents a great variety of biotopes owing to the diversity of geological material (limestone, gypsum, sandstone), of vegetation and of altitude which, from 300 m near Gode, rises to over 1 000 m to the North-West, and also to an important pattern of temporary rivers joining the perennial waters of the Wabi Shebelle. This reserve would cover approximately 32 000 km^2. It would spread out to the North on the lake of dam IIb and to the South-East on the Lower Valley of the Wabi Shebelle and would be bordered as follows :

- to the North, by the Dare Ledae temporary river, the Daketa-Wabi Shebelle influx, the Gelansalle temporary river, Duhun. To the North-East, by a line from Duhun to Danan, including the large depression to the North of Danan.

The reserve would be limited at 55 km to the West of Gode by the Lac-Dima temporary river flowing from El Kere and the Baoua temporary river flowing from Danan, and this because of the hydro-agricultural development project to be carried out in the Gode region.

In the Kugno region where an irrigation project is also planned it would be necessary to "neutralize" the outskirts of this zone.

2.2. Completely Protected Reserve of the Lower Fafen

This reserve would mainly include the vast plateaus with bright red weathered material of the Shilavo region where fauna is specific (fire-red "garanouk" gazelles and crested guinea-flows for instance), and continue Westward with the Dobowein basin where numerous gazelles may be found, to end Southwards along the Wabi between Mustahil and Ferfer. It would occupy approximately 8 000 km^2.

2.3. Entirely Protected Reserve of Kebri Beya

This reserve would cover an area of approximately 1 600 km^2 on the sandstone plateaus between Kebri Beya and Degahbour crossed by the main track. This zone because of its park savannah aspect presents the typical character of reserves usually visited in Kenya or West Africa. Besides, the fauna is at present very abundant and varied. A large road and the comparative proximity of Harar should allow converting very soon this reserve into a National Park.

The list of the soil-categories utilizable as fauna reserves is relatively long. Other entirely or only partly protected reserves could then be created in a second phase particularly once roads are built.

3. Annexe : Main animals observed in Lower Ogaden and the Middle Belt : the locality following the name of animal indicates the zone where it has been most frequently seen.

- Antilopes.
- white-tail gazelle (medafiyel) : in all Lower Ogaden.
- camel-gazelle (garanuk) : Imi, El Kere, Degahbour, Kebri Beya.
- oryx (Salah) : Mustahil, Godere, Kelafo.
- water-buck : between Kelafo and Mustahil.
- ambaraile : between Kelafo and Mustahil, Imi.
- dick-dick : in all Lower Ogaden.
- karkaro : all Lower Ogaden, especially the Imi and Mustahil region.
- wild pigs : Ginir,Lege-Hida region.
- lions (ambessa) : all Ogaden but especially to the North of Imi near Hamaro-Hadad and up to Shek Hussien.
- elephants (Zohon) : South bank of the Wabi between Imi and Kugno, Errer Valley.
- hippopotamuses : in the Wabi Shebelle.
- crocodiles : in the Wabi Shebelle and Kelafo lake.
- baboons : in the Middle Belt in Harar and in the river canyons of Arussi.
- monkeys : in the outskirts of the fringing forest on the Wabi Shebelle.
- ostriches : Valley of the Wabi Shebelle.
- giraffes and zebras have been seen between Dolo and El Kere. Though they have not been observed in the Basin, it seems possible that they come from the South.

To this non-exhaustive list can be added jackals, marabous, various species of vultures and small birds.

Snakes seem very few. Boas have been seen in the swampy zones of the Shebelle plain.

TABLE 2 - LOCATION, EXTENSION AND MAIN CHARACTERISTICS OF THE SOILS OF THE WABI SHEBELLE AS REGARDS THEIR FERTILITY AND UTILIZATION

Soil class (1)	N° (1)	Location (2)	Extent km^2	FERTILITY (3) o.m.	N	Total P_2O_5	K	To [illegible] / T[illegible] P_2O_5	Factor limiting fertility (3)	Present utilization (4)	Suggested utilization (4)	Type of fertilizer used (5)	Mechanization possibilities (6)	Anti-erosion installations or anti-erosion cultural practice (7)	Amelioration of the hydrological balance Hydro-agricultural installations (8)
[illegible] soils.	1.	Godere = Mustahil	6.637	L	L	M	H			p.	p. reserve				
	2	N.O. of Basin canyons of Wabi and affluents	7.663	L											
	3	Lower Ogaden	20.000	L	L	M	M-H			p.	p. reserve				
	4	South El Kere	500	L	L	M	M-H			p.	p. reserve.				
	5	Lower Ogaden	331	L	L-M	H	L-H				Forest (Fik-Degah-Medo)				
	6	Babile													
	7	Ramis & Galetti	720	M											
	8	Arussi		H	H	H				crops-forest	Forest-[illegible]				
	9	Skek Hussien mountains	540	H	H	H				Forest	"Garden-forest" coniferous				
	10a b	Harar-Babile	905	M	M	M	L-M	4	Nitrogen Phosphorus Potash	Prevailing bush	10a : Forest 10b : cultivated	urea, ammonitrate ammonium sulphate lime superphosphate potash chloride (10b)	Yes (10b)	- Contour bed-ploughing - Contour ploughing	
Vertisols	11	Degah-Medo El Har	545	L	L	H	H	< 1	Nitrogen	P. sorghum	Sorghum and P	Ammonium sulphate			
	12	Ogaden	1.411	M	H	M		<1,5	Nitrogen	P. sorghum	Sorghum and P	Ammonium sulphate	Yes		- flood control. - Contour network for erosion control.
	13a	Lower Valley Wabi	2.155	M	M	H	H	< 1	Nitrogen		Crops and pastures.	Urea, ammonium sulphate.	Yes		irrigation
	b	Fafen									Pastures and sorghum, maize	Ammonium sulphate, lime nitrate(after rainy season)	Yes		flood control
	14	Higher Valleys Fafen and Borale	710							P	P				
	15	Plateaus of Jijiga, Babile, Eik, etc...	6.339	H	H	M	H	< 1	Nitrogen	Extensive past, some sorghum	Important extension of sorghum	Urea, ammonium nitrate, ammonium sulphate and lime nitrate (end of rainy season)	Yes	Contour ploughing	
	16	Lege Hida	710	H	M	M	M		generally medium	P. and some sorghum	Considerable extension of sorghum	Urea, ammonium nitrate, ammonium sulphate and lime superphosphate.	Yes		
	17	North Sebre-Dollo [illegible] Hida, [illegible]a-Gudo	1.382	H	H	H-M	H-M		generally medium	Cultivated North of Sebre Dollo - Prevailing bush near Lege-Hida.	Considerable extension of crops (maize, wheat, sorghum)	Urea, ammonium nitrate, ammonium sulphate, lime superphosphate	Yes	Contour ploughing	wind - screen
	18	Adaba , North Bale,	3.000	H	H	H-M	H		Nitrogen	Crops	Intensive crop-growing	Urea, ammonium sulphate, ammonium nitrate, lime nitrate.	Yes	Contour ploughing	wind - screen

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Soil class (1)	N° (1)	Location (2)	Extent km²	FERTILITY (3) o.m.	N	Total P_2O_5	K	[illegible] P_2O_5	Factor limiting fertility (3)	Present utilisation (4)	Suggested utilisation (4)	Type of fertilizer used (5)	Mechanisation possibilities (6)	Anti-erosion installations or anti-erosion cultural practice (7)	Amelioration of the hydrological balance Hydro-agricultural installations (8)
	19	Kula, Adele, Kofele, Dodola	2.356	H	H	H	L	< 2	nitrogen potassium	extensive pastures	Intensification of pastures	Lime nitrate, urea, potassium chloride, eventually lime.			ind - screen
	20	Hirna - Kuni, Bedessa, Bedessa, Gelemaso	311	H						crops	Crops				
Andosols	21	Above 3200 m	880	H	H		H			none	Reserve				
Calcimagnesic soils	22 a & b	South Cherober - Harar	9.645	H	H	M	H	4,4	phosphorus	P. Crops in places especially 22 a.	P. Crops in places especially 22 a.	lime superphosphate		Contour bed-ploughing & Contour ploughing	
	23	Alluvial dep. of the Higher Valleys of Chercher	964	H	H	M	H	2,6	phosphorus	Crops	Crops	Lime superphosphate			
	24	Hills North of Gurgura	1.743							p.	p.				
	25 a & b	Limestone hills of Harar	555	H	H	H-M	M		nitrogen potash	p. (25b) Crops (25a)	Crops (25a)	Urea, ammonium nitrate, ammonium sulphate, potassium chloride			
	26	Wabi canyon	2.160	H	H	H				bush	Reforestation				
Soils with a calcareous differenciation & melanic horizon.	27	Fik, Degah - Medo, Segeg	1.431	M	L	H	M-H			p.	Reforestation around Fik, Degah-Medo - Segeg				
	28	Fik, Degah - Medo	340							p. M	p.				
	29	Caramera mounteins (Jijiga)	253	H	H	H	M			P.	P. Reforestation				
	30	Asa Osmane	75	M						Partly irrigated cultivation	Irrigated cultivation		Yes		Density irrigation
	31	Ginir-Wabi Shebelle - EL Kere	9.360	L	M	M	H	1,5	Nitrogen, phosphorus (31b)	p.	Sorghum, pastures (31b)	Ammonium sulphate, urea lime, superphosphate, (31b)	possible	Contour ploughing	
	32	South of Harar Oura	700	M	K	M	H	1	Nitrogen	p.	Sorghum	Ammonium sulphate	possible	Contour ploughing	
	33	Kebo Degahbur	.	M	M	H	H	> 2	Nitrogen	p.	Sorghum	Ammonium sulphate, urea.	Yes	Contour ploughing	
	34	Gedeb plain	983	H	H	M	H	3	Phosphorus Nitrogen	Crops	Crops	Lime superphosphate, urea, ammonium nitrate, ammonium sulphate.	Yes		Wind screen
	35	Jijiga Shakum Borale	1.852	M-H	M	H	M			P	P				
	36	East Gerer plateau	1.070	M	M	L	M			P.	p.				
	37	Degahbur-Kebribeyah	1.236	M	M	M	M			P.	P. Reserve				
Soils with a differenciation and pallid horizon	38 (a-b)	Shekosh-Kebri-Dahar(38a)	1.699	L						p.	p.				
		El Kere (38b)	300	L	L	L	L		Low fertility level	Sorghum (38b)	Sorghum (38b)	Ammonium nitrate, ammonium sulphate, lime superphosphate, potassium choride (38b)			Flood control (38b) and Contour network for erosion control.

TABLE 2 - LOCATION, EXTENSION AND MAIN CHARACTERISTICS OF THE SOILS OF THE WABI SHEBELLE AS REGARDS THEIR FERTILITY AND UTILIZATION

Soil class (1)	N° (1)	Location (2)	Extent km^2	FERTILITY (3) o.m.	N	Total P_2O_5	K	[illegible]	Factor limiting fertility (3)	Present utilization (4)	Suggested utilization (4)	Type of fertilizer used (5)	Mechanization possibilities (6)	Anti-erosion installations or anti-erosion cultural practice (7)	Amelioration of the hydrological balance Hydro-agricultural installations (8)
	39	Lower Ogaden	24.792	L	L	M	H			p.	p, Reserve				
	40	Imi region	970	L						p.	p, Reserve				
	41	Jerer alluvial deposits	370	L	L	M	H			p.	p.				
	42	Duhun	430	L	L	M	H	1	Nitrogen	Partly sorghum	Sor[illegible]	Ammonium nitrate Ammonium sulphate			[illegible] control
	43	Dobowein North Danan	800	L	L	M	M			p.	p, Reserve				
	44	Shilavo	5.450	L						p.	p, Reserve				
	45 (a-b)	Degahbour	2.700	L	L	M	M-H	2	Nitrogen	Sorghum	Sorghum	Ammonium nitrate Ammonium sulphate	Yes		Wind-screen
	46	Sese ene - Degahbur-Gelelcha	1.300	L	M	H	H			p.	p.				
	47	Sesebene - Degahbur - Gelelcha.	3.900	L	L	M				p.	p.				
Soils with a gypsum differenciation and pallid ho[illegible]	48	Duhun	1.700	L	L	M	H			P.	P.				
	49a	Alluvial deposits of Webi Shebelle	1.300	L	L	H	H	< 1	Nitrogen	p.	Crops	Urea, ammonium nitrate, ammonium sulphate	Yes		[illegible] wind screen
	b	Alluv. dep. of Fafen	560	L	L	H	H	<1		p.					
	50	Depressions of Lower Ogaden	700	L	L	H	H	<1	Nitrogen	Sorghum	Sorghum	Ammonium sulphate, lime nitrate	Possible		Flood control Contour network for the control of erosion.
	51	Alluvial deposits of Daketa, Sulul tributaries	915	L	L	H	H	< 1	Nitrogen	p.	Sorghum in	Ammonium sulphate			Diff. [illegible] flood control.
	52	Dobowein, North Danan	780	L	L				Nitrogen	P.	P. Sorghum	Ammonium sulphate			Contour network for the control of erosion.
	53	El Habed	642	L	L						p.				
	54	Lower Ogaden	23.400	L	L-M	H	H			p.	P. Reserve				
[illegible]	55 (a-b)	Chercher	2.824	H	H	M-H	H		Phosphorus	Crops espe	Crops : 55a [illegible]	Lime superphosphate		Contour beds	
	56	Kofele	[illegible].270	H	H	H	H	< 2	Nitrogen	Pastures	[illegible] of pastures	Lime nitrate, urea & eventually lime			Wind-screens
Persiallitic soils	57	Marar	1.470	M	M	M	M		Low fertility level	Crops	Crops	Urea, ammonium nitrate, lime nitrate, lime superphosphate, potassium chloride.	Yes, on slope less than 8 per cent.	Contour beds & Contour ploughing	
	58	Boke, Midegalola, Gebiba	1.100	H	H	M	H	> 5	Phosphorus	P. Crops	P. Crops	Lime superphosphate	Yes	Contour ploughing	
	59 (a-b)	Duhun - El K[illegible], North E st Gini & [illegible]	1.530	L	L	M	L-M	4	Low fertility level	P.	P. Crops : 59a, Forest : 59b.	Lime nitrate, ammonium nitrate, ammonium sulphate, urea lime. Superphosphate potassium chloride (59a).	Possible (59a)		

TABLE 2 - LOCATION, EXTENSION AND MAIN CHARACTERISTICS OF THE SOILS OF THE WABI SHEBELLE AS REGARDS [illegible] AND UTILIZATION

Soil class (1)	N° (1)	Location (2)	Extent km²	FERTILITY (3) o.m.	N	Total P_2O_5	K	N / 5	Factor limiting fertility (3)	Present utilization (4)	Suggested utilization (4)	Type of fertilizer used (5)	Mechanization possibilities (6)	Anti-erosion installations or anti-erosion cultural practice (7)	Amelioration of the hydrological balance Hydro-agricultural installations (8)
Ferral-litic soils	60	Harar	575	M	M	M	L-M		especially nitrogen	Crops	Crops	Lime nitrate, ammonium nitrate, ammonium sulphate, urea, and if possible lime superphosphate potassium chloride	Possible on slope less than 8 %	Contour beds Contour ploughing	
	61	Chercher, North Ginir	1.270	H	H	H	H		Nitrogen	Crops		Lime nitrate ammonium nitrate, urea.	Possible on slope less than 8 per cent (63a)	Contour beds and Contour ploughing	
	62	Shek Hussien mountain	140	H	H					Forest	"garden-forest" coniferous.				
	63 (a-b)	Debre Salam	1.770	L	L	L-M	H		Nitrogen phosphorus	Crops	Crops	Lime nitrate, ammonium nitrate, urea, lime super-phosphate.	Possible on slope less than 8 per cent (63a).	Contour beds and Contour ploughing	
	64 (a-b)	Ticho, South Adaba, Dodola	2.040	H	H	H	H		Nitrogen (64b)	Forest, crops, livestock (64a), livestock, crops (64b)	Forest, live-stock (64a), livestock (64b).	Lime nitrate, ammonium nitrate, urea.			
Hydro-morphic soils	65a	Alluvial deposits of Wabi Shebelle	100	H	H-M	H	H		Nitrogen	P. Some Sorghum and Maize	Irrigated	Ammonium nitrate, Ammonium sulphate.	Yes		Density irrigation
	b	Alluvial deposits of Fafen	50	H	H					[illegible]	Pastures and sorghum		eventually		Flooding
	66	Outskirts of Harar lake		H	H					P.	P.				
	67	Alluvial deposits of Wabi Shebelle Canyons	1.830	M-L	M-L	H	H		Nitrogen	Some Sorghum	Some Sorghum	Ammonium nitrate, Ammonium sulphate.			Flooding [illegible] in places.
	68	Shilavo								wells	Searching for water				
	69	Alluvial deposits of Errer, Daketa, Gobele.	438	M	L	H	M			P.	P.				
Sodic Soils	70	Ferfer	136	Sal[illegible]						P.	P.				

(1) See legend of map at 1/1.000.000 and Chapter V.
(2) See legend of map at 1/1.000.000 and Chapter V.
(3) See fertility scale, Chapter VI A.
(4) Also see Chapters V and VI.
(5) Also see Chapters V and VI A.
(6) Also see Chapters VI E.
(7) Also see Chapters VI B.
(8) Also see Chapters VI E and D.
*p : poor pastures during the rainy season.
*P : suitable pastures most of the year.

VII CONCLUSION

The Basin of the Wabi Shebelle covers 180 000 km^2 and its altitude varies from more than 3 500 m on the Western and North-Western mountains to less than 300 m in the South-Eastern end.

The variations of altitude related to an increasing rainfall from the South-East to the North West, led to delimit 6 climatic types : Ogadenian, Ethiopian, Fickian, Gedebian, Tichean, Boraluku which are linked to the usually described climatic groups of Peguy's grid.

The forest vegetation on mountains has actually completely disappeared on the High Plateaus owing to land-clearing. As altitude decreases and climate becomes drier, the vegetation presents the aspect of a thicket becoming gradually looser towards the South East. The geological substratum strongly affects the qualitative composition of the vegetation and all the more so in dry zones.

Most of the Basin consists of limestone gypsum or sandstone sedimentary layers. To the North, West and North West, mainly on the High Plateaus, volcanic formations are widely represented and in Harar the base is apparent.

Tectonic movements are weak and only marked by faults the most important of which are at present occupied by the Lower Valleys of the Wabi Shebelle and of the Fafen.

The differences of altitude, the climatic variations and the hydrostactic unbalance characterizing the drainage pattern between the upstream and downstream parts of the Basin allow distinguishing three large geomorphological units :

- The Northern and Western outskirts of the Basin consisting of mountains and of the High Plateaus where the relief is convex and scarcely cut by rivers.

- The Lower Ogaden zone presenting a concave relief with plateaus and glacis.

- These two large regions are linked together by a zone consisting of plateaus deeply cut by canyons which are the signs of the hydrostatic unbalance between the downstream part and the upstream part, of the Basin.

Owing to the different climates and bed-rocks, the soil forming-processes are numerous and varied :

The best represented soil-forming processes are vertisolisation, fersialisation and migration and accumulation of soluble salts. Other processes contribute to the formation of andosols or to the accumulation of organic matter.

The following clay minerals have been identified :

- illite which is observed in numerous calcareous soils as well as in ferrallitic and fersiallitic soils.

- montmorillonite which is abundant in all vertisols but also at the base of the profiles of ferrallitic and fersiallitic soils and of calcareous soils when drainage weakens.

- kaolinite which is not very abundant and is rather considered as a residual mineral (in particular material derived from sandstone).

The presence of amorphous material was observed in particular in the andosols of mountains and in a smaller proportion, in the chernozems of Arussi.

The content of organic matter progressively increases from the drier and warmer zones (with 1 per cent) to the more humid and cooler zones (with 8 per cent). On mountain tops it may amount to 20 per cent. Organic matter is always of a calcic type.

Accumulation of soluble salts and particularly of calcium carbonate is the main differenciationg factor of soils in Lower Ogaden and in the Middle Belt. The dynamics of limestone is represented in all its forms : dissolution in some soils, in others, accumulation at different phases : powdery accumulation, with masses and nodules, formation of crusts. This is also true for gypsum but different phases are only observed in the drier zones (Lower Ogaden).

Accumulation of sodium chloride is only distinctly observed in the dry areas of the South Eastern part of the Basin (Ferfer zone). However, soil is not alkalinized.

Accumulation of iron and alumina sesquioxides is seldom observed for two reasons :

- no generalized formation of hardpan occurred as in Central or West Africa.

- the redox conditions linked to a basic pH are not favourable to iron migration or accumulation.

A rubefaction of the profile may be observed in the wetter parts of the Basin but also in dry zones. However there is an exception : in the Kofele region, soil pH is slightly acid and is favourable for the formation of numerous iron and manganese concretions and in places, of a friable ironpan.

Gley and pseudo-gley formations are an exception.

All the soil classes are represented in the Basin except raw mineral soils and podzolized soils. The classification presented no difficulty except for the isohumic soil class which was modified in order to account for the influence of limestone and gypsum on the morphology of the profile. Weakly developed soils, vertisols, calcimagnesic soils and soils with a calcareous or gypseous differenciation constitute the five most extended soil-classes.

The agricultural, pastoral and forest possibilities in the Basin of the Wabi Shebelle are very important. They are closely linked to the climatic conditions and mainly depend on the altitude.

Agriculture is mostly concentrated between 2.500 m and 3.200 m for temperate crops and between 1.600 and 2.500 m for tropical crops.

- above 3.200 m, the cold temperature is a limiting factor.
- below 1.600 m, the dry climate is the unfavourable factor. In fact, two zones may be distinguished :
- between 1.000 and 1.600 m (Middle Belt) plants requiring little water may be cultivated in dry-farming on vast areas defined as cultivation extension-zones.
- between 200 m and 1.000 m (Lower Ogaden) cultivation is only possible:
- by irrigation in the Lower Valley of the Wabi Shebelle
- by Flooding in the Lower Valley of the Fafen.
- in small depressions where rain and runoff waters are collected.

Livestock-breeding is extensive in all the Basin. However, on the High Plateaus farmers keep their animals in good condition practically all year round. Conversely, in the South below 1.600 m, livestock wander seeking pastures and water-points and the condition of herds becomes precarious at the end of the dry season.

The forest has practically disappeared on the High-Plateaus owing to intensive land-clearing and only remains on steep mountain slopes.

Improvement of the agricultural, pastoral and forest potential is linked to the combination of the following four important factors :

- amelioration of soil-fertility ;
- erosion-control, soil-conservation ;
- amelioration of the hydrological balance of soils ;
- improvement of the cultural techniques (mechanization) ;
- utilization of more productive selected crop varieties.

As regards fertility, soils are generally very poor in nitrogen and well-supplied in phosphorus and potash. The nitrogen content should be increased by adding fertilizers and so should be the content of organic matter in the dry zones where it is soon mineralized (especially in the irrigated areas of the Lower Valley of the Wabi-Shebelle). In some cases, especially on the High Plateaus, the general fertility level is low and requires a complete mineral fertilization and sometimes acidity must be corrected (Kofele region).

. Water erosion is very active on the High Plateaus and in part of the Middle Belt and this is linked to the resumption of a generalized erosion process in relation to the hydrostatic unbalance of the drainage pattern between the High-Plateaus and Ogaden. This is a geographical type of erosion and consequently it is slow. But the equilibrium is precarious and at present an acceleration of erosion is observed and is due to the fact that forests disappear. This erosion forming gullies and lavakas (Harar)will be increased by mechanized cultivation.

Anti-erosion measures are now urging such as reforestation of mountains and for cultivation zones, control of runoff water (stabilization of gullies, contour ploughing, terraces).

. Wind-erosion is particularly considerable on all Lower-Ogaden and on the Middle Belt where it mainly affects soils with dominant sand or silt. It can be checked by placing wind-screens.

Amelioration of the hydrological balance of soils may be mostly considered as a consequence of actions carried out for soil conservation. These may be completed by placing wind-screens in some regions with a relatively dry and windy climate as on the High Plateaus (region of Dodola and Robi).

Mechanized cultivation is possible on large areas, for instance on the High Plateaus and on the Middle Belt. But if it is not carried out carefully it might soon lead to a disastrous erosion. This is then a double-edged arm but it may highly facilitate the generalization of anti-erosion measures.

Using selected crop-varieties producing a high yield is absolutely necessary in order to justify the general increase of the production potential of soils (agriculture and especially livestock breeding).

The Basin of the Wabi Shebelle also presents a very rich and varied fauna. We therefore suggest the creation of two national parks (Harar and Arussi) and three entirely protected reserves (Wabi Shebelle, Lower Fafen and Kebri Baya).

BIBLIOGRAPHY

AUBERT (G.), 1971, Les sols isohumiques in Encyclopedia Universalis, vol. IX, (interférences à Litszt), Paris, pp. 197-199.

AUBREVILLE (A.), 1949, Climats, forêts et désertification de l'Afrique Tropicale, Soc. Ed. Geog. Mar. Colon. Paris, p. 351.

BABIN (B.), 1964, Analyse physique et fertilité dans les sols des régions humides de Côte d'Ivoire, Cah. ORSTOM 1964, Pedol. I, pp. 29-40.

DAINELLI (G.), 1948, Carta Geological dell'Africa orientale, 1/2.000.000, Roma.

FIELDES (M.), PERROTT (K.W.), 1966, Rapid field and laboratory test for allophane, New-Zeal., J. Sci., 9, 3, pp. 623-629.

FURON (R.), 1960, Geologie de l'Afrique, Payot Ed. Paris, p. 400.

FURON (R.), COMBART (J.), 1964, Notice explicative de la Carte Géologique de l'Afrique (1/5.000.000), UNESCO-Asga, p. 39.

PEGUY (P.), 1961 - Précis de climatologie, Masson, Paris,

RUELLAN (A.), 1971, Les sols à profil calcaire différencié des plaines de la basse Moulouya (Maroc Oriental), Mém. ORSTOM n° 54, p. 302.

TERMIER (H. et G.), 1956, L'évolution de la lithosphère, Orogenèse I, Masson Ed. Paris, p. 498.

TECHNICAL APPENDIX ON THE WORKING METHODS OF THE SOIL-SCIENCE DIVISION

This appendix includes the following divisions :

1. Survey in the field
2. Photographic interpretation
3. Laboratory analysis
4. Soil map and legend
5. Reports.

1. Survey on the field

1.1. Working methods

1.1.1. Survey scales

The survey is more or less detailed as a function of the scale of map.

For the map at 1/50 000 of the Lower Valley of the Wabi Shebelle, transections approximately 10 km apart and with directions indicated after examining aerial views were systematically surveyed and a soil profile (pit) was made every kilometer. Besides, in the Gode zone bore holes were made perpendicularly to transections every 1 300 m.

For the map at 1/60 000 of the Fafen Valley, traverses were placed as function of the types of vegetative cover linked to the flooding intensity. Consequently, pits were dug and examined in zones where noticeable differences appeared in the vegetation.

For the map at 1/250 000 of the entire Basin, observations were carried out on the one hand along the tracks, and on the other hand in zones selected after studying the aerial views, in the form of soil-chains or sequences. Owing to the quality of photographies and to the homogenousness of geomorphological units, it seems that all the main types of soils have been studied despite the difficulties of access and the large areas to be mapped.

Together with the soil-survey, the geological survey which was lacking for most of the Basin was also carried out.

1.1.2 Soil sampling :

Once the soil profile described and the various horizons determined, approximately 800 g of soil samples were taken in each "complete" horizons. Thus samples of a continued profile were obtained.

1.2. Results of survey

9 000 km transections and tracks surveyed
1 502 pits dug (250 drilled) and observed.
4 157 soil samples taken

This work was distributed as follows :

- Lower Valley of the Wabi Shebelle :

  . transections : 1 600 km
  . pits : 800 (245 drilled)
  . Soil samples : 2 700

- Fafen Valley :

  . transections : 1 500 km
  . pits : 102
  . soil samples : 357

- Bassin of the Wabi Shebelle for the map at 1/250 000 :

  . transections and tracks : 6 000 km
  . pits : 355 (5 test holes)
  . soil samples : 1 200

2. Photographic interpretation

The interpretation of aerial photographs was either made on coupled photographs or on mosaics established at the "Water Resources Department". This represented a considerable amount of work considering the extent of the areas to be interpreted.

Approximately 4 000 photographs (scale varying from 1/50 000 to 1/60 000) were examined in this way.

The sharpness of photographs as well as the sparse aspect of the vegetation allow to believe that the extension of field observations to zones presenting the same aspect on photographs, give the interpretation the highest degree of probability. This is true for all the scales of maps, for instance :

Delimiting soil-types for the map at 1/50 000 in the Valley of the Wabi Shebelle is made far easier because of the correlation between the vegetative cover (colour of photograph) and the type of soil on which it grows. Hence :

  . light zones : sandy soils
  . grey zones : vertisols and clay soils
  . dark zones : organic soils.

The extrapolation of the limits of soils between the transections observed is consequently relatively easy and accurate enough.

- The delimitation of the main types of soils for the map at 1/250 000 as well as of the parent-rocks and original material (both being closely related in an arid environment) is also often facilitated by the aspect of the vegetation or by other characteristics. Thus, the relation between the aspect of the vegetation and soils may be observed as follows :

- vegetation with a loose striped pattern : red soils with a calcareous slab.
- vegetation with a fine striped pattern : whitish-yellow soils with a gypsum slab...
- uniform and fine dappled vegetation : bright red soils on sandstone.
- uniform and coarse dappled vegetation : calcareous vertisols on limestone.
- zebra-striped vegetation indicating discontinued deposits of wind-blown and shallow sand.
- dense, dark vegetation in easily flooded basins etc ...

Another particularly original aspect is the "cockade" morphology with regular fine "pricks" corresponding to termitaries. One may also mention the "caterpillar" shape of basalt hills scattered on the sedimentary formations of Ogaden.

This list is not exhaustive and only gives a few examples of the close relations which may exist between the nature of soil and the aspect of the vegetation and between the morphology and the parent-rock in an arid environment.

3. Laboratory analyses

3.1. Methods of soil-analysis

All the analyses which might be used in order to know the suitabilities of soils for dry-farming or irrigated cultivation and to determine their characteristics for their classification, have been made, namely :

Physical analysis

- soil moisture.
- refuse percentage.
- extraction of clay for ATD and X rays.
- field capacity of soils by pH measurement with pressure membrane apparatus (wilting point and equivalent moisture).

They are all described in : "Methods of Analyses used in Soil Laboratory" by J.O. Job, Wabi Shebelle project -Water Resources Commission Addis Abeba.

- saturated paste for the measurement of electrical conductivity.
- calcium carbonate (methode of Bernard Calcimeter)
- electrical conductivity and pH

Chemical analysis :

- organic carbon
- nitrogen
- exchangeable bases with soils containing CO_3 Ca, without CO_3 Ca

  Ca^{++} + Mg^{++} by complexometry
  Na^{+} and K^{+}: flame photometry

- Exchangeable capacity
- total phosphorus
- soluble salts in soils and in :

  sulphate water by complexometry
  chloride water by the Volhard method.

Besides, the following analyses were carried out in the field on soils for irrigation.

- soil permeability by the double cylinder method.
- apparent specific density by the method of cylinder sampling.

3.2. Selection of analysed profiles

439 profiles are analysed. They are included either in soil chains or sequences and this for the mapping at all the different scales, or in cartographical units for the mapping at 1/50 000 and at 1/60 000. In the last case, the analysis of several profiles for a same type of soil enables studying more closely the mean characteristics of the unit.

4. Cartography

3 types of maps are drafted :

- the maps at 1/50 000 and 1/60 000 though they are semi-detailed, may be considered as complete enough as regards soil survey to be used in the elaboration of a preliminary irrigation plan.
- a map at 1/250.000 delimiting the eventual zones for a regional development project.

- a map at 1/1.000.000 which is a general synthesis of the pedological data on the basin.

4.1. Map at 1/50.000 of the Lower Valley of the Wabi Shebelle 11 sheets.

This map was terminated in July 1970 and corresponds to a total area of 1,3 million hectares between Imi and Ferfer and 410 km long (along the river) by 30 km wide.

It consists of 11 sheets and is presented with two types of legends :

- a pedological legend classifying soils according to their origin and type of evolution.

- a legend concerning the fitness of soils for irrigation and the areas covered by each category.

382.000 ha (9.500 gashas) are found suitable for irrigation with two main soil-classes :

<u>Class I</u> : Very suitable soils for irrigation : approximately 280.000 ha

<u>Class II</u>: Scarcely suitable soils for irrigation : approximately 100.000 ha

Depending on the nature of soils, sub-classes with different cultural aptitudes are determined. Each sub-class is allocated symbols indicating the modification of soil quality required to prepare the soil for irrigation (necessity of drainage on a small or large scale, weak or excessive salinity, topography,microrelief, etc...).

4.2. <u>Map at 1/60.000 of the Valley of the Fafen</u> : 6 sheets

This soil map besides representing various types of soils also indicates the extent of easily flooded zones and the intensity and nature of floods (originating from the Fafen or from its tributaries). These data allow knowing the duration of grazing as well as crop-growing possibilities.

4.3. <u>Map at 1/250.000 of the entire Basin of the Wabi Shebelle</u> : 16 sheets

This map represents the entire Basin, i.e. : 180.000 km2 or 1/6 of the Empire.

4.3.1. Mapping method

The different types of soils, the suitable zones for mechanized dry-farming and the extension zones were delimited directly on aerial views at 1/50.000, either through stereoscopic vision or on mosaic. The reduction to 1/250.000 was then made by projection. This considerable work (an area of 7.200 km2) presents the advantage of obtaining accurate cartographical limits but also of making available for eventual local development schemes, original maps at 1/50.000 of the entire Basin.

4.3.2. Utilization of the map at 1/250.000

From a pedological point of view this map is very interesting since it is the first document of this type achieved in Ethiopia. Furthermore it represents zones where considerable variations of altitude, and consequently of climate, contribute to the surprising variety of soil-forming processes.

As to its practical use, this map provides an accurate knowledge of :

- The dry farming zones of arid Ogaden, as well as the suitable areas of long grazing periods.

- The crop extension zones in the Middle Belt,

- the possible zones for mechanized cultivation on the High Plateaus (Arussi, Chercher, Harar),

- all the essential data on the fertility of soils.

4.4. Soil map at 1/1.000.000 of the Basin of the Wabi Shebelle

It was drafted from a reduction of the map at 1/250.000 with simplified limits and regrouping of certain soil types.

This synthetical map has both the advantages of being a convenient size and of summarizing all the pedological knowledge acquired on the Basin of the Wabi Shebelle as well as its implications as regards agricultural development.

4.5. Soil legends

- For the maps at 1/50.000 of the Valley of the Wabi Shebelle and at 1/60.000 of the Valley of Fafen, specific soil legends are established as far as soil-phases.

- for the maps at 1/250.000 and 1/1.000.000, a single soil legend exists as far as soil families. For the map at 1/1.000.000 a certain number of soil families are regrouped and may only be found separately mapped at 1/250.000.

- For the map at 1/250.000, a legend of soil utilization (mechanization possibilities, crop extension zones, irrigation areas) is given as well as the pedological legend.

5. Reports

The following reports are available :

- a general report on the types of soils and their utilization in the Basin of the Wabi Shebelle describing the morphological and physico-chemical characteristics as well as the fitness of all these soils for crop-growing, pastures or forests. It is completed with a pedological map at 1/1.000.000.

- a report describing the soils of the Lower Valley of the Wabi Shebelle and their utilization is completed by the map at 1/50.000 of the same region.

- a report accompanying the map at 1/60.000 of the Lower Valley of the Fafen.

- Scientific notes are also forthcoming.

Plate I - ARUSSI-CHERCHER

GEDEB plain (ARUSSI) ; in the background Mount ENKOLO

Canyons on the Eastern border of the basalt plateaus ; SERU region (ARUSSI)

Plate II - ARUSSI-CHERCHER (continued)

A valley on basalt high plateaus : Region of INDETU (ARUSSI)

Ploughing in CHERCHER (KURFACHELE region) ; brunified soils on basalt

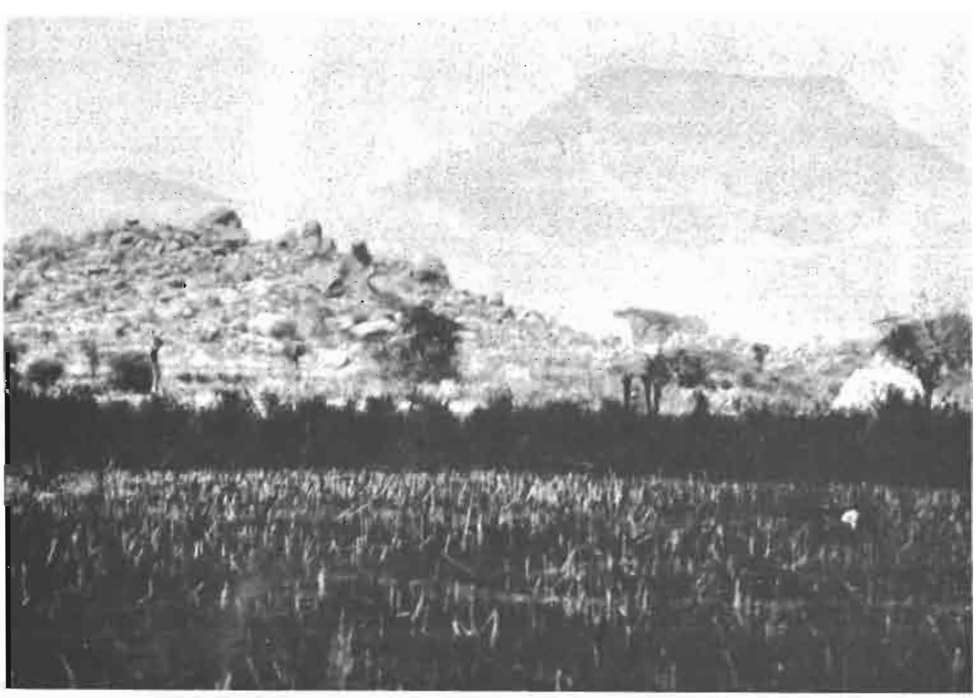
Plate III - HARAR

HADOW plateau (HARAR - JIJIGA track)

Granite chaos of BABILE

Plate IV - HARAR (continued)

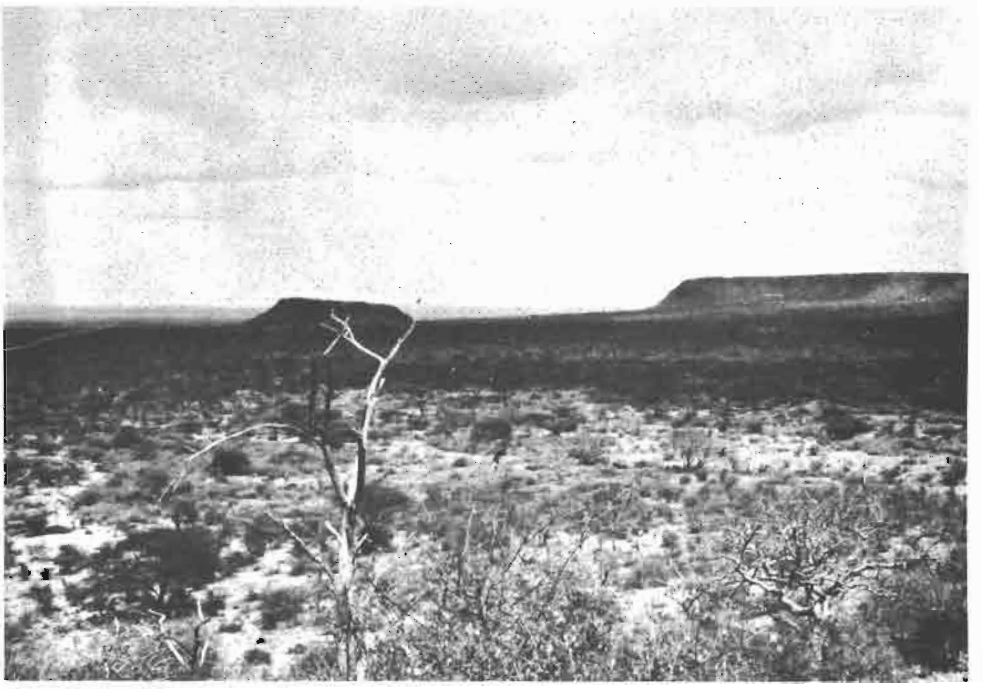
Crops (maize and groundnuts on fersiallitic soil (BABILE region)
granite chaos in the background



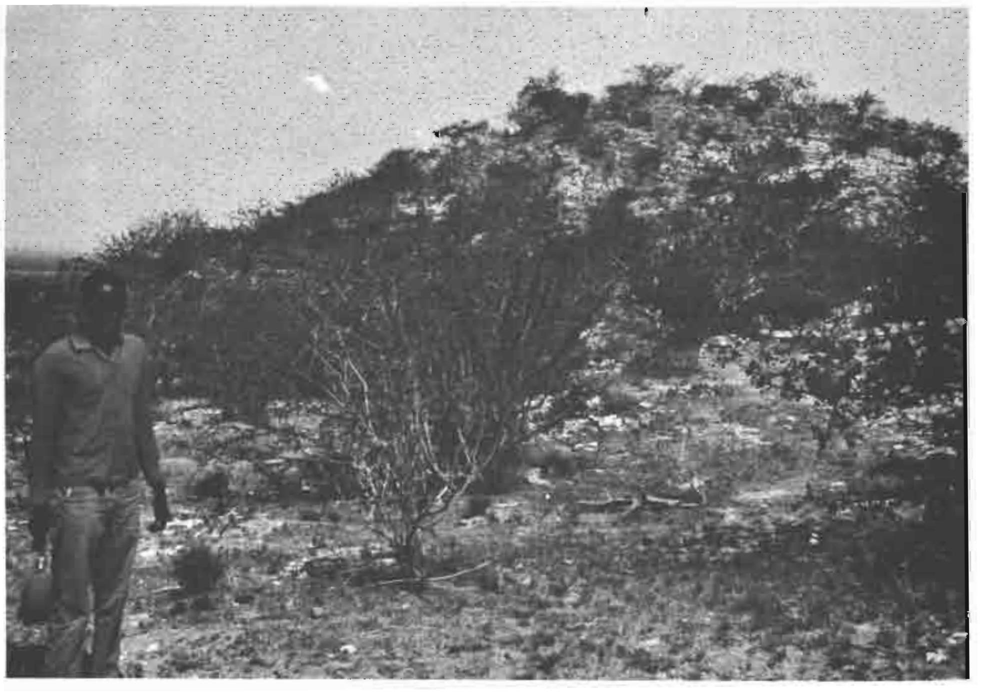
BABILE region

in the foreground : sorghum on fersiallitic soil
in the middle : granite chaos
in the background : limestone plateau of KONDUDO

Plate V - LOWER OGADEN



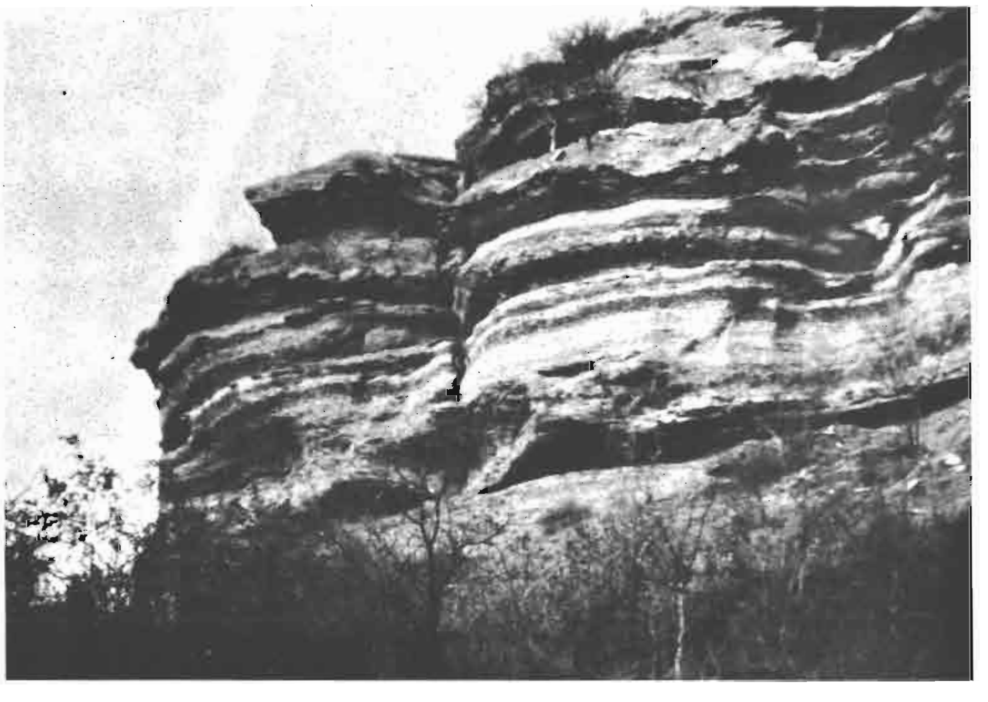
Gypsum outcrops on colluvial deposits.
In the background, tabular plateaus and limestone remnants (MUSTAHIL limestone) - (GODE-KELAFO region)



Gypsum hill (main gypsum formation) with a «cockade» aspect (GODE region)

Plate VI - LOWER OGADEN (continued)

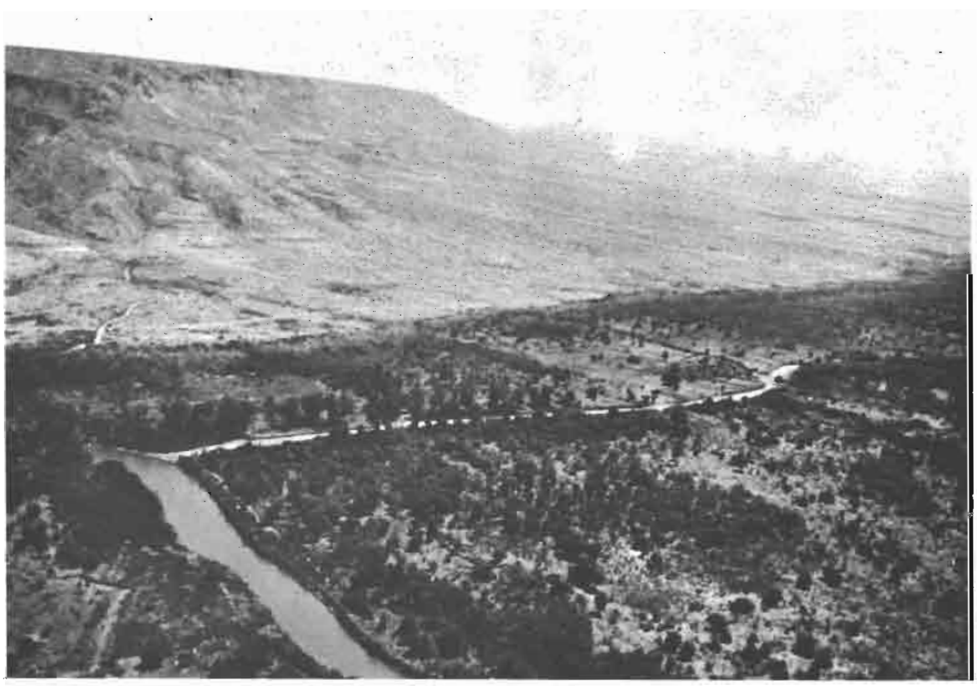
Limestone remnant (MUSTAHIL limestone)
Note the concave slope and the erosion scarifications.
(GODE region)



Gypsum bluff (main gypsum formation)
(South of KUGNO)

Plate VII - LOWER OGADEN (continued)

Bluff of GESOMA sandstone (EL KERE region)



The WABI near KELAFO - Note the distinct contact between the alluvia deposits of the river and those of the temporary rivers.

Plate VIII - LOWER OGADEN (continued)

Tiger bush pattern (KEBRI DAHAR region)

Plate IX - Vertisols

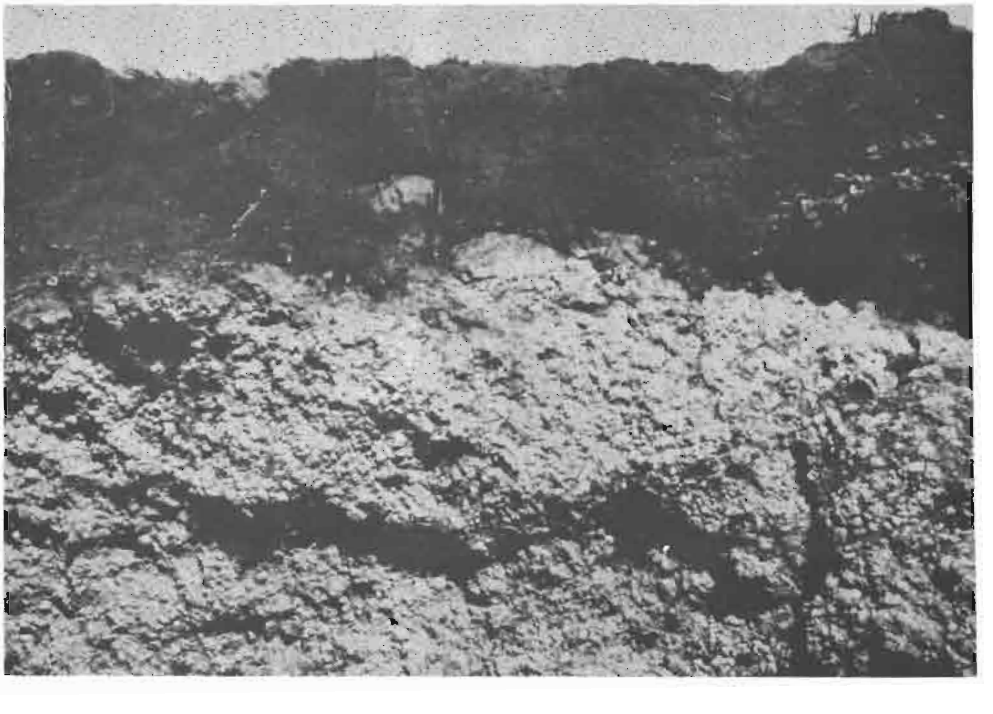
Carbonated grumosolic vertisol
(Lower Valley of the WABI SHEBELLE)
Note the accumulation of gypsum
crystals in the depth.

Calcic grumosolic vertisol
(High plateaus of ARUSSI)

Plate X - Soils with a calcareous accumulation
- with a melanic horizon -

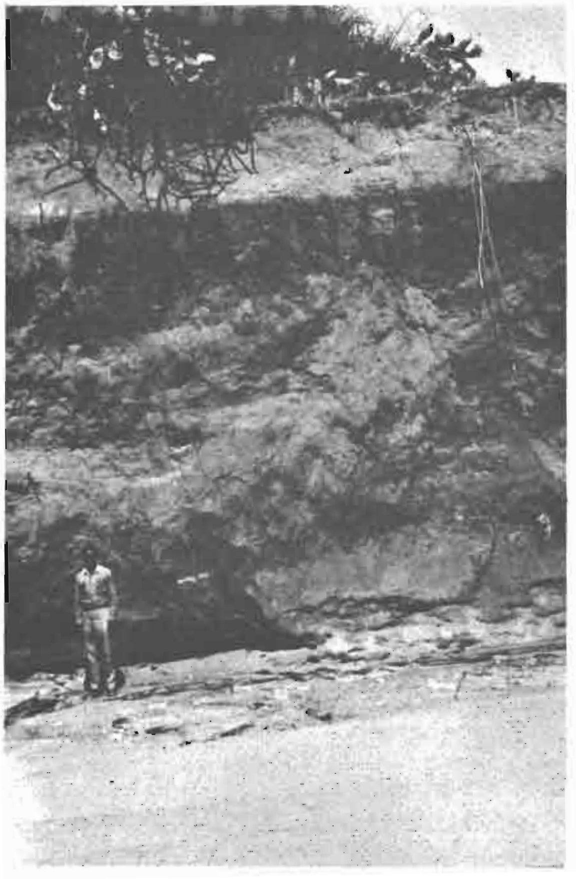
Soil with a nodular crust (JIJIGA)
from top to bottom :

- melanic horizon
- nodular crust
- weathering material



Details of nodular crust

Plate XI - Soils with a calcareous accumulation (continued)
- with a pallid horizon -



Soil with diffuse lime on alluvial deposits
(EL KERE region)

Calcic soil with lime masses and nodules
on sandstone colluvial deposits
(DEGAHBOUR Basin)

Calcareous soil with lime masses and nodules
on limestone plateaus of LOWER OGADEN

Plate XII - Erosion

Gully erosion on vertisols (ADABA region)
- Note the important lime concretions at the base of soils

«Lavaka» erosion on fersiallitic soils
(HARAR region)

የኢትዮጵያ ንጉሠ ነገሥት መንግሥት
ብሔራዊ የውሃ ሀብት ልማት ኮሚሽን መሥሪያ ቤት

IMPERIAL ETHIOPIAN GOVERNMENT

NATIONAL WATER RESOURCES COMMISSION

ETHIOPIA - FRANCE COOPERATIVE PROGRAM

WABI SHEBELLE SURVEY

IN COLLABORATION WITH

FRENCH MINISTRY OF FOREIGN AFFAIRS — NATIONAL WATER RESOURCES COMMISSION — BCEOM_ORSTOM_EDF IGN_BDPA

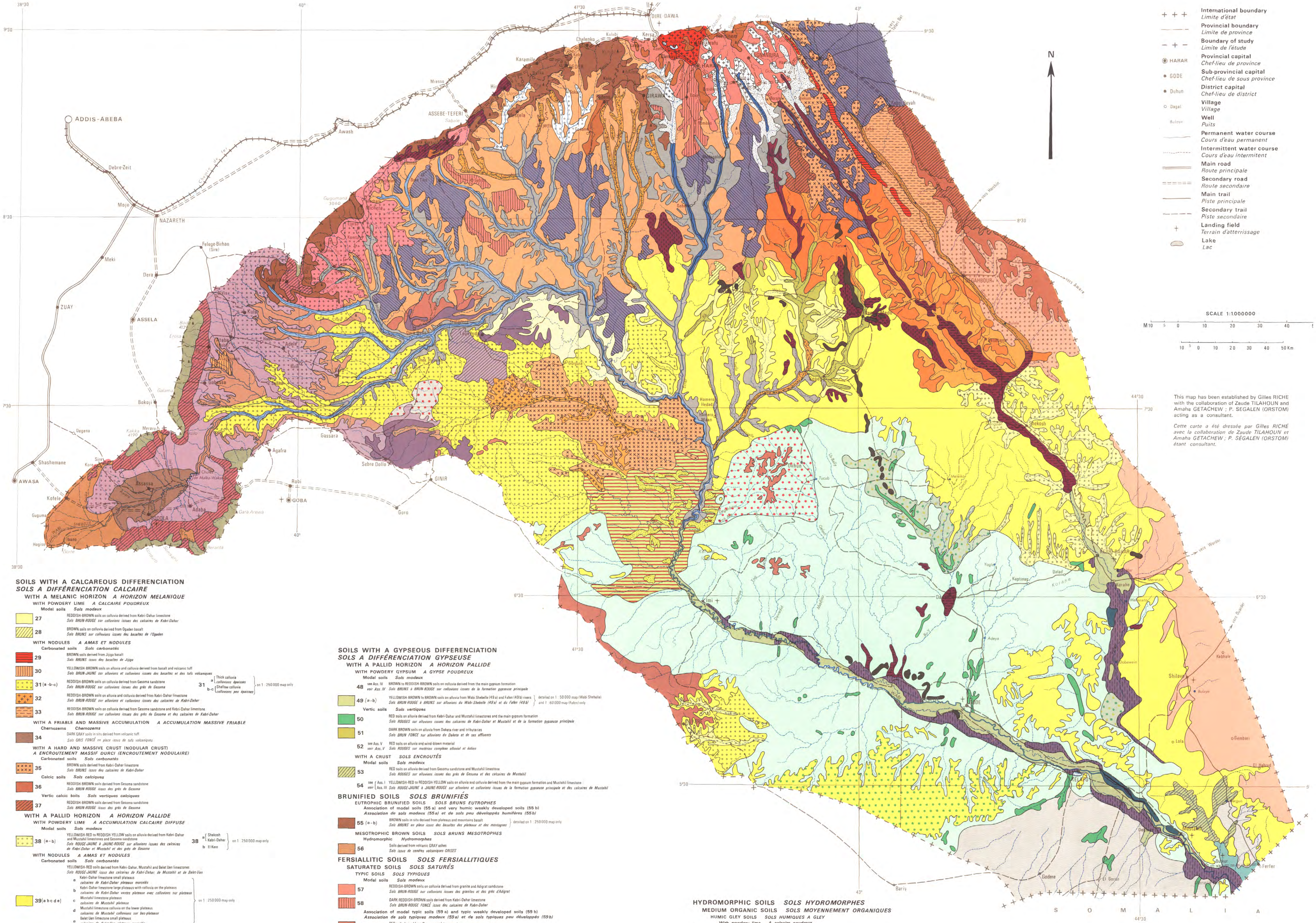
V

SOILS MAP - CARTE DES SOLS

Wabi Shebelle Basin

OCTOBER 1973

ORSTOM



LEGEND OF THE SOILS MAP
LEGENDE DE LA CARTE DES SOLS

WEAKLY DEVELOPED SOILS *SOLS PEU EVOLUÉS*

XEROSOLS *SOLS XÉRIQUES*

GRAY SOILS *SOLS GRIS*

Gypseous soils *Sols gypseux*

1 (a-b) GRAY soils derived from the main gypsum formation
Sols GRIS issus de la formation gypseuse principale

NON CLIMATIC SOILS *SOLS D'ORIGINE NON CLIMATIQUE*

ERODED SOILS *SOLS D'EROSION*

Lithic soils with powdery lime *Sols lithiques à calcaire poudreux*

2 YELLOWISH-RED soils derived from Kebri-Dahar limestone
Sols ROUGE-JAUNE issus des calcaires de Kebri-Dahar

3 see Ass. I / *voir Ass I* — Soils with superficial gypsum flag derived from the main gypsum formation
Sols sur dalle de gypse peu profonde issue de la formation gypseuse principale

4 see Ass. II / *voir Ass II* — Soils with superficial gypsum flag derived from Ferfer gypsum
Sols sur dalle de gypse peu profonde issue des gypses de Ferfer

5 BROWNISH-GRAY soils derived from Ogaden basalt
Sols GRIS-BRUN issus des basaltes de l'Ogaden

Lithic calcic soils *Sols lithiques calciques*

6 LIGHT GRAY soils derived from granite boulders
Sols GRIS CLAIR issus des chaos granitiques

7 RED soils derived from Adigrat sandstone
Sols ROUGES issus des grès d'Adigrat

Humic soils *Sols humifères*

8 on 1/250 000 map only — REDDISH-BROWN soils derived from basaltic ash and basalt
Sols BRUN-ROUGE issus de scories basaltiques et de basaltes

9 see Ass. VI / *voir Ass VI* — BROWN soils derived from Gesoma sandstone and plateau basalt
Sols BRUN issus des grès de Gesoma et des basaltes de plateaux

SOILS DEVELOPED ON COLLUVIA *SOLS D'APPORT COLLUVIAL*

With calcareous flecks *A mouchetures calcaires*

10 (a-b) YELLOWISH-BROWN soils on colluvia derived from granites
Sols BRUN-JAUNE sur colluvions issues de granites
10 a Shallow colluvia / *colluvions peu épaisses*; b Thick colluvia / *colluvions épaisses* — on 1 : 250 000 map only

VERTISOLS *VERTISOLS*

GRUMOSOLS

VERTISOLS GRUMOSOLIQUES A DRAINAGE EXTERNE REDUIT

CARBONATED VERTISOLS *VERTISOLS CARBONATÉS*

With powdery lime and powdery gypsum *A calcaire poudreux et cristaux de gypse*

11 BROWN soils on alluvia and colluvia derived from Ogaden basalt
Sols BRUNS sur alluvions et colluvions des basaltes de l'Ogaden

12 REDDISH-BROWN soils on alluvia derived from Kebri-Dahar and Mustahil limestones and from the main gypsum formation
Sols BRUN ROUGE sur alluvions issues des calcaires de Kebri-Dahar et Mustahil et de la formation gypseuse principale

13 (a-b) BROWN soils on alluvia from the Wabi Shebelle (13 a) and Fafen (13 b) rivers
Sols BRUNS sur alluvions du Wabi Shebelle (13 a) et du Fafen (13 b) — detailed on 1 : 50 000 map (Wabi Shebellé), and 1 : 60 000 map (Fafen) only

14 BROWN soils on alluvia from the Borale and the Fafen rivers
Sols BRUNS sur alluvions du Borale et du Fafen

With calcareous nodules *A amas et nodules calcaires*

15 BROWN soils on colluvia derived from Kebri-Dahar limestone
Sols BRUNS sur colluvions issues des calcaires de Kebri-Dahar

CALCIC GRUMOSOLS *VERTISOLS CALCIQUES*

With nodules in the depth *A nodules en profondeur*

16 REDDISH-BROWN soils on colluvia derived from basalt of the plateaus and Gesoma sandstone
Sols BRUN-ROUGE sur colluvions issues des basaltes des plateaux et des grès de Gesoma

17 REDDISH-BROWN soils derived from plateaus basalt
Sols BRUN-ROUGE issus des basaltes des plateaux

18 DARK GRAY soils derived from plateaus basalt
Sols GRIS FONCÉ issus des basaltes des plateaux

19 DARK GRAY soils derived from plateaus basalt with a volcanic ash layer on the surface
Sols GRIS FONCÉ en place issus des basaltes des plateaux avec recouvrement cendreux

20 BLACKY-GRAY soils on alluvia derived from Kebri-Dahar limestone
Sols GRIS-NOIR sur alluvions issus des calcaires de Kebri-Dahar

ANDOSOLS *ANDOSOLS*

DIFFERENCIATED SOILS *SOLS DIFFÉRENCIÉS*

SATURATED SOILS *SOLS SATURES*

With a melanic horizon *Melaniques*

21 GRAY soils derived from mountain' basalt
Sols GRIS issus des basaltes des montagnes

CALCIMAGNESIC SOILS *SOLS CALCIMAGNÉSIQUES*

CARBONATED SOILS *SOLS CARBONATÉS*

ASSOCIATION OF MODAL BROWN CALCAREOUS SOILS (22 a) AND MODAL RENDZINA (22 b)
ASSOCIATION DE SOLS BRUNS CALCAIRES MODAUX (22 a) ET DE RENDZINES MODALES (22 b)

22 (a-b) BROWN soils derived from Kebri-Dahar limestone
Sols BRUNS issus des calcaires de Kebri-Dahar — detailed on 1 : 250 000 map only

BROWN CALCAREOUS SOILS *SOLS BRUNS CALCAIRES*

Modal soils *Sols modaux*

23 BROWN soils on alluvia derived from Kebri-Dahar limestone
Sols BRUNS sur alluvions issues des calcaires de Kebri-Dahar

RENDZINA *RENDZINES*

Modal rendzina *Rendzines modales*

24 BROWN soils derived from Kebri-Dahar limestone
Sols BRUNS issus des calcaires de Kebri-Dahar

SATURATED SOILS *SOLS SATURÉS*

ASSOCIATION OF MODAL BROWN CALCIC SOILS (25 a) AND MODAL CALCIC RENDZINA (25 b)
ASSOCIATION DE SOLS BRUNS CALCIQUES MODAUX (25 a) ET DE RENDZINES CALCIQUES (25 b)

25 (a-b) BROWN soils derived from Kebri-Dahar limestone
Sols BRUNS issus des calcaires de Kebri-Dahar — detailed on 1 : 250 000 map only

CALCIC RENDZINA *RENDZINES CALCIQUES*

Modal rendzina *Rendzines modales*

26 BROWN soils derived from plateaus basalt and volcanic tuff.
Sols BRUNS issus des basaltes de plateaux et de tufs volcaniques

SOILS WITH A CALCAREOUS DIFFERENCIATION
SOLS A DIFFÉRENCIATION CALCAIRE

WITH A MELANIC HORIZON *A HORIZON MELANIQUE*

WITH POWDERY LIME *A CALCAIRE POUDREUX*

Modal soils *Sols modaux*

27 REDDISH-BROWN soils on colluvia derived from Kebri-Dahar limestone
Sols BRUN-ROUGE sur colluvions issues des calcaires de Kebri-Dahar

28 BROWN soils on colluvia derived from Ogaden basalt
Sols BRUNS sur colluvions issues des basaltes de l'Ogaden

WITH NODULES *A AMAS ET NODULES*

Carbonated soils *Sols carbonatés*

29 BROWN soils derived from Jijiga basalt
Sols BRUNS issus des basaltes de Jijiga

30 YELLOWISH-BROWN soils on alluvia and colluvia derived from basalt and volcanic tuff
Sols BRUN-JAUNE sur alluvions et colluvions issues des basaltes et des tufs volcaniques

31 (a-b-c) REDDISH-BROWN soils on colluvia derived from Gesoma sandstone
Sols BRUN-ROUGE sur colluvions issues des grès de Gesoma
31 a Thick colluvia / *colluvions épaisses*; b-c Shallow colluvia / *colluvions peu épaisses* — on 1 : 250 000 map only

32 REDDISH-BROWN soils on alluvia and colluvia derived from Kebri-Dahar limestone
Sols BRUN-ROUGE sur alluvions et colluvions issues des calcaires de Kebri-Dahar

33 REDDISH-BROWN soils on colluvia derived from Gesoma sandstone and Kebri-Dahar limestone
Sols BRUN-ROUGE sur colluvions issues des grès de Gesoma et des calcaires de Kebri-Dahar

WITH A FRIABLE AND MASSIVE ACCUMULATION *A ACCUMULATION MASSIVE FRIABLE*

Chernozems *Chernozems*

34 DARK GRAY soils in situ derived from volcanic tuff.
Sols GRIS FONCÉ en place issus de tufs volcaniques

WITH A HARD AND MASSIVE CRUST (NODULAR CRUST)
A ENCROUTEMENT MASSIF DURCI (ENCROUTEMENT NODULAIRE)

Carbonated soils *Sols carbonatés*

35 BROWN soils derived from Kebri-Dahar limestone
Sols BRUNS issus des calcaires de Kebri-Dahar

Calcic soils *Sols calciques*

36 REDDISH-BROWN soils derived from Gesoma sandstone
Sols BRUN-ROUGE issus des grès de Gesoma

Vertic calcic soils *Sols vertiques calciques*

37 REDDISH-BROWN soils derived from Gesoma sandstone
Sols BRUN-ROUGE issus des grès de Gesoma

WITH A PALLID HORIZON *A HORIZON PALLIDE*

WITH POWDERY LIME *A ACCUMULATION CALCAIRE DIFFUSE*

Modal soils *Sols modaux*

38 (a-b) YELLOWISH-RED to REDDISH-YELLOW soils on alluvia derived from Kebri-Dahar and Mustahil limestones and Gesoma sandstone
Sols ROUGE-JAUNE à JAUNE-ROUGE sur alluvions issues des calcaires de Kebri-Dahar et Mustahil et des grès de Gesoma
38 a Shekosh, Kebri-Dahar; b El Kere — on 1 : 250 000 map only

WITH NODULES *A AMAS ET NODULES*

Carbonated soils *Sols carbonatés*

39 (a b c d e) YELLOWISH-RED soils derived from Kebri-Dahar, Mustahil and Belet Uen limestones
Sols ROUGE-JAUNE issus des calcaires de Kebri-Dahar, de Mustahil et de Belet-Uen
- a Kebri-Dahar limestone small plateaus / *calcaires de Kebri-Dahar plateaux morcelés*
- b Kebri-Dahar limestone large plateaus with colluvia on the plateaus / *calcaires de Kebri-Dahar vastes plateaux avec colluvions sur plateaux*
- c Mustahil limestone plateaus / *calcaires de Mustahil plateaux*
- d Mustahil limestone colluvia on the lower plateaus / *calcaires de Mustahil colluvions sur bas-plateaux*
- e Belet Uen limestone small plateaus / *calcaires de Belet-Uen plateaux morcelés*

on 1 : 250 000 map only

40 see Ass. III / *voir Ass. III* — RED soils in situ derived from zoogen sandstone
Sols ROUGES en place issus de grès zoogènes

41 REDDISH-BROWN soils on alluvia from Jerer river
Sols BRUN-ROUGE sur alluvions du Jerer

42 see Ass. IV / *voir Ass. IV* — YELLOWISH-RED soils on alluvia derived from Gesoma sandstone
Sols ROUGE-JAUNE sur alluvions issues des grès de Gesoma

43 see Ass. V / *voir Ass. V* — RED soils on alluvia and wind-blown material
Sols ROUGES sur matériau complexe alluvial et éolien

Calcic soils *Sols calciques*

44 RED soils derived from Gesoma sandstone
Sols ROUGES issus des grès de Gesome

45 (a-b) RED soils on alluvia (45 b) and colluvia (45 a) derived from Gesoma sandstone
Sols ROUGES sur alluvions (45 b) et colluvions (45 a) issus des grès de Gesoma — detailed on 1 : 250 000 map only

Vertic carbonated soils *Sols vertiques carbonatés*

46 REDDISH-BROWN soils on colluvia derived from Kebri-Dahar limestone
Sols BRUN-ROUGE sur colluvions issues des calcaires de Kebri-Dahar

WITH A HARD AND MASSIVE CRUST (NODULAR CRUST)
A ENCROUTEMENT MASSIF DURCI (ENCROUTEMENT NODULAIRE)

Carbonated soils *Sols carbonatés*

47 LIGHT-BROWN soils derived from Kebri-Dahar limestone
Sols BRUN-CLAIR issus des calcaires de Kebri-Dahar

SOILS WITH A GYPSEOUS DIFFERENCIATION
SOLS A DIFFÉRENCIATION GYPSEUSE

WITH A PALLID HORIZON *A HORIZON PALLIDE*

WITH POWDERY GYPSUM *A GYPSE POUDREUX*

Modal soils *Sols modaux*

48 see Ass. IV / *voir Ass. IV* — BROWN to REDDISH-BROWN soils on colluvia derived from the main gypsum formation
Sols BRUNS à BRUN-ROUGE sur colluvions issues de la formation gypseuse principale

49 (a-b) YELLOWISH-BROWN to BROWN soils on alluvia from Wabi Shebelle (49 a) and Fafen (49 b) rivers
Sols BRUN-ROUGE à BRUNS sur alluvions du Wabi-Shebelle (49 a) et du Fafen (49 b) — detailed on 1 : 50 000 map (Wabi Shebelle) and 1 : 60 000 map (Fafen) only

Vertic soils *Sols vertiques*

50 RED soils on alluvia derived from Kebri-Dahar and Mustahil limestones and the main gypsum formation
Sols ROUGES sur alluvions issues des calcaires de Kebri-Dahar et Mustahil et de la formation gypseuse principale

51 DARK BROWN soils on alluvia from Daketa river and tributaries
Sols BRUN FONCE sur alluvions du Daketa et de ses affluents

52 see Ass. V / *voir Ass. V* — RED soils on alluvia and wind-blown material
Sols ROUGES sur matériau complexe alluvial et éolien

WITH A CRUST *SOLS ENCROUTÉS*

Modal soils *Sols modaux*

53 RED soils on alluvia derived from Gesoma sandstone and Mustahil limestone
Sols ROUGES sur alluvions issues des grès de Gesoma et des calcaires de Mustahil

54 see Ass. I, Ass. III / *voir* — YELLOWISH-RED to REDDISH-YELLOW soils on alluvia and colluvia derived from the main gypsum formation and Mustahil limestone
Sols ROUGE-JAUNE à JAUNE-ROUGE sur alluvions et colluvions issues de la formation gypseuse principale et des calcaires de Mustahil

BRUNIFIED SOILS *SOLS BRUNIFIÉS*

EUTROPHIC BRUNIFIED SOILS *SOLS BRUNS EUTROPHES*

Association of modal soils (55 a) and very humic weakly developed soils (55 b)
Association de sols modaux (55 a) et de sols peu développés humifères (55 b)

55 (a-b) BROWN soils in situ derived from plateaus and mountains basalt
Sols BRUNS en place issus des basaltes des plateaux et des montagnes — detailed on 1 : 250 000 map only

MESOTROPHIC BROWN SOILS *SOLS BRUNS MESOTROPHES*

Hydromorphic *Hydromorphes*

56 Soils derived from volcanic GRAY ashes
Sols issus de cendres volcaniques GRISES

FERSIALLITIC SOILS *SOLS FERSIALLITIQUES*

SATURATED SOILS *SOLS SATURÉS*

TYPIC SOILS *SOLS TYPIQUES*

Modal soils *Sols modaux*

57 REDDISH-BROWN soils on colluvia derived from granite and Adigrat sandstone
Sols BRUN-ROUGE sur colluvions issues des granites et des grès d'Adigrat

58 DARK REDDISH-BROWN soils derived from Kebri-Dahar limestone
Sols BRUN-ROUGE FONCÉ issus des calcaires de Kebri-Dahar

Association of modal typic soils (59 a) and typic weakly developed soils (59 b)
Association de sols typiques modaux (59 a) et de sols typiques peu développés (59 b)

59 (a-b) RED soils derived from Gesoma sandstone
Sols ROUGES issus des grès de Gesoma — detailed on 1 : 250 000 map only

FERRALLITIC SOILS *SOLS FERRALITIQUES*

WEAKLY DESATURATED OR SATURATED SOILS
SOLS FAIBLEMENT DESATURÉS ou SATURÉS

TYPIC SOILS *SOLS TYPIQUES*

Modal soils *Sols modaux*

60 RED soils on complex material derived from Kebri-Dahar limestone, Adigrat sandstone and granites
Sols ROUGES sur matériau complexe issu des calcaires de Kebri-Dahar, des grès d'Adigrat et des granites

HUMIC SOILS *SOLS HUMIQUES*

61 YELLOWISH-BROWN soils derived from basalt of the plateaus
Sols BRUN-JAUNE issus des basaltes des plateaux

62 see Ass. VI / *voir Ass. VI* — YELLOWISH-BROWN soils on colluvia derived from Gesoma sandstone
Sols BRUN-JAUNE sur colluvions issues des grès de Gesoma

Association of typic modal soils (63 a) and weakly developed soils (63 b)
Association de sols typiques modaux (63 a) et peu développés (63 b)

63 (a-b) RED soils derived from Gesoma sandstone
Sols ROUGES issus des grès de Gesoma

Association of very humic weakly developed soils and typic humic weakly developed soils
Association de sols humifères peu développés et de sols typiques peu développés humiques

64 REDDISH-BROWN soils derived from mountains basalt
Sols BRUN-ROUGE issus des basaltes des montagnes

HYDROMORPHIC SOILS *SOLS HYDROMORPHES*

MEDIUM ORGANIC SOILS *SOLS MOYENNEMENT ORGANIQUES*

HUMIC GLEY SOILS *SOLS HUMIQUES A GLEY*

With powdery lime *A calcaire poudreux*

65 (a-b) BROWN soils on alluvia from Wabi Shebelle (65 a) and Fafen (65 b) rivers
Sols BRUNS sur alluvions du Wabi-Shebelle (65 a) et du Fafen (65 b) — detailed on 1 : 50 000 map (Wabi Shebelle) and 1 : 60 000 map (Fafen) only

Calcic soils *Sols calciques*

66 on 1/250 000 map only — BROWN soils on alluvia from the Harar lakes
Sols BRUNS sur alluvions des lacs de l'Harar

MINERAL HYDROMORPHIC SOILS *SOLS HYDROMORPHES MINÉRAUX*

SOILS WITH PSEUDOGLEY *SOLS A PSEUDOGLEY*

With powdery lime *A calcaire poudreux*

67 LIGHT BROWN soils on sandy alluvia from Wabi Shebelle river and affluents
Sols BRUN CLAIR sur alluvions sableuses du Wabi-Shebelle et de ses affluents

With nodules *A amas et nodules calcaires*

68 on 1/250 000 map only — GRAY soils on colluvia derived from Gesoma sandstone
Sols GRIS sur colluvions issues des grès de Gesoma

Calcic soils *Sols calciques*

69 YELLOWISH-BROWN soils on sandy alluvia from the Errer and Daketa rivers and affluents
Sols BRUN-JAUNE sur alluvions sableuses de l'Errer et du Daketa et de leurs affluents

SODIC SOILS *SOLS SODIQUES*

SOILS WITH NON DEGRADED STRUCTURE *A STRUCTURE NON DEGRADÉE*

SALINE SOILS WITH SALT EFFLORESCENCES *SOLS SALINS A EFFLORESCENCES SALINES*

70 RED soils on complex alluvia derived from Gesoma sandstone Belet Uen limestone and Ferfer gypsum
Sols ROUGES sur alluvions complexes issues des grès de Gesoma des calcaires de Belet-Uen et des gypses de Ferfer

SOILS ASSOCIATIONS *ASSOCIATIONS DE SOLS*

	Localisation	Unities
Ass. I	Lower-Ogaden / *Bas Ogaden*	3 + 54
Ass. II	South El Kere / *El Kéré Sud*	4 + part. 39 c
Ass. III	North Imi / *Imi Nord*	40 + 54
Ass. IV	Duhun	42 + 48
Ass. V	Dobawein-North Danan	43 + 52
Ass. VI	Shek Hussien	9 + 62

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ብሔራዊ የውሃ ሀብት ልማት ኮሚሽን መሥሪያ ቤት

IMPERIAL ETHIOPIAN GOVERNMENT

NATIONAL WATER RESOURCES COMMISSION

ETHIOPIA - FRANCE COOPERATIVE PROGRAM

WABI SHEBELLE SURVEY

IN COLLABORATION WITH

FRENCH MINISTRY OF FOREIGN AFFAIRS

NATIONAL WATER RESOURCES COMMISSION

BCEOM-ORSTOM-EDF IGN-BDPA

V

The Soils of the Lower Valley of the Wabi Shebelle

Report

JANUARY 1973

The present report is a summary of the pedological studies undertaken from 1968 to 1972 by the Soil Science Division of the WABI SHEBELLE Project, for the entire Basin of the Wabi Shebelle.

The scientific studies were condudted from 1968 until the achievement of this report by M. SEGALEN, Consultant in Ethiopia, "Inspecteur de Recherches" O.R.S.T.O.M. (France).

To the soil-science studies participated the following engineers and technicians :

- Christian MASSONI, "Maître de Recherches" O.R.S.T.O.M. (France), Chief of the Soil Science Division of the Project.

- Gilles RICHE, "Maître de Recherches" O.R.S.T.O.M., (France), Chief of the Soil Science Division of the Project.

- Jean Oliver JOB, "Ingénieur chimiste" O.R.S.T.O.M. (France), Chief of the Laboratory for soil analyses.

- Jean François MERGAUX, I.G.N. cartographer (France).

- Zawde TILAHOUN, Head Technician of the Water Resources Commission (Ethiopia).

- Melle Guerra GEBREMESKAL", Ingénieur chimiste of the Water Resources Commission (Ethiopia).

TABLE OF CONTENTS

Pages

Pages

Pages

L I S T O F T A B L E S (or figures)

Pages

L I S T   O F   P L A T E S

- The eleven soil maps of the Lower Valley of the Wabi-Shebelle are included in a special file.

INTRODUCTION

Of all the soils surveys of the Wabi Shebelle Basin, the most worthy of attention are those on the Lower Valley, this region presenting possibilities for hydro-agricultural development.

Consequently, a systematic survey was carried out from Imi to Ferfer along a 450 kilometers'distance. A map at 1/50 000 was drafted representing an area of 1,3 million hectares among which 380 000 ha are suitable for irrigation, and many soil samples were analysed in order to determine their different characteristics and their potentialities.

GENERAL DESCRIPTION OF THE ZONE

The Wabi Shebelle flows along approximately 400 km in a steep canyon and, 40 km North of Imi, it enters a plain which spreads out downstream. Sometimes bounded by limestone or gypsum escarpments, it generally gives place in its surroundings to a glacis due to the temporary rivers of Ogaden which seldom join the main river.

The ancient meanderings of the river in its alluvial flats give the Wabi Shebelle the aspect of a succession of crescents alternating on either side of the river, linked end to end and spreading out downstream. The mean width of this plain is about 2 to 3 km in the Imi region and 10 km in the Gode region and Shebelle plain.

The Wabi flows embanked from 5 to 10 meters deep in its alluvium between Imi and Kelafo, but from Kelafo to Mustahil the river is divided into many shallow arms. Some large areas are flooded during each peak flood (Juncaceae zone) whereas other areas are permanently flooded (Cyperaceae zones).

I. NATURAL ENVIRONMENT

A. CLIMATE

The climate of the Lower Valley of the Wabi Shebelle belongs to the Ogadenian semi-arid type and is characteristic of equatorial latitude, i.e :

- Lower thermic amplitudes throughout the year and between night and day than in other arid regions.
- A regime of rainfall with two rainy seasons.

1. Temperatures

The mean annual temperature is 28°2, the mean maximum and minimum being respectively 28°7 and 26°6 and the extremes being 34°4 and 23°4.

The variations from one month to the next are small : 3°2 (maximum) and 4°6 (minimum).

The mean daily variation is 11°2 for the year with a maximum of 14° in December and a minimum of 9°4 in July. Consequently, the Valley of the Wabi

Shebelle enjoys relatively mild temperatures (the highest is always under 40°) and low thermic amplitudes though nights are quite cool.

2. Rainfall** See table 1

Rainfall in the Lower Valley has a xerique regime. But the sun reaches its zenith twice a year, hence two short rainy seasons.

- The first in March-April-May which is the longest.

- The second in September-October.

This is considered as an "equatorial cycle" though the rainfall intensity is completely different from that observed in classic equatorial climates.

In fact, the mean annual rainfall never exceeds 350 mm and is usually about 200 mm. A considerable rainfall variation may be observed from one year to the next, for instance, at Imi and Kelafo stations, the difference is 1 to 2 for 1970 and 1971. Furthermore, for the same months, important interannual variations are recorded (from 1 to 5).

Rains are due to heavy and localized storms and form grey columns swiftly blown on by a very strong wind but in general the soil is not deeply soaked, owing to previous long arid periods. An hour's rainfall turns the plain into a huge lake where water only seeps into the soil some hours later. The depressed areas are soaked for 4 or 5 days if other storms do not occur.

**: Gode weather station (Wabi Shebelle Project Survey)
Pluviometric stations of Imi, Gode, Kelafo, Mustahil.

TABLE 1

RAINFALL IN THE LOWER VALLEY OF THE WABI for 3 years

1969 - 1970 - 1971 in millimeters.*

Locality	Year	1st rainy season (March - April - May)		2nd rainy season (October - November)		Total annual rainfall	Total mean rainfall for 3 years
			Mean rainfall for 3 years		Mean rainfall for 3 years		
IMI	1969	68,0		68,9		136,9	
	1970	147,6	90,5	95,5	78,5	243,1	169,0
	1971	56,1		71,2		127,3	
GODE	1969	114,7		144,9		259,6	
	1970	236,0	175,4	54,7	108,4	290,7	283,8
	1971	175,7		125,8		301,5	
KELAFO	1969	91,1		153,7		244,8	
	1970	162,1	107,3	57,1	81,8	219,2	189,1
	1971	68,9		34,9		103,8	
MUSTAHIL	1969	162,0		151,5		313,5	
	1970	117,3	187,1	90,3	127,8	207,6	314,7
	1971	282,1		141,6		423,7	
FERFER	1969	40,6		123,6		166,2	
	1970	157,0	82,3	54,1	93,6	211,1	175,9
	1971	49,4		103,2		152,6	

* Short rainfalls in the 2 months before or after the rainy season are not included in the total rainfall as they do not influence the hydrologic balance of soil.

3. Wind*

In these semi-arid regions where no natural barriers exist, a calm atmospheric situation is unfrequent and wind is one of the main features of the Ogadenian climate.

In the Wabi Shebelle plain, the wind rises at about 10 a.m, blows until evening and at about 7 p.m. stops suddenly to blow again violently at 1 a.m. and drop at sunset.

The wind condition is determined mainly by the breeze effect from the Indian Ocean. This is the case of nightwind due to the gale which started blowing on the previous afternoon on the Somalian coast.

The main direction of wind is S.W. and its mean annual velocity is 3,6 m/s.

The minimum velocity corresponding to the rainy seasons in October, November and December is 2,5 m/s and the maximum velocity during the dry months of June, July, August and September is about 5 m/s. These values are relatively low for a subarid region with no natural wind barrier.

When the atmospheric situation is calm, very important whirlwinds materialized by a dust column slowly moving across the plain, contribute to the general powdering of soil with a film of fine particles.

4. Hygrometry

The mean annual hygrometry is 53,2 % ; at 6 a.m. it is 67,8 %, and at 6 p.m. : 39,2 %.

In the morning, the maximum hygrometric degree never exceeds 88 % during the rainy season but minimum values are always under 50 % at 6 p.m.

Consequently, hygrometric conditions are moderate in the morning and poorer in the afternoon but the saturation degree of atmosphere is never under 25 %, which is very different from hygrometric conditions in other arid zones.

5. Soil evaporation and water deficiency : S. Table 2

Evaporation was measured with a Piche evaporameter and an evaporation pan of Colorado type.

Mean annual evaporation measured on evaporation pan Ep is : 3810 mm and on Piche : EP = 2.976 mm, the ratio being :

EP = 0,81 Ep ; these data call forth some remarks :

- Evaporation data Ep are distinctly higher than EP (Piche data), this owing to the "oasis effect" observed around the evaporation pan.

- However, evaporation values are in both cases very high and can only be accounted for by the hygrometric deficiency in the afternoon and the permanent influence of steady and relatively high wind. It is difficult to relate these data to real evaporation in soils, for want of measurements directly carried out on the field.

* Gode station.

To characterize with some accuracy the water deficiency of soils, the ETP (calculated by the Turc formula applied to arid zones) was used. The monthly water deficiency : DM is consequently the difference between monthly rainfall PM and ETP calculated for the month considered : ETPm . Thus ;

$$Dm = Pm - ETPm$$

TABLE 2

MONTHLY WATER DEFICIENCY : in the LOWER VALLEY of the WABI SHEBELLE.

	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
ETPm	157	186	173	168	138	135	110	136	145	116	141	151
Pm	0	4,2	26,8	23,8	57,4	2,7	0	0	0	112,1	32,8	0
Pm-ETPm	- 157	-181,8	-146,2	-144,2	- 80,6	-132,3	-110	-136	-145	- 3,9	-108,2	-151
ETPM	159	181	166,0	134	139	102	131	130	131	127	155	155
Pm	0	4,2	50,7	150,7	34,6	0	0	0	0,8	54,7	0	0
Pm-ETPm	- 159	-176,8	-115,3	+ 16,7	-104,4	-102	-131	-130	-130,2	- 72,3	-155	-155
ETPm	173	196	176	150	127	107	118	143	158	129	154	155
Pm	0	0	2,6	10,3	162,8	0	0	0	0	112,3	13,5	0
Pm-ETPm	- 173	-196	-173,4	-139,7	+ 35,8	-107	-118	-143	-158	+ 16,7	-140,5	-155

Table 2 representing 1969, 1970, 1971 shows that the soil can theoretically supply water to a continuous vegetative cover during 2 periods of one month each and sometimes only during a period of two weeks.

These data correspond relatively well to observations made in the Wabi Shebelle plain. In this very flat zone, runoff is weak and can only be observed in the depressed zone of the plain itself, where drainage conditions can therefore exist for about one month during each rainy season. However, trees growing in the lower areas have a longer vegetative cycle due to deeper infiltrati water.

Nevertheless, during approximately 10 months of the year, the soil is subject to intense evaporation conditions which deeply influence the evolution of soils and the dynamics of soil solutions, as will be seen later.

B. VEGETATION

According to the botanical survey by J.L. GUILLAUMET, one may note in the Wabi Shebelle and its vicinity 5 types of vegetation related both to the nature of the soil and to its hydrological regime.

- Fringing forest along the Wabi Shebelle.

- Graminea Community in the alluvial zones which are not or scarcely flooded.
- Bushy communities in flood zones.
- Gyrocarpus habebensis and Cassia ind. communities in the valley periphery on colluvial deposits and alluvia of temporary rivers.
- Halophyte groups on saline soils.
- Thicket with Commiphora sp. and Andropogon cyrtocladus on limestone plateaus.
- Thicket with Boswellia spp. and Jatropha rivae on gypsum hills.

1. Wabi Shebelle alluvial plain.

- The fringing forest along the Wabi Shebelle stretches over the sandy natural levees of the river and is seldom more than 200 meters wide.

North of Imi and South of Kelafo, a palmgrove with Hyphaene thebaïca predominates.

Between Imi and Kelafo, the fringing forest with Tamarix nilotica prevails and also grows in the Shebelle plain on the sides of an ancient natural levee of the Wabi where it is approximately 200 m wide.

- Gramineae communities in zones which are not or seldom flooded, suddenly appear and turn the dry plain into a very large and green 20 cm thick carpet, where Aristida spp. and Cenchrus spp. predominate.

- The bushy communities of alluvial zones not liable to flooding include two types :

. The Suaeda fruticosa and Cadaba glandulosa group growing on top of small dunes near the Wabi or on flat areas where they may constitute thick covers (zone E and F and South-East and North-West ends of Gode plain).

. The Cassia spp.group consisting of a thick or loose thicket of small thorny shrubs about 1,50 m high, is frequently seen at the limits of the alluvia of the Wabi and of temporary rivers.

- Savannah with Acacia spp. is a very dense tree savannah with tall acacias (mean height : 10 m) in weakly flooded zones of the Kelafo region.

. In zone E, to the North-East of Gode, a real "park-savannah" exists with very tall flat-domed acacias.

- Swampy communities of flood zones.

In the flood zones of Shebelle and Mustahil, the prevailing communities mainly consist of Halophytes, namely : Scirpus maritimus, Cyperus cf fenzelianium, Ipomea sp, Indigofera sp, Dichantium annulatum.

2. Alluvia of temporary rivers and colluvia on the periphery of the plain

On the periphery of the brown and yellowish, brown alluvia of the Wabi Shebelle, on the yellowish-red alluvia of temporary rivers and on the reddish-yellow colluvial deposits of hills, the following groups can be seen :

- Groups with Gyrocarpus habebensis and Cassia ind.

These two plants form a shrubby community, 3 to 6 m high, but here and there one or the other of these 2 species grows in a practically unmingled stand.

- Halophyte community

It grows on the saline soils of the alluvial fans of temporary rivers, particularly in the extreme South-Eastern part of the Valley, between Burkur and Ferfer, where : Urochondra setulosa, Cenchrus biflorus and also Cucumella Kelleri predominate.

3. Hill zones and plateaus on either side of the plain :

On the gypsum hills grows a more or less dense thicket of Boswellia spp. and Jatropha rivae.

- On the limestone plateaus grows a usually dense thicket of Commiphora sp. and Andropogon cyrtocladus.

4. Action of man on the vegetation.

- The vegetation is hardly modified by man.

- Land clearing only was undertaken in the Kelafo and Mustahil region for cultivation after waters subside.

- Generalized bush-fires do not exist, fires being limited to cultural and pastoral areas (Mustahil, Kelafo and Bu-Y zone). Consequently, the climacic vegetation is practically unchanged, especially in the periphery of the Valley.

- Conversely, if trees no longer exist in several zones, this is due to the presence of livestock and to overgrazing conditions.

- Nevertheless, the local population generally spares trees which provide a meagre shade.

As to the irrigable zones of the Lower Valley, the study of vegetation is resumed as regards the physiognomical aspect, density and location zones, in paragraph : IV. 2.6. : "Nature and density of the vegetative cover and fitness of soils for land-clearing".

C. GEOLOGIC FORMATIONS.

The Wabi Shebelle Valley is covered with alluvial deposits from the Northern and North-Eastern basaltic high Plateaus, and is commanded at a variable distance from the river by the Ogaden Jurassic and Cretaceous formations and their weathered deposits. Consequently, two completely different geologic formations may be studied alternatively, i.e. :

1. Jurassic and Cretaceous formations in the outskirts of the Wabi Shebelle valley :

1.1. Stratigraphy

1.1.1. The main gypsum formation (Upper Jurassic and Lower Cretaceous) consists of a series of well stratified gypsum layers, either transparent slabs or crystallized beds sometimes grooved by superficial weathering. These layers are approximately 50 cm thick and are intercalated with scarcely fossiliferous greyish-green marl, 5 to 10 m thick. Thin limestone beds (1 to 2 m thick) are frequent in the Mustahil, Kelafo and Gode regions.

It constitutes all the hills below the level of the limestone bluff. Its morphological structure is usually circular, resembling a flattened half-orange, and is relatively thick (20 to 30 cm) with concentric lines marking out the gypsum beds. The characteristic "cockade" aspect of these hills is very distinct, for instance towards the Northern bank of the Wabi around Gode and near Kelafo.

The main gypsum formation, at the limit of the alluvia of the Wabi Shebelle, often presents a small vertical bluff 5 to 10 meters high, laterally alternated with the alluvial fans of temporary rivers to the South-West of the Gode plain. This formation generally limits the Wabi alluvial plain to the North-East of the Madiso temporary river. Downstream, on the right bank of the Wabi Shebelle between Kelafo and Mustahil and beyond, it forms large flat zones scarcely scoured by temporary rivers. It is situated only a few meters above the level of the Shebelle plain towards which the formation gently slopes, the limit between alluvial deposits being marked out by saline gypsum crusts.

In Imi region, especially to the North of this locality and on both Wabi banks, a layer of red <u>zoogenous sandstone</u> with numerous molluscs constitutes the upper part of 15 to 20 m high tabular hills rising above the gypsum plateaus. The morphological structure of these hills is characterized by a very broken up bluff displaying sharp angles due to the heterogeneous nature of sandstone.

1.1.2. <u>Mustahil limestone</u> (Barremian, Lower Cenomanian).

Consisting of reddish-brown limestone at the base, and dolomitic limestone on top with numerous red siliceous segregations, it is 20 to 30 cm thick in the Mustahil and Gode regions. This limestone is rich in fossils forming large beds with Brachiopods, Echinids, Lamellibranches, Gastropods, Belemnits, and Ammonits.

This formation surmounting the main gypsum only remains North of Imi and far enough from the Wabi : Godja hills 30 km North of Imi and the hills West of Imi.

The Mustahil limestone which forms high horizontal tabular hills in the distance is relatively near the river. In the South of Gode, only 30 km to the South of this town, it comes very close to the Wabi between Gode and Kelafo and forms the Didjinober hill on the Northern bank and two other hills on the left bank, the big Galuen hill dominating Kelafo town on the Southern bank.

Between Kelafo and Burkur, the Mustahil limestone scarp on the Northern bank culminates over the Wabi at approximately 100 m height, but on the left bank only two important remnants exist in the Mustahil zone facing Burkur (Menelik mountain).

Karstification of this formation is unfrequent and is only observed on the Burkur-Mustahil track where caves exist in the limestone bluff.

1.1.3. Ferfer gypsum (Cenomanian)

Consisting of greenish-grey and sometimes multicoloured gypsum intercalated with marlstone layers rich in sodium chloride and fossils (Lumachelle type), this formation is only represented between Burkur and Ferfer, on the Northern bank of the Wabi, by a low and level zone where temporary rivers from the North meander.

1.1.4. Belet Uen limestone (Upper Cenomanian Turonian)

Consisting of limestone conglomerates with many-coloured gypsum intercalations, it outcrops to the East of Ferfer and its weathered material is transported to the Burkur Ferfer region.

1.1.5. Gesoma sandstone (Upper Cretaceous)

It outcrops on the vast Shilavo plateau and on the Duhun tabular mass. This sandstone is very friable and the sand resulting from weathering is transported by temporary rivers to the Wabi banks in the Imi and Burkur - Ferfer regions.

1.2. Parent material derived from these formations.

Erosion and weathering of geologic formations give the following material :

- For the main gypsum formation : a silty powdery weathered material of a greyish colour mainly composed of gypsum micro-elements. This material is also calcareous with a large quantity of sodium chloride.

- For the Mustahil limestone, a very fine sandy and powdery material, yellowish-red to red and poor in gypsum and sodium chloride.

- In the foot-hill formations, the material derived from both these series are deeply mixed and constitute a yellowish-red limestone material with abundant gypsum and sodium chloride.

- In Imi region, from the zoogenous sandstone is derived through weathering a distinctly red material with medium sands and a small quantity of gypsum.

1.3. Parent material from the alluvia of temporary rivers.

The origin of these alluvia is more complex owing to the fact that they have been transported along great distances.

1.3.1. Alluvia of temporary rivers of Imi zone are rich in coarse sands. They mainly consist of weathered Gesoma sandstone from Duhun region in the East and from the limit of the Basin in the West. They are calcareous, scarcely saline and with a low gypsum content.

1.3.2. Alluvia of temporary rivers between Gode and Burkur.

Their texture is fine but usually without much clay. They are composed of yellowish-red mixed materials resulting from the weathering of Mustahil limestone and main gypsum and consequently, are rich in limestone, gypsum and sodium chloride.

1.3.3. Burkur and Ferfer alluvia of temporary rivers.

These deep red, very saline alluvial deposits have a medium gypsum texture. Their origin is complex : the red colour being due to the weathering of Gesoma sandstone from the El Habred region, and the very high salinity, to the weathering of Ferfer gypsum ; besides, weathering material from Belet Uen limestone is also mixed with these alluvia.

2. The alluvial plain of the Wabi Shebelle.

The alluvial deposits of the Wabi which flows down from the High Plateaus, constitute the parent material on which the soils of the Wabi Shebelle Valley are developed. They are completely different from those of the local environment and consist of :

- Brown alluvia with a remote basaltic origin and composed of clay to clayey silt with a predominance of montmorillonite concentrating especially in weakly depressed zones.

- Yellowish-brown more sandy alluvia forming the ancient natural levees of the Wabi and presenting a large quantity of mica (phlogopite) derived from Harar granite and transported to the river by the left bank tributaries.

- All intermediate forms exist : the alluvial deposits are frequently interstratified with predominating clayey or sandy beds and crossbeddings in the sand can often be observed. The non-weathered clay deposits usually display a conchoidal or rounded structure.

- As revealed by observations made on the Wabi banks and in the periphery of the plain, these alluvia are 2 to 6 m thick and overlay the main gypsum formation or weathered material on which the bed of the Wabi rests, from Imi to Burkur. This also explains the important sulphate and chloride contamination in the deeper parts of the alluvial deposits.

3. Basalt formations of the Wabi Shebelle Valley.

The basalt formations existing along the Northern border of the Wabi Shebelle Valley from Gode to Imi, are rich in ferromagnesian minerals, especially olivine. They form hills 20 to 50 m high with a characteristic.

caterpillar or "crescent" morphological structure and are usually located in the gypsum formations but also, in several places, in the midst of the Wabi Shebelle alluvia. This is the case of the "crescent-shaped" hills, about 20 meters high,3 km away from Gode bridge, and of two small outcrops only 2 to 3 m high, 14 km to the South-East of Gode and also on the right bank.

. These basalt formations are very different from the sedimentary soils through which they jut and, consequently, they raise a stratigraphic problem : as will be seen further on, they are probably related to the tectonic movements which caused the formation of the Wabi Shebelle Valley.

D. GEOMORPHOLOGY OF THE LOWER VALLEY OF THE WABI SHEBELLE AND ITS SURROUNDINGS.

1. Formation of the Lower Valley of the Wabi Shebelle.

The Wabi Shebelle Valley between Imi and Ferfer is not a classic valley with encased terraces but consists of a chain of basins along which the river flows. In fact, it is a tectonic basin resulting from tectonic movements as shown by the following observations :

- The valley is rectilineal from Imi to Ferfer and its N.W - S.E direction corresponds to one of the main directions of faults in East Africa.

- Tilted rocks due to a secondary S.W - N.E fault can be seen in the Kelafo region.

- Sedimentary layers distinctly slope towards the valley between Mustahil and Burkur on the left bank of the Wabi.

- Finally, the basaltic flows with olivine seen along a S.E. - N.W. line in the Wabi Shebelle Valley (from Gode to the North of Imi), are most probably the remains of a fracturation of sedimentary series.

Therefore, a tectonic movement upsetting the equilibrium profile of the stream pattern, occurred at a probably contemporary age with the formation of the great Ethiopian lakes. This was followed for the Wabi Shebelle by an active recurrence of regressive erosion upstream from Imi and by the quick filling in of collapsed areas with alluvial deposits from the High Plateaus. Even now, during the flood period, the Wabi Shebelle still transports large quantities of suspended load : up to 70 kg/m3 as measured at Gode. This quick sedimentation is revealed by the existence of ancient river channels still well preserved in Gode plain and particularly upstream from Kelafo on the left bank and in the Shebelle plain between Kelafo and Mustahil. The inhabitants of the region often speak of an "ancient Wabi" and of now-abandoned villages which existed on the river bank.

This intense sedimentation still continues, the river and its tributaries upstream from Imi being in an active degradation phase. This fact is emphasized :

- Upstream, by the presence of Malka - Wakana falls and of canyons characterizing the Malka-Wakana valley up to the North of Imi with gorges more than 800 m deep in the Lagahida region. In this area, the Wabi flows very swiftly to reach the level of the Lower Valley where the river recovers its equilibrium profile and becomes a "mature" and sinuous river cross-cutting its own meanders in Imi region, leaving its former channel for another in the Gode and Kelafo zones or dividing into various arms between Kelafo and Mustahil.

- Downstream, the level of the Wabi bed progressively rises owing to the deposits left by the river. It must be noted that everywhere the river bed is higher than the level of ancient alluvial deposits in the outskirts and consequently, the Wabi alluvial flats slope down from the river to the farthest part of the alluvial plain. This fact is very important as regards hydro-agricultural developments.

2. Valley peripheral alluvial formation.

There is no visible connection between the Wabi Shebelle and the temporary rivers flowing from the Ogaden hills towards the river between Imi and Ferfer, except for the most important such as the Madiso and several others, or when these rivers merge in a zone where the Wabi alluvial deposits are not largely spread : particularly in the North of Imi.

In fact, two large alluvial formations existed on the border of the Wabi Shebelle Valley :

- A very important ancient alluvial formation contemporary with the fault which caused the formation of vast alluvial fans with numerous big boulders (limestone and basalt at Gode and calcareous-basalt, granite, granite-gneiss, quartzite at Imi and Northern Gode on the left bank of the Wabi Shebelle). Gode town is built on an ancient alluvial fan.

This active erosion can be explained by the action of a semi-arid climate of the same pattern as the actual climate but with very concentrated and more important rainfall.

- The present alluvial formation is characterized by a relatively weak climate - erosion with, in the downstream part of temporary rivers, alluvial fans consisting only of fine elements. The characteristic "causse" aspect of the landscape around the valley with its scarp and concave slope turned towards the Wabi Shebelle is due to this present eroding process.

3. Limits between the alluvial deposits of the Ogaden alluvial formation and the Wabi Shebelle alluvia.

3.1. Limits :

The limits between the red alluvia of temporary rivers and the brown Wabi Shebelle alluvia are very distinct. But in fact, a cross-section in these alluvia shows that those of the Wabi Shebelle always cover the peripheral alluvia of temporary rivers, which confirms the weak character of the sedimentation process of the Ogaden alluvial system. This is probably true for the whole valley.

Thus, the tectonic basin was probably originally filled in by the red alluvia of temporary rivers. This can be observed in the Gode, Northern Gode and Imi regions where these alluvia (either presenting many boulders as in Gode or none at all in Northern Gode) rest directly on the gypsum substratum (Gode) or on the limestone layers of the main gypsum formation (Northern Gode).

Later on, the Wabi probably covered these red deposits with its own alluvia, while progressively moving its bed from one edge of the basin to the other.

The alluvial layer of the Wabi is never more than 5 to 6 m thick in the centre of the basin and becomes progressively thinner at the periphery. At Gode, on the Northern bank of the Wabi, the transition from red to brown alluvia can distinctly be seen, the former progressively disappearing under the latter towards the Wabi, this brown alluvial layer being less than 1 m thick.

The presence of alluvia of temporary rivers underlying those of the Wabi largely explains the salinity of the deep water table in the Gode and Shebelle regions.

3.2. Natural drains in the outskirts of the Wabi Shebelle alluvia.

The Wabi Shebelle alluvia slope down from the river bank to the periphery, conversely, the slope of the alluvia of temporary rivers is positive as it turns away from the Wabi. Consequently, a hollow hinge is formed at the limit of two types of alluvial deposits and is usually occupied by one or several small ditches. The latter drain water from temporary rivers and bring it to the Wabi, sometimes very far downstream. This is a very favourable factor for soil-reclamation as it largely prevents the contamination of Wabi alluvia by saline waters from the gypsum environment.

These natural drains can be seen, in particular 11 km to the South of Gode at the limit of the Adamboi plain, in the plains upstream from Kelafo and in most of the other Wabi Shebelle alluvial plains.

E. FLOOD ZONES

The climatic context of the Lower Valley is largely modified by the influence of flooding which occurs when the Wabi Shebelle overflows in different points of the valley,for instance in the ox-bows of Imi region and particularly south of Kelafo in the Shebelle and Mustahil plains, or on areas where runoff water spreads over the alluvial fans of large temporary rivers during rainfall on the plateaus commanding the valley.

1. Wabi Shebelle floodings.

This flooding occurs twice a year in June-July and in September-October and corresponds to the two rainy seasons on the High Plateaus. It more or less affects zones considered here because of their topographic situation with regard to the Wabi Shebelle.

1.1. Zones of long-duration flooding.

1.1.1. Shebelle plain.

In this plain, the zone of long-duration flooding spreads downstream from the Kelafo gully over approximately 10 000 ha, and presents a dense Cyperaceae vegetation. Here, the river separates into many anabranches.

- This zone is characterized by important flooding : approximately 0,50 to 1 m during several months, but the rest of the year, ground water is never under 1,50 m depth and the capillary fringe never less than 30cm below the surface.

1.1.2. Mustahil plain.

On the left bank of the Wabi, North of Mustahil, the flood area is approximately 4 000 hectares with a dense Gramineae vegetation. The ground water level is sometimes lower than in the Shebelle plain during the dry season : approximately 2 m deep in the middle of the plain with a capillary fringe about 80 cm below the surface.

1.2. Zones of temporary flooding.

1.2.1. Shebelle zone

The zone of temporary flooding begins 6 kms to the East of Kelafo and is the largest flooded area during peak floods. It stretches along the border of the long-flooded zone of the Shebelle plain on approximately 3 500 ha, and also to the South, beyond the ancient natural levee of the Wabi where water is supplied by the river through functional arms only during high flow ; here the flooded area is about 25 000 ha.

Flooding is 50 cm high during peak floods but in the dry period, the ground water level falls to a 4 meters'depth, the capillary fringe remaining at 1,50 m depth. Natural vegetation consists of a dense copse to the North of Kelafo but, to the East in the Shebelle plain, rushes predominate with stands of tall Acacias.

1.2.2. Ox-bows of the Wabi.

Between, the North of Imi and the South of Kugno, the Wabi cross cuts many of its ox-bows and consequently, the latter are regularly flooded at each peak flood along a 90 kilometers'distance : 6 000 hectares are then flooded. The highest water level varies from 0,60 to 1 m above ground and natural vegetation consists of trees with a very dense undergrowth.

2. Floodings of the Ogaden alluvial formation.

This flooding usually occurs during the rainy season in the lower part of alluvial fans of temporary rivers throughout Ogaden. In the Wabi Shebelle Valley, it can be observed in the same circumstances and especially at the limit between the alluvia of temporary rivers and of the main river. The intensity and duration of flooding vary according to the importance of temporary rivers and of their drainage basin. The amplitude is usually low and gives rise to saline water spreadings : Southern end of Gode plain, Southern part of the Shebelle plain, Northern part of the Mustahil plain.

In other cases, important and long-duration flooding occurs in Ogaden, in vast zones which are mainly :

2.1. The BU-Y flood zone.

Located in the Northern peripheral part of the Gode North-Eastern plain, 60 km away from Gode, it spreads over 7 000 hectares and its natural vegetation is rich in graminea and numerous acacias. Moreover, the flood zone stretches far up to the lower course of the temporary river. 5 km to the East of BU-Y, another flood zone corresponding to a smaller temporary river is approximately 3 000 hectares.

2.2. Southern-Kelafo flood zone.

Kelafo lake is supplied by a large temporary river flowing from the South. Also in the South, a weakly flooded zone stretches on about 3 000 ha.

2.3. Flood zone, South East of Mustahil.

Behind the Mustahil hills, 20 km to the South East, a very large and intensely flooded zone receives water from a group of temporary rivers originating from the Somalian borders and spreads on approximately 6 000 ha. Many small anabranches of temporary rivers run across this zone and are often marked out by trees, the rest of the vegetation consisting of a thick carpet of dense gramineae.

F. DUNE FORMATIONS

Two types of dune formations are known :

1. Small round dunes along the Wabi Shebelle and especially on the Southern bank of Gode plain. They consist of sandy to silty mounds : 3 to 4 meters'diameter at the base and 2 to 3 m high, they are crowned with a bush of *Sueda fruticosa* or of *Cadaba glandulosa*.

These symmetrical dunes are formed by whirlwinds around a vertical axis. During the warmer hours of the day, dust columns slowly whirling about the plain, sometimes meet a shrub : the dust from the lower part of the column is checked by the leaves and falls. Progressively, the ground level rises and the leaves of the shrub grow longer until the latter is smothered by the growth of the dune : the live dune becomes a dead dune, and its material can again be blown away by wind.

2. Large dunes.

More important dune formations exist in Gode plain, 12 km to the South-East on the Kelafo track. Approximately 15 meters high, they form small rows on which *Sueda fruticosa* bushes or tall *Acacias* grow.

To the East of this dune formation, a small barkane with a 20 meters diameter is the only example of this type seen in the Lower Valley.

II. SOIL FORMING PROCESSES

The semi-arid climate characterizing this region has a mean rainfall under 300 mm and two rainy seasons with intense evaporation in relation with a permanent dry wind. It conditions :

- A vegetation of limited growth with a short vegetative cycle and consequently a low and soon mineralized accumulation of organic matter.

- A frequent accumulation in soils of soluble salts such as gypsum and sodium chloride.

However, when the pedoclimate becomes damp, and such is the case in flood zones, pedologic differenciation processes distinctly appear, for instance :

- Soluble salts are washed down and tend to accumulate in the depth, especially gypsum.

- In clayey soils, vertic features appear very distinctly, their permanent character being the presence of a thick grumosolic horizon.

- In permanently flooded zones (Cyperaceae zones), a considerable accumulation of organic matter forms a 1 to 2 m thick layer.

A. MIGRATION AND ACCUMULATION OF SALTS.

Owing to the pedoclimate, draining conditions last about one month during each rainy season, and consequently, only the most soluble salts can be washed down and accumulate.

Calcium and sodium exist in large quantities in the sedimentary materials and are therefore the predominant cations ; the migration of these two elements takes place as follows :

- Calcium bicarbonate $(CO_3H)_2$ Ca not very soluble : 2 me/l of water.

- Gypsum : SO_4Ca, 2 H_2O, more soluble : 24 me/l of water.

- Sodium chloride : ClNa, very soluble : 6 200 me/l of water.

The solubility of gypsum being deeply affected by the concentration of sodium chloride, dissolved gypsum in soil solutions may reach much higher values.

1. Limestone.

The soils of the plain and its surroundings are generally affected by limestone.

1.1. Types of limestone accumulation.

1.1.1. Powdery lime :

Lime remains powdery in the recent alluvia of the Wabi Shebelle and in those of temporary rivers in spite of the high content (respectively 20 to 30 %) of total limestone. Calcareous nodules are only formed when there is a frequent low-amplitude pulsation of water-table : Wabi Shebelle banks between Burkur and the Somalian border and foothills with ground-water flow (Mustahil region).

1.1.2. Limestone accumulations and nodules.

On the plateaus surrounding the valley, the limestone presents very individual characteristics such as accumulations and abundant hard nodules resting on the parent-rock. This is also true for the ancient alluvial fans of Gode region. However, the powdery lime content in the fine earth-coating remains very high : approximately 30 %.

These observations allow to note that :

- The climate seems unsuitable for the migration of calcium carbonate as, despite the abundance of total limestone in soils, there is no individualization of this limestone in recent alluvia.

- The nodules of plateaus and alluvial fans are probably after effects of a former and damper climate with more deeply contrasted rainy and dry seasons. This is confirmed by observations on the formation of alluvial fans containing stones.

1.2. Origin of lime in recent alluvia.

The yellowish-brown and brown Wabi Shebelle alluvia with a 20 % average content of lime, have no calcareous gradient with depth, consequently, lime is a specific feature of the alluvial material. This lime is undistinguishable by the unaided eye and consists of particles the size of very fine granular material (silt). Therefore, non-calcareous alluvia from the basalt and granite High Plateaus (respectively Arussi - Chercher and Harar) were contaminated during their transportation by calcareous erosion material torn from the vast plateaus of the Middle Belt.

The peripheral alluvia of temporary rivers resulting from the erosion of limestone from plateaus, are richer in powdery lime (30 % of total calcium carbonate in soils), this fact confirming that a calcareous contamination of Wabi-Shebelle exists.

The erosion by whirlwinds at the periphery of the valley and the powdering of the plain by fine calcareous elements, probably also contributed during successive sedimentations to an increase of the calcium carbonate percentage in materials in general.

1.3. Specific case of basaltic weathering.

In the lithic soils of basalt hills, whitish calcareous films cover small weathered basalt boulders.

This individual aspect corresponding to the weathering of basalt is due to the semi-arid climate preventing the elimination of calcium ions which become carbonated.

2. Gypsum.

2.1. Some data on gypsum dynamics.

The Ogadenian climate is favourable for the mobilization of gypsum, in fact, the latter can be found everywhere, this owing to :

- The inexhaustible gypsum source constitued by the main gypsum formation : low round hills preceding the large limestone plateaus.

- The solubility in water of gypsum which is 15 times higher than that of limestone and which increases in direct proportion to the concentration in sodium chloride of the solution.

2.2. Types of gypsum accumulation.

In the Wabi Shebelle zone, gypsum presents two individual aspects corresponding to different gypsum concentrations, i.e. :

- Crusts in some of the alluvia of temporary rivers.

- Powdery gypsum accumulation consisting of crystals in the Wabi Shebelle alluvia and in part of the alluvia of temporary rivers.

2.2.1. Gypsum crusts.

An important gypsum accumulation can be observed in the lower areas of the alluvial fans of temporary rivers which are regularly flooded by water with gypsum (and very often chlorides) from the upstream part, and in the beds of temporary rivers where this water flows.

In the deposits of alluvial fans, the accumulation begins at a 50 cm to 1 m depth and is often 1 to 2 m thick. It consists of a reddish friable crust with many small gypsum crescent-shaped and transluscent crystals welded by a gypseous cement.

These crusts are probably formed as follows :

- During the rainy season, runoff water from gypsum hills and loaded with sulphates uses the ramifications of the main beds of temporary rivers and spreads over the lower part of alluvial fans. Water seeps into the soil and gypsum is then deposited at variable levels, depending on the quantity of seepage water. This explains the large amount of gypsum clustering in the thick deposits, either of alluvial fans of temporary rivers, or of the valleys of the two large temporary rivers of Imi at Mustahil on both sides of the Wabi Shebelle Valley, and on the left bank between Mustahil and Burkur.

- Less frequently, gypsum forms in the alluvial deposits concretionary accumulations similar to the sand-roses of deserts but with a finer crystallisation.

Soils developed on these materials belong to the soil class with gypsum differenciation and to the crust sub-class.

2.2.2. Powdery gypsum accumulation

This type of gypsum accumulation with crystals of saccharoïd type, either separated or forming very small cemented and friable heaps, exists in the lower part of alluvial fans of temporary rivers and in all the Wabi Shebelle alluvial plain.

In the higher parts of alluvial fans

As seen further above, in the lower parts of alluvial fans, gypsum crusts are usually very thick. Conversely, in the higher parts, infiltration of water is episodic and most of the gypsum is supplied in small quantities by ground-water flow and the individual aspect of gypsum is not very pronounced.

In the Wabi Shebelle plain, there is no surface runoff owing to the absence of slope and because no direct connection exists between the drainage systems of temporary rivers and of the plain. The gypsum sources constituted by the underlying alluvia of temporary rivers are often deep and only small quantities of gypsum are liable to be supplied by the water - table as the latter does not often reach upper alluvial flats . Consequently, the gypsum accumulation remains powdery and can be observed in particular in soils with a clayey texture at a 80 cm to 1 meter's depth, mainly in vertisols. In more sandy soils, gypsum crystals exist only in small interstratified clayey deposits.

Soils developed on this material belong to the soil-class with gypsum differenciation, sub-class with powdery gypsum and vertisol class.

2.2.3. Weathering in situ of gypsum rock.

On the large, flat, level zones with gypsum slab of the right bank of the Wabi Shebelle from Kelafo to Burkur and beyond, the slopes are gentle and runoff and drainage of rainwater are weak. A very fine disaggregation of the gypsum slab can therefore be observed as well as a low grade gypsum reprecipitation on flinty calcareous nodules resting on the slab. This is a very limited and weakly-developed process, especially in colluvial and level zones.

Soils formed on these materials are called xeric soils in early stage of development.

Even on gypsum hills and their colluvia, the weathering of gypsum is but a very fine disaggregation of gypsum material resting directly on the slab in situ. Soils formed here belong to the class of erosion soils in early stage of development.

3. Sodium chloride

Marly-gypseous formations are usually rich in sodium chloride. Salt apparently originates from the thick grey marlstone layers intercalated between the gypsum beds of the main gypsum formation between Imi and Burkur, and in the Ferfer gypsum formation (zone between Burkur and the Somalian border).

3.1. Extension and intensity of soil salinity.

Sodium chloride being a very soluble salt, it can be found in all the soils of the valley, its concentration varying according to the type of alluvial deposits and to the geographical position.

The lower zones of alluvial fans are generally very saline in the depth with a 1 : 2 extract 10 me/100 g of soil. Conversely, Wabi alluvial soils are scarcely saline with 1 : 2 extract 2 me/100 g of soil. Alluvial soils with a low salt content in the Wabi plain are consequently "framed" by often very saline soils in the depth. This "framing" is geographically represented as follows :

Between Imi and Kelafo, chlorides only appear in several places as efflorescences on gypsum crusts between Gode and Didjinober on the left bank of the Wabi. Chloride exists at a mean depth (from 0,50 - to 1 m) in the alluvial fans of temporary rivers (lower parts).

From Kelafo to Mustahil, chlorides appear on the Southern bank of the Wabi between Galue and Mustahil where they leave whitish deposits on the gypsum crusts at the limit of the Wabi alluvia. Upstream from Mustahil, the soils of alluvial fans of temporary rivers are generally very saline up to the surface but saline efflorescences are scarce.

Between Burkur and Ferfer, salinity affects a very large zone: approximately 7 500 hectares. Saline layers or efflorescences can be seen on vast areas covered with halophytic vegetation. The mean content of the 1 : 2 extract then exceeds 15 me/100 g of soil.

3.2. Origin of soil salinity

3.2.1. Alluvia of temporary rivers

As previously said, sodium chloride sources are frequent in the Ogadenian landscape, particularly in the gypseous marl of low hills near the valley, or forming the lower parts of limestone plateaus. Salinity mainly affects the lower areas of alluvial fans at the limit of the alluvia of the Wabi Shebelle. This is probably due to the same reason as for gypsum. Water with gypsum chloride originating from the remote parts of the country seeps into the downstream parts of the alluvia of temporary rivers, with salt concentration in the depth when the alluvia are permeable, or forming whitish efflorescences when the salt deposit rests on a surface impervious material generally consisting of a gypsum crust : outskirts of the Shebelle plain between Kelafo and Mustahil.

- In the Burkur Ferfer zone, salt concentration is more important owing to the abundance of chloride in the neighbouring geologic material (Ferfer gypsum), as well as to a drier climate than in other parts of the valley.

3.2.2. Alluvia of the Wabi Shebelle.

The alluvia of the river are scarcely saline : 2 me/100 g sodium chloride of soil (1 : 2 extract).

Piezometers placed in Gode plain revealed that at a 12 to 15 meters'depth, according to location, saline ground-water at 10 me/1 could be found. Its level practically does not vary during the rainy season in Ogaden and the chloride concentration does not change either. Consequently, one may consider that the influence of runoff water from the hills is negligible and especially, that the lateral supplies of chloride are practically non-existent.

As in the case of gypsum, there is a distinct "discontinuity", and the evolution of chloride dynamics is practically independent in the Wabi Shebelle plain, compared to that of alluvia of temporary rivers. This important feature is studied in the chapter on soil reclamation.

3.3. Salinity and alkalinization of soils.

Sodium in soil may present two aspects :

- Sodium chloride : Cl Na which is part of the composition of solutions shows efflorescences at the surface or crystals within the soil when the latter dries up.

- Sodium at ionic stage (Na^+) fixed on the absorbing complex. When ratio E.S.P exceeds 15 %, the soil is alkalinized : a finely structured sodic clay is formed that can be easily eroded under irrigation by washing away of sodium ions.

3.3.1. For saline alluvia of temporary rivers and for the Wabi alluvia, numerous analytical data show that there is no alkalinization of the solution. In fact, the study of ionic balance and of the absorbing complex after extraction of solutions 1 : 2 and 1 : 10, show that :

- The washing out of sodium is almost complete in the first extraction (1 : 2 extract) in the form of chloride, and practically non-existent in the second extraction (1 : 10 extract). Therefore, only a small quantity of sodium is fixed on the complex.

- Ratio E.S.P. remains under 3 % . The oversaturation of soil with calcium resulting from the dissolution of gypsum and limestone (in smaller quantity), prevents the fixation of sodium on the complex and consequently, the alkalinization of the solution.

- The fact that no sodium bicarbonate (a salt indicating the beginning of alkalinization) exists, is moreover confirmed by a pH close to 8,0.

- Data concerning pH show that the differences between pH 1/2,5 and pH 1/10 do not exceed 2/10 pH unit. These data indicate that there is no hydrolysis of sodium in the solution (see table 3).

- From these analytical data may be drawn the conclusion that no alkalinization takes place in the alluvia of temporary rivers and of the Wabi Shebelle, this being proved by field observations.

The types of soils formed on these materials belong to the soil-class with gypsum differenciation, salinity probably being a superimposed feature.

3.3.2. Saline soils of the Burkur-Ferfer region.

Analytical data reveal a very slight alkalinization for horizon 0-10 cm of the soil zone.

As a matter of fact, in the upper horizon can be observed :

- Sodium bicarbonate (CO_3NaH) 0,3 me/100 g of soil (1 : 2 extract)

- Ration E.S.P. : under 5 % whereas, in the depth, it is under 3 %.

- A decrease of pH of 0,4 pH unit in the upper horizon between pH 1/2,5 and pH 1/10.

Besides, this very slight alkalinization can be observed on the field in the surface horizon which presents in some places only, 10 cm thick very hard parts when dry.

Conversely, in lower horizons, soils have a high salinity degree but do not tend to alkalinization.

These soils are classed among sodic soils with no deteriorated structure.

3.4. Conclusions on the influence of sodium in soils.

Apart from the saline soils of the Burkur-Ferfer region, the soils of the valley present no alkalinization process owing to the general over-saturation of soils in Ca^{++} resulting from the solubilisation of gypsum and also in small proportions, of limestone, these two elements mainly composing the parent materials.

Salinity due to sodium chloride is therefore a superimposed feature of soil. Sodium practically only exists as a salt moving freely in the soil solutions. This is very important as regards soil-reclamation by irrigation in this zone, as the risk for agriculture is not the deterioration of the structure, but mainly toxicity phenomenons due to saline solutions.

However, these may be controlled by adequate drainage.

TABLEAU 3.

General data on salinity (Cl Na) of soils in the Wabi Shebelle Valley.

	1 : 2 extract Cl Na me/100 g	1:10 extract* Cl Na me/100 g	E.S.P.	pH 1/2,5	pH 1/10
Wabi alluvia	1	0,1	3 %	8,1	8,0
All. of temp. rivers	2,5	1,2	3 %	8,2	8,2
Saline soils 0 - 10 cm.	39,7	14,4	5 %	8,0	7,6
Saline soils 10 cm +	17,0	7,0	3 %	8,2	7,6

B. VERTIC CHARACTERISTICS OF SOILS.

Vertic characters are permanent features in soils presenting a fine clayey texture of montmorillonitic type and subject to weak or moderate floods and pronounced dry periods. Vertic characters usually present two aspects in the area under study.

1. The weakly-developed "vertisolisation" of vertic soils is revealed by some vertical cracks in the depth with a prismatic structure and not yet well-developed gilgai microrelief. These characters are also seen in the clayey and unfrequently flooded alluvia of the Lower Valley of the Wabi Shebelle as well as in the lower zones of alluvial fans of temporary rivers : for instance in the outskirts of the Valley where they occupy a large area.

2. "Vertisolisation s.s. " characterizes vertisols and affects zones which are regularly and strongly flooded by the Wabi Shebelle or its "tributaries". It is particularly developed between Kugno and the frontier but especially between Kelafo and Mustahil in the Shebelle and Mustahil plains.

Vertisols in this case present very pronounced features such as broad shrinkage cracks and a very coarse prismatic structure largely developed in the depth and with distinct slickensides. At the surface can be seen a strongly-developed horizon with rounded structure and very pronounced gilgai relief.

* 1 : 10 extract uses the same earth sample as for 1 : 2 extract.

3. Grumosolic surface horizons.

Furthermore, there is a characteristic development of a 20 to 40 cm thick crumbly or granular surface horizon, progressively changing as it deepens into a coarse angular blocky structure and finally, into a prismatic structure. This type of horizon is essential for soil reclamation as its friable character considerably facilitates cultivation.

It is difficult to explain the forming process of this horizon, nevertheless, one may envisage the influence of the root system of gramineae covering the horizon which, combined together with the presence of limestone in soils, could be defined as a granular to subangular blocky structure.

C. ACCUMULATION OF ORGANIC MATTER (see Table 4)

1. It is difficult to distinguish a humic surface horizon in zones not liable to flooding or in other words, in soils where the pedoclimate only depends on regional climatic conditions. The colouring is scarcely different in surface horizons and in deep horizons and the content of organic matter which is approximately 1 % in the first 20 cm soon falls to 0,5 %.

The C/N ratio is approximately 9.

Because of the semi-arid climate, the tree or graminea vegetation has a short vegetative cycle and soil receives only a poor supply of organic matter. Futhermore, during rainy periods, the temperature is always high and favourable for a quick mineralization and does not allow accumulation of organic matter or the development of even a week humic horizon.

2. In flood zones, the content of organic matter increases with the duration and intensity of flood, these determining the type of soil as well as the nature of the vegetative cover. For instance :

- Vertisols of weakly-flooded zones contain 2,4 % of organic matter forming a 30 cm thick layer, and lower down, the content is approximately 1 % under a graminea cover.

- Soils of highly-flooded (during the flood period) ox-bows, have a relatively low content of organic matter : 2,2 % from 0 to 30 cm depth and 0,3 % below, probably because of the existence in the vegetative cover, of trees which provide but a scant litter (Tamarix nilotica).

- Conversely, strongly flooded zones presenting a Gramineae cover have a very high content of organic matter : 6,6 % from 0 to 10 cm depth and below : less than 1 %.

- Practically permanently-flooded soils with a Papyrus cover have a high content of organic matter : 11 % from 0 to 15 cm depth and 1,5 % from 15 to 20 cm depth.

In the two last cases, the horizon with abundant humus is not very thick and the content of organic matter suddenly decreases. Because of the warm and damp conditions of the pedoclimate in these zones, humus is quickly mineralized.

TABLE 4

Mean content of organic matter in % in the main types of soils in the Wabi Shebelli zone and mean C/N

Wabi alluvia

					C/N
Not flooded	Soils with gypsum differenciation Medium texture	0 - 20 cm 1,0	20 - 80 cm. 0,8	80 cm$^+$ 0,4	8
Not flooded	Soils with gypsum differenciation Sandy texture	0 - 20 cm 0,6	20 - 80 cm. 0,4	80 cm$^+$ 0,3	9
Weakly flooded	Vertisols	0 - 30 cm 2,4	30 - 90 cm. 1,0	90 cm$^+$ 0,8	12
Strongly flooded Tree vegetation.	Soils with gypsum differenciation	0 - 30 cm 2,2	30 cm$^+$ 0,3		
Strongly flooded Gramineae.	Organic hydromorphic soils	0 - 10 cm 6,6	10 - 80 cm. 0,9	80 cm$^+$ 0,4	
Practically permanently flooded Papyrus	Organic hydromorphic soils	0 - 15 cm 11,0	15 - 50 cm 1,5	50 cm$^+$ 0,8	

Alluvia of temporary Rivers

Not - flooded	Soils with gypsum differenciation	0 - 10 cm 0,7	10 - 80 cm. 0,6	80 cm$^+$ 0,3	9

This observation is true for all the soils of the Lower Valley, the C/N always being very low : approximately 10 and characterizing a mull of calcic type quickly disappearing through a mineralizing process. This gives an idea of the difficulties which must be solved in order to keep a maximum of organic matter in irrigated soils.

III. SOIL SURVEY.

Note : In this part dedicated to the description and study of soil physico-chemical characteristics, the various soil series are presented in the same order as in the legend of the soil map at 1/50 000.

- Non-irrigable soils are described very shortly as they are studied in the general report on the soils of the Wabi Shebelle Basin.

- In the chapter on soil-reclamation, soils are grouped together in classes corresponding to their fitness for irrigation.

A. LEGEND OF SOIL MAP.

SOILS IN EARLY STAGE OF DEVELOPMENT.

Xeric

. Gypseous.

- derived from gypseous marl.

1. Yellowish - grey soils : fine sands in situ with surface gypsum slab ; large flats : Imi, Kelafo, Mustahil, Burkur.

2. Yellowish - grey soils : loam with gypsum buried 50 cm deep under colluvial deposits ; large flats : Imi, Kelafo, Mustahil, Burkur.

Non climatic

. Lithic eroded soils with powdery lime.

- derived from gypseous marl :

3. Yellowish - grey soils : sandy loam in situ with surface gypsum slab ; low hills.

4. Whitish - yellow soils : loam with not very deep gypsum slab resting on colluvia ; glacis at the foot of low hills.

5. Yellowish - red soils : loam to clay loam with debris and calcareous nodules on colluvia ; slopes under the bluffs of limestone plateaus.

6. Red soils : silty loam with gypsum slab, 20 cm under colluvia ; near Gode (Glacis) and Ferfer (Plateaus).

- derived from basalts :

7. Light-brown soils : fine sand to very stony loam on weathered basalt boulders ; hills.

Soils of eolian origin with powdery lime.

8. Yellow soils : fine sand to loam on dunes, near Gode.

VERTISOLS AND VERTIC SOILS.

With grumosolic topsoil

Brown to reddish-brown vertisols with powdery lime and crystals or gypsum crusts in the depth.

- On reddish-brown alluvia of temporary rivers, derived from limestone.

9. Reddish-brown grumosolic vertisols ; clayey to silty clay layer, 40 cm thick with gypsum crust at 1 meter's depth ; easily flooded : alluvia of BU-Y temporary river.

- On brown alluvia of temporary rivers, derived from basalt.

10. Brown grumosolic vertisols : clay to silty clay, 40 cm thick, and further down : gypsum crystals ; easily flooded ; alluvia of temporary rivers, North West of Gode.

- On brown alluvia of the Wabi Shebelle.

Imi - Gode series.

11. Brown grumosolic vertisols : clay 30 cm thick ; a few gypsum crystals under 60 cm depth ; flooded.

12. Brown vertic and grumosolic soils : clay 30 cm thick, some gypsum crystals under 30 cm depth.

13. Brown vertic grumosolic soils, 20 cm thick ; clay - silty loam to clay loam with gypsum crystals in the depth.

Kelafo - Mustahil - Burkur series.

14. Brown grumosolic vertisols, 30 cm thick clay, silty to clayey loam with gypsum crystals 90 cm below - Weakly flooded.

15. Reddish - brown grumosolic soils on clay layer 20 cm thick, with gypsum crystals under 1 m depth (Kelafo only).

16. Brown grumosolic soils on 30 cm thick clay with many gypsum crystals in the depth ; strongly flooded ; Mustahil plain.

17. Brown vertic grumosolic soils on 20 cm thick clay layer ; weakly flooded ; Shebelle plain.

SOILS WITH LIMESTONE DIFFERENCIATION.

Under melanic horizon.

. With modal powdery lime.

- On colluvia derived from limestone.

18. Yellowish-red soils with fine sand rich in limestone ; weakly developed debris : debris slope under limestone plateaus : Gode to Burkur.

19. Yellowish-red soils with medium and fine sand ; limestone and basalt pebbles ; small hillocks of large alluvial flats : Imi.

. With accumulation and nodules.

- Derived from limestone.

20. Yellowish-red soils : silty loam to loam in situ with calcareous nodules : limestone plateaus : Gode to Burkur.

- Derived from sandstone.

21. Red soils : fine sand and loam with calcareous heaps and nodules in situ - Lower plateaus : Imi.

- On alluvia of ancient temporary rivers.

22. Yellowish-red soils : coarse and fine sands with limestone boulders forming conglomerates at a small depth ; hillocks of large alluvial fans : Gode.

SOILS WITH GYPSUM DIFFERENCIATION

. With modal powdery gypsum.

- On brown alluvia of the Wabi Shebelle.

Imi - Gode series.

23. Brown silty clay and not very humic soils ; fine sand ; oxbows of the Wabi Shebelle.

24. Brown to yellowish-brown silty loam to silty clay soils in the depth.

25. Brown clay soils, fine sand : Gode.

26. Brown soils : silty loam to silty clay in depth : Gode.

27. Brown soils : clay loam : Gode

Southern Kelafo - Mustahil, Burkur series.

28. Clay brown soils and brownish yellow loam ; weakly flooded to flooded : Kelafo.

29. Brown soils ; silty to clayey loam in the depth.

- On brownish-yellow Wabi Shebelle alluvia.

Imi-Northern Gode series.

30. Brownish-yellow soils with fine and coarse sands.
Wabi Shebelle natural levees.

31. Brownish - yellow soils ; sand to clayey fine sand.
Imi - Northern Gode-Kelafo series.

32. Brownish yellow soils : silty loam and fine sand ancient or recent natural levees of the Wabi Shebelle.

Southern Kelafo - Mustahil - Burkur series.

33. Brownish - yellow soils : silty loam to fine sand and medium sand in the depth : Wabi Shebelle natural levees.

34. Brownish - yellow soils : silty loam to clayey silty loam in the depth.

- On reddish - yellow alluvia of temporary rivers.

35. Reddish - yellow soils. Often saline, fine sand to loam with boulders in the depth. Alluvia of alluvial fans. Low position ; Gode to Burkur.

36. Reddish - yellow soils with loam and medium sand. Alluvia of alluvial fans - low position ; Imi.

37. Reddish - yellow sands : silty loam ; recent alluvia of large temporary rivers.

38. Reddish - yellow soils with fine sand to silty loam : recent alluvia of large temporary rivers ; Madiso.

. Vertic with powdery gypsum.

- On brown alluvia of the Wabi Shebelle.

Northern Gode series.

39. Brown soils with dominant silty clay.
Gode - Kelafo series.

40. Brown clay soils.

- On yellowish-red alluvia of temporary rivers.

41. Yellowish-red soils ; silty to clayey loam ; recent alluvia of small temporary rivers.

- On yellowish - brown alluvia of the Wabi Shebelle, overlaying red basaltic alluvia.

42. Yellowish - brown soils : silty loam to red clayey loam. Gode Modal with crusts.

- On red colluvial deposits derived from basaltic formations.

43. Red sands ; clayey fine sand to clay with gypsum crusts at a 60 cm depth ; debris slope of basalt hills ; Gode.

- On yellowish-red alluvia of temporary rivers.

44. Yellowish-red soils ; loam to silty loam with a gypsum crust at approximately 70 cm depth. These soils are saline in depth ; alluvial fans. Low position ; Gode.

45. Yellowish-red soils; silty loam to silty clay with a gypsum crust at a 70 cm depth. These soils are saline when not very deep ; alluvial fans ; low position ; from Gode to Burkur.

46. Yellowish-red soils, clayey loam to silty loam with gypsum accumulation of sand-roses ; alluvial fans ; low position ; Imi - Gode.

- On yellowish-brown alluvia of the Wabi Shebelle, overlaying the yellowish-red alluvia of temporary rivers.

47. Yellowish-brown soils ; clayey sand to yellowish-red clay ; Gode.

HYDROMORPHIC SOILS.

Moderately organic soils.

. Humic gley.

- On brown alluvia of the Wabi Shebelle.

Shebelle plain series.

48. Brown clay soils ; strongly flooded (Papyrus zones)

Mustahil plain series.

49. Brown clay soils ; strongly flooded (Gramineae zones).

SODIC SOILS

- With non deteriorated structure ; saline soils with saline efflorescences.

50. Red soils ; silty loam to clay loam with gypsum slab at a moderate depth : Burkur - Ferfer.

B. DESCRIPTION OF SOILS.

I. SOILS IN EARLY STAGE OF DEVELOPMENT : (series 1-2-3-4-5-6-7-8)

Soils in early stage of development are consequently not very thick. Depending on their type of formation, two categories may be considered : xeric and non-climatic soils in early stage of development.

1.1. Xeric soils in early stage of development (series 1-2)

They spread over large gypsum zones between Kelafo and Mustahil and beyond, on the Southern bank of the Wabi and, from Kugno to Imi on the Northern bank of the Wabi.

The yellowish-grey (2,5 Y 8/4) upper horizon consists of a fine gypsum powder, the real texture of which cannot be easily determined and seems to be composed of loam to silty loam resting on a gypsum slab. The depth of the latter varies according to local colluvial depositions and leads to distinguish two types of soils :

Series 1 : Yellowish-grey soils (2,5 Y 8/4), loam in situ with surface gypsum slab.

Type profile n° 6-219

0 - 5 cm : Yellowish-grey (2,5 Y 8/4) ; silty loam ; single-grained powdery structure ; no rootlets ; distinct transition to :

5 - 25 cm : Many-coloured gypsum stones and yellowish-brown gypsum crystals (10 YR 7/6) or light yellow (5 Y 8/3) mixed with a yellowish-grey material (2,5 Y 8/4) ; silty loam with single-grained structure ; dry and compact ; no rootlets ; sudden transition to :

25 cm+: Gypsum slab.

Series 2 : Yellowish-grey soils (2,5 Y 8/4) ; silty loam with gypsum slab, 70 cm below the colluvia.

Type profile n°6-210

0 - 20 cm : Yellowish-grey (2,5 Y 8/4) ; silty loam ; single-grained structure ; dry, friable and powdery ; no rootlets ; distinct transition to :

20 - 70 cm : Yellowish-grey (2,5 Y 8/4) ; silty loam, single-grained structure ; powdery, flattened and friable angular fragments ; no rootlets ; sudden and regular transition to :

70 cm+: Greyish gypsum slab.

These two soil series are closely associated and characterize zones with a "tiger-bush" vegetation but do not enable to determine relations between types of soils and zones with or without vegetation (see chapter on vegetation).

Main characteristics of series 1 and 2

Gypsum dissolution : Surface soil consists of desintegrated gypsum, nevertheless low grade reprecipitations are observed when vertical movement of water occurs during the rainy season.

- These soils are composed of 21 % of calcium carbonate in the upper horizon but of less than 10 % in the horizon resting on the gypsum slab.

- Water pH : 1/2,5 is approximately : 8,0.

- The average content of organic matter is 1,1 %, but in the colluvial type, the content is higher (1,5 %) than in the type in situ (0,8 %).

- Conductivity is high : 1,9 to 2,8 mmhos/cm of 1 : 10 extract corresponding to the abundance of gypsum and to the presence of sodium chloride in large quantities, but varying up to 21 me/100 g of soil or 1,2 %.

1.2. Non-climatic soils in early stage of development (series 3-4-5-6-7-8).

1.2.1. Erosion soils in early stage of development (series 3-4-5-6-7).

These soils are formed in zones with steep slopes or on glacis where sheet erosion is particularly important and consequently, they can be found in the outskirts of the valley bordering limestone plateaus. These soils are shallow ; they contain many stones and their vegetation consists of small *Acacia* and *Commiphora* and a discontinued or non-existent graminea carpet. The soil mass is composed of limestone which remains powdery.

1.2.1.1. Soils derived from gypseous marl (series 3 and 4).

They are formed on gypsum hills in front of limestone plateaus and on the latter's colluvia :

Series 3 : Yellowish-grey soils (2,5 Y 8/4) ; silty loam in situ with surface gypsum slab.

Type profile : n°6-111 : gypsum hill position.

0 - 8 cm : Yellowish-grey (2,5 Y 8/4) : silty loam ; single-grained structure ; powdery ; a few rootlets ; sudden transition to :

8 cm+ : Greyish-white and transluscent gypsum slab.

Series 4 : Whitish-yellow soils (5 Y 8/3) ; loam with not very deep gypsum slab on colluvial glacis on low hills.

Type profile : 6-110

0 - 20 cm : Whitish-yellow (5 Y 8/3) ; loam ; single-grained structure ;

very powdery ; a few rootlets ; short and regular transition to :

20 - 50 cm : Whitish-yellow (5 Y 8/3) ; loam coating gypsum ; not very hard elements forming powder ; not very compact mass ; few rootlets ; sudden transition to :

50 cm+ : Gypsum slab in situ.

Main characteristics of series 3 and 4.

The only difference between these two soil series is the depth of the gypsum slab. These soils also consist of a powdery horizon of disagregated gypsum resting on the slab.

- In the first 10 cm (5) as well as in the 20 first centimeters (6), the organic matter content is approximately 1 %.

- These soils are composed of limestone to powdery lime (from 10 to 20 %).

- 1/2,5 water pH is approximately 8,0.

- Conductivity of 1 :10 extract is high : 2,2 to 3,5 mmhos/cm, on account of the saturation of the extract with gypsum.

- Sodium chloride contents are lower than in series 1 and 2 with : 0,5 to 2,9 me/100 g of sodium chloride, i.e. : 0,02 to 0,16 % of soil, this owing to steeper slopes which facilitate lateral drainage.

1.2.1.2. Soils derived from limestone (series 5-6).

Series 5 : Yellowish-red (5 YR 5/8) ; loam to clay loam with calcareous debris and nodules on colluvia : slope under the scarps of limestone plateaus.

Type profile : 6 330

0 - 20 cm : Light brownish-yellow (10 YR 6/6) ; loam ; fine subangular blocky structure, weakly developed and tending to single-grained structure; 70 % of coarse elements consisting of limestone blocks and drifted calcareous nodules ; numerous roots and rootlets ; gradual transition to :

20 - 70 cm : Yellowish-red (5 YR 5/8) ; clay loam ; subangular blocky and weakly developed structure tending to single-grained structure; 80 % of the same coarse elements ; numerous roots and rootlets; sudden transition to :

70 cm+ : Reddish massive and medium grained limestone slab (Mustahil limestone).

Main characteristics.

These soils are formed directly at the foot of the limestone plateaus surrounding the valley. They are very stony and also contain calcareous nodules originating from superficial formations of plateaus.

- The content of organic matter is relatively higher than the average content of these types of soils (1,7 %), as the vegetation is more developed (owing to numerous stones which cause the condensation of water vapour from atmosphere) and keeps the pedoclimate in a more humid condition. Besides, the cracking of the limestone rock is favourable for the development of a relatively dense vegetation with trees.

- These soils contain 47 % of calcium carbonate as powdery lime.

- pH is approximately : 8,0.

- Conductivity is very low : 0,06 mmhos/cm of 1 : 10 extract because these soils are well drained.

Series 6 : Yellowish-red to red soils (5 YR 5/8). Silty loam with gypsum slab 20 cm deep on alluvia near Gode (Glacis) and Ferfer (Plateaus).

Type profile : 6-443.

0 - 5 cm : Reddish-yellow (5 YR 6/8) ; loam ; crumbly to medium granular and fine granular structure ; friable aggregates ; no rootlets; friable structure ; small black limestone gravels ; gradual transition to :

5 - 20 cm : Yellowish-red to red (5 YR 5/8) ; silty loam with medium to fine granular structure tending to single-grained structure ; very friable ; some rootlets ; sudden transition to :

20 cm+ : Gypsum slab.

Main characteristics.

These soils are not thick and are formed on limestone colluvia resting on a gypsum slab. They are very frequent in the North of Imi and near Gode, forming glacis below the gypsum hills, the colluvial material being derived in this case from Mustahil limestone. This type of soil can also be observed to the East and North East of Burkur, but this time, on the Ferfer gypsum formation, the red colluvial deposits being derived from Belet Uen limestone.

- The content of organic matter is low : 0,9 % but the structure is well developed, probably because of the existence of abundant iron oxides (corresponding to the reddish colour).

- Calcareous soils (19 to 22 % of powdery lime).

- Water pH : 1/2,5 is approximately : 8,0.

- Conductivity is high : 2,8 mmhos/cm of 1 : 10 extract.

Series 7 : Light brown soils (7,5 YR 6/4) ; fine sand to very stony loam on weathered basalt boulders from basalt hills.

Type profile : 6-91 : hilltop of the basalt hill in Gode plain.

0 - 5 cm : Light brown (7,5 YR 6/4) ; loam ; single-grained structure ; numerous basalt gravels ; no rootlets ; sudden transition to :

5 - 15 cm : Light greyish-brown (7,5 YR 6/4) ; loam ; fine to medium sub-angular blocky structure ; some basalt gravels ; distinct transition to :

15 - 50 cm : Small basalt pebbles, weakly developed or very rounded (balls) as a result of the disaggregation of the rock in situ. (Average size 5 to 7 cm) coated with yellowish-brown fine earth (10 YR 5/6) ; loam with single-grained structure, distinct transition to :

50 cm+ : Basalt in situ belonging to the "organ" type with calcareous film in the cracks.

All these basalt stones and gravel are coated with a fine white calcareous film.

Main characteristics.

These soils exist on small basalt hills between Gode and Imi, on the Northern bank of the Wabi and on the hill of Gode plain.

The weathering of basalt is weak and its only manifestation is the formation of boulders with a fine superficial calcareous film (see chapter II A).

- Consequently, soils are very pebbly.
- Content of organic matter is very low : 0,5 %.
- Content of calcium carbonate is moderate : 11 to 19 %
- pH 1/2,5 is approximately : 8,3.
- Conductivity is very low : 0,1 mmhos/cm of 1 : 10 extract, the soil being very well drained and salt sources being few.

1.2.2. Soils derived from wind-blown material.

Series 8 : Yellow soils (2,5 YR 8/4) : fine sand to loam on dunes : vicinity of Gode.

Type profile 6-56.

0 - 10 cm : Yellowish-grey (10 YR 7/4) ; sand to fine single-grained loose sand ; numerous rootlets ; distinct transition to :

10 - 20 cm : Light yellow (2,5 Y 8/4) ; loam with horizontal stratifications; numerous small yellow micas ; loose ; numerous rootlets.

Main characteristics.

These soils are developed on small round dunes, 3 to 4 m. high, to the South of the Wabi, to the West of Gode and on bigger dune formations to the East of Gode ; the latter are approximately 10 m high and vegetation consists of tall flat-domed Acacias.

The fine elements which usually constitute these soils are mainly derived from the weathered alluvia of the Wabi, micas being abundant.

- Calcium carbonate content is moderate : 17 to 21 %

- pH 1/2,5 is approximately : 8,1.

- Conductivity is low : 0,1 mmhos/cm of 1 : 10 extract.

2. VERTISOLS AND VERTIC SOILS WITH A GRUMOSOLIC STRUCTURE *

(Series 9-10-11-12-13-14-15-16-17).

These soils are well represented in the Lower Valley and are formed on three types of clay alluvia from different origins :

- Brown and reddish-brown alluvia of basaltic origin (alluvia of temporary rivers to the North West of Gode).

- Alluvia derived from Mustahil limestone (alluvia of BU-Y temporary rivers, North West of Gode).

- Brown alluvia of the Wabi Shebelle spreading on the largest area.

- The forming process of vertisols and vertic soils are described in chapter II B.

2.1. Morphological and mean textural characteristics and variations between series.

2.1.1. Mean profile.

At the surface : pronounced gilgai microrelief and dense graminea vegetation.

0 - 15 cm	: Brown to dark reddish-brown (5 YR 3/2) ; clay to silty loam; medium to fine strongly developed subangular blocky structure ; dry and very friable ; numerous rootlets ; gradual and regular transition to :
15 - 30 cm	: Brown to reddish-brown (5 YR 4/4) ; clay ; medium to coarse strongly developed angular blocky structure ; friable ;

* When the soil series for a group, sub-group or family are numerous, they are studied together with the description and physico-chemical characteristics of a mean profile and variations according to each series.

numerous rootlets, distinct transition to :

30 - 80 cm : Brown to reddish-brown (5 YR 4/4) ; clay ; subvertical shrinkage cracks (when dry) ; 0,5 to 3 cm wide and limiting a coarse prismatic structure with slickensides ; dry and compact ; rootlets ; gradual transition to :

80 cm+ : Same type of horizon with small gypsum crystals.

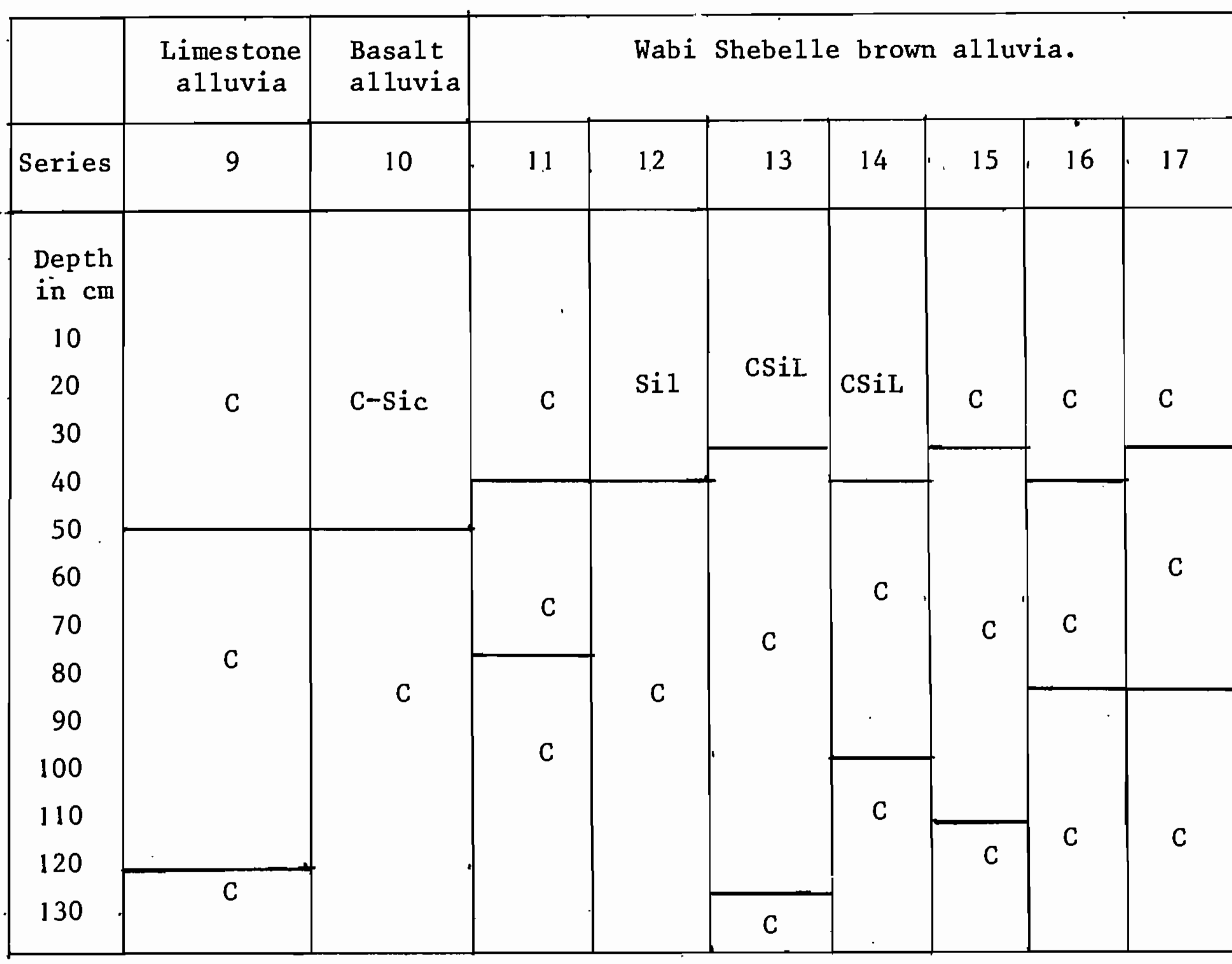
- In this mean profile the structure is very divided up in the first horizon and more homogeneous in the second (15 to 30 cm). Both these horizons are described as "grumosolic" or friable, compared to the massive and dry, compact deeper horizon.

The transition between these two horizons is very sudden.

The deeper horizons are very compact and they present a prismatic structure. Prisms measuring 50 x 30 x 20 cm have often been separated from the profiles. Slickensides are very distinct in vertisols and non-existent in vertic soils, but in both cases, shrinkage cracks are always numerous and from 1 to 5 cm wide.

The gypsum accumulation is always powdery and can be observed at about 80 cm depth. It never becomes crusty.

2.1.2. Morphological and textural variations between series.



- The grumosolic horizon is very well developed on alluvia from basaltic and limestone (40 cm thick) origin, of the BU-Y and other nearly temporary rivers (series 9 and 10).

In the Wabi plain it is only 20 to 30 cm thick.

- The prismatic horizon is well differenciated in all the series with distinct slickensides on prisms, except in vertic soils (12 to 17) where only shrinkage cracks can be seen.

- The powdery gypsum accumulation of crystals, the formation of which was alluded to in chapter II A, is present at a more or less high level in the profile, depending on the pulsation level of water table or of perched water table. It reaches the base of the grumosolic horizon in series 10 and 12 and in other series it remains between 90 cm and 120 cm.

The texture always consists of clay and heavy clay in depth. Conversely in the grumosolic horizon the texture is lighter in some series (series 12-13 14).

2.2. Mean chemical characteristics and variations between series.

2.2.1. Mean profile.

Depth cm	CO_3Ca %	Organic matter %	pH 1/2,5	Saturation extract conductivity mmhos/cm	K^+ me/100 g	Na^+ me/100g	E.S.P.	Saturation extract: NaCl ‰ of soil	Saturation extract: SO_4Ca, $2H_2O$ ‰ of soil.	Total P_2O_5 ‰
0-30	19	2,4	8,1	2,0	1,4	0,2	0,8	0,09	0,70	1,9
30-80	20	1,0	8,0	4,3	0,9	0,3	1,1	0,27	1,06	1,8
80+	19	0,8	7,9	7,4	0,7	0,3	1,2	0,92	1,70	1,8

In natural conditions, the content of organic matter is high for the region : 2,4 % owing to the topographic position of vertisols usually located in low and weakly flooded areas or in basins collecting rain-water.

- These soils contain 19 to 20 % of calcium carbonate and pH is approximately 8,0.

- The exchangeable potassium content varies from medium to low whereas in the depth can be noted a slight increase of exchangeable sodium in invariable and very low quantities : 0,2 to 0,3 me/100 g.

- The E.S.P. ratio varies from 0,8 to 1,2 and shows no sign of alkalinization.

- Conductivity of saturated paste remains low at the surface and is moderate in the depth.

- Soluble salts can be divided into two groups :

- Chloride (mainly sodium chloride).

- Sulphate (mainly gypsum).

The chloride content increases in the deeper parts : from 0,2 to 0,5 g/1000, but is still low though not negligible : without drainage, a toxicity-effect due to the concentration of chloride may be observed under irrigation in horizons at a medium depth.

Gypsum also increases with the depth from 0,5 to 0,8 g/1000. The gypsum concentration indicates that the saturation extract dissolves all the gypsum in soils, the highest gypsum solubility being approximately : 1,1 g/1000. Consequently, gypsum accumulation is low in vertisols and this is confirmed by observations.

2.2.2. Variation between series.

Variation mainly concern organic matter,exchangeable potassium E.S.P., and soluble salts of saturation extract measured in ‰ (see table in following page).

The content of organic matter varies according to the flood degree, consequently, to the degree of development of graminea vegetation in the series considered. For instance, for horizon 0-30 cm, the content varies from 0,9 % in the alluvia of BU-Y temporary river (series 9), to 7,8 % in the Mustahil flood area (series 16).

- Series 9-11-12-14 : low organic matter content.

- Series 10 - 13 - 15 - 17 : medium organic matter content.

- Series 16.... : high organic matter.

Conductivity of the saturation extract increases with the depth. At 80 cm depth and deeper down, conductivity is high in series 9-13-14-16 and 17. In the other series it varies from medium to low.

Exchangeable sodium : Na^+ (sodium fixed on the complex) exists in small quantities with a maximum of 0,8 me/100 g in series 11 and a minimum of 0,2 me/100 g in series 9 and 14.

- The ratio E.S.P. is also very low with a maximum of 2,2 in series 11 and a minimum of 0,4 in series 12.

Soluble salts :

Chloride concentration increases with the depth and its maximum is 1,2 ‰ of soil in series 10 and the minimum is 0,06 ‰ of soil in series 9 and 12, these values being low. The chloride content enables to classify these

Depth cm	Series	9	10	11	12	13	14	15	16	17
0 - 30		0,9	2,0	1,1	1,2	3,0	1,1	2,4	7,8	2,6
30 - 80	Organic matter	0,7	0,6	0,9	1,0	1,0	0,6	1,2	0,9	0,6
80^+	%	0,7	0,6	0,8	1,0	1,0	0,5	1,1	0,5	0,6
0 - 30	Saturation extract	1,6	0,5	1,6	2,6	2,0	3,1	2,1	2,0	5,0
30 - 80	conductivity	9,0	0,7	3,2	2,2	5,0	3,3	3,1	4,0	8,0
80^+	mmhos/cm	11,2	0,5	6,6	2,2	12,0	11,0	3,1	12,0	10,0
0 - 30	Exchangeable Na^+	0,2	0,3		0,10	-	0,4	0,3	-	
30 - 80		0,2	0,3	0,8	0,15	-	0,2	0,3	-	
80^+	me/100 g	0,3	0,2	0,5	0,10	-	0,3	0,6	-	
0 - 30		1,5	0,4	-	0,6	-	1,6	0,6	-	
30 - 80	E.S.P.	1,3	0,6	4,0	0,9	-	0,4	0,6	-	
80^+		1,3	0,6	2,2	0,4	-	1,6	1,2	-	
0 - 30	Saturation extract	0,23	0,01	0,10	0,03	0,04	0,08	0,02	0,07	0,23
30 - 80		1,00	0,06	0,08	0,03	0,23	0,04	0,07	0,14	0,92
80^+	NaCl ‰ of soil	1,10	0,01	0,78	0,04	1,85	1,16	0,07	1,85	1,16
0 - 30	Saturation extract	0,44	0,17	0,34	1,03	0,58	1,13	0,75	0,58	1,37
30 - 80	$CO_4Ca, 2(H_2O)$ ‰	1,13	0,20	1,10	0,79	1,37	0,99	1,03	1,06	1,72
80^+	of soil.	1,20	0,14	1,40	0,79	2,75	2,0	1,03	2,75	2,06

soils in scarcely saline soils in the depth (10 - 11 - 12 - 15) and in moderately saline soils in depth (9 - 13 - 14 - 16 - 17).

The gypsum content varies from 0,17 ‰ and 1,5 ‰ of soil, which shows that the gypsum supply in soils is poor.

2.3. Conclusion on vertisols and vertic soils.

Vertisols and vertic soils of the Wabi Shebelle Valley present the following main characteristics :

- Texture consisting of clay and occasionally, of silty loam at the surface.

- Grumosolic topsoil, very well developed and moderately thick (30cm).

- A weak accumulation in the depth of chloride which may concentrate when irrigated and insufficiently drained.

- Poor gypsum supply.

- No profile alkalinization.

3. SOILS WITH A CALCAREOUS DIFFERENCIATION WITHOUT A MELANIC HORIZON (series 18 to 22)

This class of soils includes :

- Soils with powdery lime.

- Soils with calcareous accumulation and nodules.

The genesis of these two types of calcareous accumulation is described in chapter II A.

These soils exist in the surroundings of the valley on ancient stony lime colluvia or alluvia and present no agricultural value. Nevertheless, they constitute the environment of irrigable zones and are shortly described herein.

3.1. Soils with powdery lime.

Series 18 : Yellowish-red soils (5 YR 5/8) ; fine sand, rich in calcareous debris and weakly developed ; debris slopes under limestone plateaus from Gode to Burkur.

Type profile : 6-318.

0 - 15 cm : Light grey (10 YR 7/8) ; fine sand ; medium and weakly developed granular structure tending to single-grained structure; loose and powdery dry with 50 % of coarse elements (calcareous weakly-developed gravel and coarse and scarcely developed elements, 2 to 20 cm, of fine limestone) ; many rootlets ; short transition to :

15 - 60 cm : Reddish-yellow (5 YR 6/8) ; fine sand ; scarcely developed subangular blocky structure tending to single grained structure ; 50 % of the same coarse elements as further above ; very many rootlets ; gradual transition to :

60 cm+ : Yellowish-red (5 YR 5/8) ; fine sand ; weakly developed fine subangular blocky structure tending to single-grained structure ; 90 % of the same coarse elements as above described.

These colluvial soils spread on the slopes of the large limestone plateaus. They consist of fine earth with fine predominating sand as well as of coarse calcareous and weakly developed elements of various sizes, the quantity of which increases with the depth.

There is no gypsum or sodium chloride accumulation.

Series 19 : Yellowish-red soils (5 YR 5/8) ; medium and fine sand with limestone and basalt boulders ; small hillocks of large alluvial fans : Imi.

These soils do not extend far on the Northern bank of the Wabi between Kugno and Imi, and they spread on small hillocks which may be considered as previously existing alluvial fans of temporary rivers rich in limestone and basalt boulders. Fine soil has a relatively coarse texture with medium and fine sands and is probably derived from ancient sandstone alluvia, the latter originating from Duhun sandstone and from the dismantling of the upper parts of the Godja hills. Imi - Ogaden is built on one of these hillocks.

3.2. Soils with calcareous accumulations and nodules.

Series 20 : Red soils (5 YR 4/8) ; silty loam and residual loam with calcareous nodules : limestone plateaus from Gode to Burkur.

These soils largely spread on the limestone plateaus rising above the valleys of the Wabi and of temporary rivers. They are surface soils consisting of yellowish-red material : silty loam rich in calcareous nodules resting, 15 cm below the surface on a limestone slab in situ.

These soils have a high percentage of calcium carbonate (24 to 33 %) and a relatively high organic matter content : 1,4 % which is in relation to the existence of a large thicket growing on all the plateaus not given to grazing because of difficulties of access. Gypsum and sodium chloride accumulations do not exist.

Series 21 : Red soils (5 YR 4/8) ; silty loam and loam with calcareous accumulations and nodules : Imi low - Plateaus.

These soils spread on the broken up low Plateaus, the upper scarp of which consists of zoogeneous sandstone. They are surface soils composed of a red material : silty loam to loam with few calcareous nodules resting on the sandstone slab in situ.

The percentage of calcium carbonate is moderate : 20 %, and these soils are poor in organic matter : 0,8 %, and present no gypsum or sodium chloride accumulation.

Series 22 : Yellowish-red soils (5 YR 5/8) ; coarse to fine sands with calcareous boulders often forming not very deep conglomerates : hillocks of large alluvial fans, Gode.

Type profile : 6-183 : Gode camp on the hillock.

0 - 8 cm : Brownish-yellow (10 YR 6/6) ; loam ; subangular blocky structure tending to single-grained structure ; 60 % of very weakly developed limestone boulders (size : 0,5 cm to 10 cm) with numerous limestone pebbles ; friable ; gradual transition to :

8 - 30 cm : Yellowish-red (5 YR 6/8) ; loam ; 80 % round limestone boulders from 0,5 cm to 15 cm with a redistribution of lime forming nodules and white films ; distinct and steady transition to :

30 cm+ : Conglomerated blocks of limestone boulders coated with reddish yellow calcareous films and numerous white nodules stiking on the boulders.

This type of soil largely spreads on the vast and ancient alluvial fans, North of the Wabi between Gode and Madiso temporary river. Gode town is built on one of these.

The individual characters of limestone are more pronounced in this case than for the two previous types.

Numerous nodules exist and in the base can be observed a discontinuous limestone shell. This process, described in Chapter II a. is surely contemporary with more humid climatic conditions. Sometimes, a powdery sympsum accumulation is superimposed on the calcareous accumulation. The fine soil texture consists of very calcareous, coarse to fine sands (3,5 % of calcium carbonate in the medium horizon), and the organic matter content is low : 0,7 %.

4. SOILS WITH GYPSUM DIFFERENCIATION (series 23 to 47)

This class of soils is the most frequently represented in the Wabi Shebelle Valley as it includes all the soils formed on alluvia (Wabi and temporary rivers) except vertisols and hydromorphic soils.

As regards the soil group, the differenciations depend on the intensity of gypsum accumulation (powdery or with crusts) and for the sub-group they are function of the existence of vertic characters.

Textural classification of soils :

- on Wabi alluvia : the textural profile of soils is usually complex and presents alternated yellowish-brown sandy deposits and brown clay deposits and brown clay deposits from a few centimetres to 50 cm thick.

- the sandy deposits consist of fine sand and loam. They are brownish-yellow with a single-grained structure. When dry they are "loose".

- The clay deposits consist of brown silty loam. They have a coarse angular blocky structure often tending to a cubic or platy structure. Small vertical shrinkage cracks close to one another are frequently seen. The whole structure is compact and small gypsum crystals exist in the deeper deposits.

Depending on the relative importance of these two deposits, the alluvia have been classed in two types :

- Brown alluvia with dominant clay and a medium texture of silty loam.

- Yellowish-brown alluvia where sand is dominant and presenting a mean texture of fine sand.

The distinctions between the textures of the different deposits constituting the soil profile are established for each series.

It is therefore difficult to describe a mean profile but the necessity of synthetizing the results of analyses have led to suggest using physico-chemical models, taking into account the maximum frequency of a type of horizon with the depth. Nevertheless, in order to situate the different series, six type profiles representative of largely developed soil series are described.

- On the alluvia of temporary rivers : the morphological profile is textural and simple the alluvial deposits of temporary rivers have an homogeneous character in relation to transport and deposition in regular hydrological conditions.

4.1. Soils with powdery gypsum

This group includes two sub-groups : modal soils with powdery gypsum; vertic soils with powdery gypsum.

4.1.1. Modal soils with powdery gypsum

4.1.1.1. On the brown alluvia of the Wabi Shebelle - series 23 to 29

These soils which largely spread between Kugno and the Shebelle plain, often form the transition between the soils on the brownish-yellow alluvia along the Wabi and the vertisols generally seen in the outskirts of the alluvial plain.

4.1.1.1.1. Mean morphological and textural characteristics and variations between series

Mean textural profile and morphological features

0 - 20 cm	: silty loam
20 - 90 cm	: silty loam
90 cm +	: fine or clayey sand.

The mean texture consists of silty loam, 90 cm thick, with a basis of fine or clayey sand in depth. It has already been observed that the profile is made up of stratifications of various textures. Here, clay type horizons predominate and give the whole profile a mean silty-loam texture.

- The structure is directly linked to the texture : sandy loose horizons have a single grained structure, whereas clay horizons are compact and present a weakly developed prismatic structure or cubic structure. Conversely, these horizons are sometimes friable with a fine cubic structure and aggregates with conchoidal fracture. Generally considered, the profile may be described as friable to firm.

- The gypsum accumulation is powdery, forms crystals and only exists in clay horizons.

Morphological and textural variations between series :

Types profiles : 3 type profiles represent the most extended series of this group.

Series 24	: Type profile 6 - 89 : Gode plain, two kilometers to the South-West of Gode bridge.
0 - 10 cm	: Light brown (10 YR 6/3); silty loam; relatively well developed fine subangular blocky structure; very friable; many rootlets; uniform and distinct transition to:
10 - 30 cm	: Light greyish-brown (10 YR 6/4); silty loam; a fine subangular blocky structure tending to a single grained structure; friable; numerous rootlets; distinct and steady transition to:
30 - 80 cm	: Reddish-brown (5 YR 5/4); silty-clay; small shrinkage cracks giving prismatic fragments; friable; some gypsum crystals; some rootlets; distinct and steady transition to :
80 cm +	: Yellowish-brown (10 YR 5/4) and striped brownish-black (7,5 YR 3/2); clay; subvertical shrinkage cracks giving prismatic and friable fragments with a mean well-developed subangular blocky structure; many gypsum crystals with sodium chloride.
Series 25	: Type profile 6-11 : Gode plain, one kilometer to the South of Gode bridge.
0 - 15 cm	: Yellowish-grey (10 YR 6/4) : silty loam; subangular blocky structure, tending to a single grained structure; friable and very powdery, a few rootlets; distinct and steady transition to :
15 - 70 cm	: Light-brown (10 YR 6/3); clay with medium angular blocky fragments giving a medium relatively well-developed subangular blocky structure; some subvertical shrinkage cracks, 1 to 3 mm broad; friable; a few rootlets, distinct and steady transition to :
70 - 85 cm	: Yellowish-brown; (10 YR 6/4); silty loam; single-grained structure; dry and loose; a few rootlets; distinct and steady transition to :

85 - 200 cm : Horizon with 2 to 3 cm thick clay stratifications alternated with layers of light-yellow fine sand 10 to 20 cm thick, and single-grained structure; powdery; all the horizon is very friable.

Series 28 : Type profile 6.250 : Track of the two Gode bridges

0 - 3 cm : Brown (10 YR 5/3); clay; very fine to fine angular blocky pseudo-structure; loose; soil mixed with leafmold composed of thorny mimosas; no rootlets; distinct and steady transition to :

3 - 20 cm : Brown (10 YR 5/3); clay; 0,5 to 2 cm; shrinkage cracks in all directions delimiting medium to coarse and friable blocky fragments giving a fine angular pseudo-structure; quite friable; many rootlets; distinct and steady transition to :

20 - 85 cm : Brown to reddish-brown (10 YR 5/3 to 5 YR 5/4); clay streaked with white fine sand; 0,5 to 3 cm broad shrinkage cracks delimiting big and quite friable blocky fragments giving a medium to coarse angular pseudo-structure; firm; many rootlets; distinct and steady transition to :

85 cm + : Brownish-yellow (10 YR 6/6) streaked with brown; loam; single-grained structure; very friable : numerous rootlets.

Profile observations :

- The horizons above described are not real soil horizons but merely layers of non-weathered alluvial deposits. This is confirmed by the distinct limits observed between the different textural layers.

- Great differences in the compacity of the various layers are consequences of the textural variations.

- Powdery gypsum accumulation can only be observed in horizons with clay structures.

Morphological and textural variations of all these series :

These comparative data allow to give precisions as regards the textural variations and depth of the gypsum accumulation (when the latter exists) for each mapped soil series in this soil family on brown alluvia.

-Textural variations between series are important as the textural types are frequently inverted.

-Nevertheless, for horizon 30-90 cm, the sandy texture distinctly predominates with silty loam, loam and fine sand and allows to consider that these series present a medium texture.

-In the depth (+ 80 cm), variations are important; some series consist of fine sand (23-25) and others of clay (26-29). These variations must be taken into consideration when studying the importance of the drainage system to be installed for irrigation purposes.

- A powdery gypsum accumulation is distinctly seen in series 24-26-27 29 and 34. It is not considerable in series 28 and is scarcely visible in series 23 and 25.

BROWN WABI SHEBELLE ALLUVIA								
Depth cm	23	24	25	26	27	28	29	34
10		Sil	Sil	SiC	Cl	C		
20	SiC						Fs+Sil	
30					Sil			Fs
40					Sil			
50		SCL	C			C		
60	Fs			SiL	L		SiL	
70								
80								vfSC
90								
100								
110		SiC-L	Fs					
120				C	CL	L	C	
130								SiL + C
140								
150								
Type profile		6-89	6-11			6-250		

4.1.1.1.2. Mean chemical characteristics and variations between series

-Mean profile

Depth cm	CO_3Ca	Organic matter	pH 1/2,5	Saturation extract conductivity mmhos/cm	K^+ me/100g	Na^+ me/100g	Saturation extract: NaCl °/°° of soil	Saturation extract: $SO_4Ca, 2H_2O$ °/°° of soil	P_2O_5 total °/°°
0 - 20	20	1,0	8,1	2,7	1,5	0,2	0,32	0,51	1,8
20 - 90	19	0;8	8,2	2,6	0,4	1,1	0,05	0,39	1,6
90 cm	20	0,4	9,5	9,5	0,8	1,0	1,60	1,90	1,6

The content of organic matter is low : 1,0 % is the content of most of the soils where no flooding occurs and no depression effects can be observed (except for series 23 and 28).

The average calcium carbonate content in these soils is 20% and pH is slightly over 8,0.

- The content of exchangeable K+ is high.
- The content of total P_2O_5 is also high.

Conductivity of the saturation extract increases with depth and its mean value is 9,5 mmhos below 90 cm.

The soluble salt content is still low but under irrigation if drainage is insufficient, sodium chloride may concentrate and have a toxic effect on plants.

Variations between series

These variations mainly affect organic matter and soluble salts measured in the saturation extract in °/₀₀ of soil.

Depth cm	Series	23	24	25	26	27	28	29
0 - 20 20 - 90 90 +	Organic matter °/₀	2,3 0,3 0,3	1,1 0,9 0,6	0,9 0,9 0,4	0,8 0,7 0,8	1,0 0,6 0,3	2,3 1,0 0,6	0,6 0,8 0,5
0 - 20 20 - 90 90 +	Saturation extract conductivity mmhos/cm	10,0 3,0	1,0 0,7 3,8	0,8 4,1 22,7	1,0 2,0 12,0	1,0 3,0 6,0	2,0 3,0 4,1	3,0 2,8 8,3
0 - 20 20 - 90 90 +	Saturation extract Na Cl °/₀₀ of soil	1,40 0,05	0,03 - 0,14	0,02 0,25 4,6	0,03 0,02 1,85	0,02 0,03 0,50	0,05 0,02 0,23	0,7 0,02 1,04
0 - 20 20 - 90 90 +	Saturation extract $SO_4Cl,2(H_2O)$ °/₀₀ of soil	1,70 1,03	0,26 0,24 1,23	0,27 1,20 3,44	0,29 0,68 2,06	0,31 1,03 1,7	0,51 1,03 1,20	0,20 0,96 1,72

The organic matter content is approximately 1.7 % or lower but in series 23 and 28 it exceeds 2 % owing to the influence of floods which considerably stimulates the growth of the tree vegetation :

- In series 23, the soils are formed in the ox - bows of the Wabi which are periodically flooded : Imi and Northern Gode zones.

- In series 28, general floods with a low amplitude affect the dense thicket zone North of Kelafo, and the cultivated zone downstream from Kelafo.

Conductivity of the saturation extract is variable.

It is low at the surface except in series 23 where it rises to 10 mmhos/cm.

Conversely, conductivity increases with the depth and is high in series 25 and 26 and below a 90 cm depth. Consequently, the sodium chloride content largely increases in these series (respectively 4,6 °/°° and 1,85 °/°° of soil). The other series are not very saline even in depth.

4.1.1.2. On yellowish-brown alluvia of the Wabi Shebelle : Series 30-34

These series are located on the recent or ancient natural levees of the Wabi : along the river, from Imi to the Somalian frontier where they stretch discontinuously and along the abandoned channels of the river where they usually largely spread : Gode plain : series 32, Northern Kelafo plain : series 32 and Shebelle plain : series 34.

4.1.1.2.1. Mean morphological and textural characteristics and variations between series

Mean textural profile and morphological features

0 - 10 cm : Fine sand; silty loam.

10 - 60 cm : Fine sand.

60 - 100 cm : Fine and coarse sands.

100 cm + : Loam and fine sand.

- The texture is mainly sandy to fine sand, which does not exclude stratifications of clay, loam and silt in the upper horizons, or clay horizons in the depth (V. series).

- The structure is single-grained and the horizons are friable and loose.

- The gypsum accumulation is more powdery than in the series on brown alluvia.

Morphological and textural variations between series.

Type profiles : 2 profiles are described and represent the two most largely spread series of the valley : series 32 and 34.

Series 32

Type profile : n° 6-17 : Gode plain, 7 km to the South of Gode bridge; previously existing natural levee of the Wabi, discontinuous graminea carpet :

0 - 10 cm : Light brown (10 YR 6/3); loam; single-grained structure; loose and powdery; many rootlets; gradual transition to :

10 - 30 cm : Light yellowish-brown (5 YR 6/4); loam; single-grained structure ; friable and powdery; some rootlets; distinct transition to :

30 - 65 cm : Light yellowish brown (10 YR 6/4); loam; single grained structure; very friable; a few rootlets; distinct and uniform transition to :

65 - 95 cm : Light yellowish brown (10 YR 6/4); silty; friable angular blocky fragments; powdery leading to single-grained structure; generally friable; distinct and steady transition to :

95 - 165 cm : Light brown (75 YR 6/4); silty loam; 1 to 8 mm broad sub-vertical shrinkage cracks delimiting fragments tending to be prismatic. Relatively compact horizon; no rootlets; distinct and uniform transition to :

165 cm + : Yellowish brown (10 YR 5/6); silty loam; platy structure; friable; no rootlets.

Series 34 : Type profile : n° 6-223 : ancient natural levee of the Wabi Shebelle, palm-tree vegetation : Hyphaene thebaïca, some graminea tufts.

0 - 25 cm : Light brown (7,5 YR 6/4); silty loam; subangular blocky structure with single-grained trend; very friable; powdery; numerous rootlets; distinct and uniform transition to :

25 - 60 cm : White (10 YR 8/2); fine sand; single-grained structure; loose; numerous mica crystals; some rootlets; distinct and uniform transition to :

60 - 95 cm : Brownish - black (10 YR 4/3); clay; shrinkage cracks in all directions delimiting medium to coarse angular fragments with many gypsum crystals; friable; some rootlets; distinct and uniform transition to :

95 - 135 cm : Whitish - yellow (10 YR 8/4): silty loam; fine subangular blocky structure tending to single-grained structure; powdery; very friable; very few rootlets; distinct and uniform transition to :

135 - 160 cm : Brown (10 YR 5/3); silty; cracks in all directions delimiting small fragments forming a coarse subangular blocky structure; many gypsum crystals; no rootlets; distinct and uniform transition to :

160 cm + : Fine stratification of fine sands and loam; single-grained structure; friable;

<u>Observations on profiles</u>

The horizons described are in fact layers of alluvial deposit characterised by very distinct limits.

- Textural variations are considerable : sandy layers consisting of fine sand, fine silty sand and clay layers, but loose or friable sandy layers predominate; besides, the clay layers are not very thick (10 to 30 cm) and are usually friable (except for series 31).

- Powdery gypsum accumulation can only be observed in clay horizons or in deep silty horizons.

Morphological and textural variations in all the series

On brownish yellow Wabi Shebelle alluvia					
Series	Imi-Northern Gode		Imi Northern Gode Kelafo	Southern Kelafo Mustahil-Burkur	
Series	30	31	32	33	34
Depth cm 10	L SiL	fs	SiL	SiL	fs - SiL
20			SiL		L
30					
40		fs			
50	csfs		SiL		
60				SiL	
70					CL
80					
90	cs	C	SiL		
100					
110					
120				fs	
130	L fs				SiL + C
140					
150					
Type profile			6 - 17		6 - 223

- The sandy type texture : silty loam and fine sand, largely predominates.

- Clay forms a thick deposit in series 31.

- In general, the texture of deposits of natural levees becomes finer from the upstream part to the downstream part. It is rich in fine sand and coarse sand in Imi region (Series 30), turns into silty loam towards Gode and Kelafo (series 32) and even into silty loam + clay in the Shebelle plain (series 33).

- The powdery gypsum accumulation is usually scarcely visible in clay or silt accumulations. Gypsum crystals generally appear at 1 m. depth. However; they can also be observed higher in the profile when clay deposits are present not far from the surface (series 31, Imi region).

4.1.1.2.2. <u>Mean chemical characteristics and variations between series</u>

<u>Mean profile</u>*

Depth cm	CO_3Ca %	Organic matter %	pH 1/2,5	Saturation extract conductivity mmhos/cm	K^+ me/100g	Saturation extract		P_2O_5 total °/°°
						NaCl °/°° of soil	$SO_4Ca,2H_2O$ °/°° of soil	
0 - 10	18	1,3	8,2	1,8	3,8	0,07	0,48	1,3
10 - 60	14	1,2	8,3	1,8	3,6	0,03	0,45	1,4
60 -100	17	0,9	8,2	3,6	3,1	0,16	0,92	1,5
100 +	17	0,5	8,1	4,0	1,0	0,2	1,20	1,9

- The organic matter content is slightly higher than the mean content observed in the local climatic conditions. This is due mainly to the development of a rather dense tree vegetation (<u>Tamarix</u>, <u>Hyphaene thebaïca</u>) on the natural levees (see : survey of different series) where shallow ground water exists :

- Soils contain 14 to 18 % of calcium carbonate and the pH is approximately 8,2.

- The content of exchangeable K^+ is higher : over 3 me/100 g of soil, this corresponding to the abundance of phogopite mica observed in the sandy stratifications of most of the series.

* Series 31 is very saline and is not taken into account in the average percentage.

- The total phosphorus content is high.

- Conductivity steadily increases with the depth but the values remain low. This is also true for soil salinity due to sodium chloride.

Variations between series

Depth cm	Series	30	31	32	33	34
0 - 10 cm 10 - 60 60 - 100 100 +	Organic matter %			0,6 0,4 0,3 0,3	1,3 1,3 1,3 0,7	1,3 1,2 0,9 0,5
0 - 10 10 - 60 60 - 100 100 +	Saturation extract conductivity mmhos/cm	2,0 2,0 4,0 6,0	17 27 55 50	1,0 1,1 3,9 3,1	2,2 1,0 1,0 2,7	2,0 3,0 4,0 22,0
0 - 10 10 - 60 60 - 100 100 +	Saturation extract NaCl °/oo of soil	0,2 0,2 0,20 22,00	2,70 5,30 12,30 13,40	0,03 0,03 0,23 0,07	0,18 0,04 0,04 0,03	0,02 0,04 0,25 4,60
0 - 10 10 - 60 60 - 100 100 +	Saturation extract $SO_4Ca, 2\ H_2O$ °/oo of soil	0,70 0,72 1,20 1,70	0,70 1,30 8,3 5,1	0,26 0,26 1,23 1,0	0,58 0,30 0,30 1,0	0,65 1,05 1,10 2,3

- The organic matter conten in series 32 is very low. In series 33 and 34 it is slightly above the average percentage owing to the existence of a rather dense tree vegetation.

- Conductivity of the saturation extract is generally low except in series 31 in which conductivity is high at the surface, and in series 34 in which it is high in the depth.

- Chloride content,is also high in series 31 and medium in the depth for series 34.

4.1.1.3. On yellowish-red alluvia of temporary rivers. Series 35 - 36 - 37 - 38

These series are formed on the alluvial fans in a high (series 35) or medium (series 36) position and also on recent alluvia of temporary rivers (series 36 and 38).

Series 35 : These reddish-yellow soils consisting of fine sand to loam with boulders in the depth are often saline. They occupy the higher part of alluvial fans of temporary rivers from Gode to Burkur. They are usually cut into strips by the ramifications of temporary rivers which continue downstream.

Series 36-37-38 : These three series are interesting for land reclamation and will be described in detail.

4.1.1.3.1. Mean morphological and textural characteristics and variations between series

Mean profile

Unlike the series resting on Wabi alluvia, the textural homogeneous character of the series on the alluvia of temporary rivers enable to reconstruct a mean profile.

0 - 30 cm : Reddish-yellow (5 YR 6/8); silty loam to loam; subangular blocky structure tending to single-grained structure; very friable; gradual and uniform transition to :

30 cm + : Reddish-yellow (5 YR 6/8); silty loam to loam; flat friable fragments giving a subangular blocky structure tending to a single grained structure; the whole structure is scarcely friable; numerous small gypsum crystals.

The mean texture consequently consists of silty loam to loam.

The structure is single-grained but in the depth the soil becomes massive.

The gypsum accumulation is not very deep (30 cm) and not very pronounced.

Variations between series :

Depth cm	Series 36	Series 37	Series 38
10			
20	L ms	SiL	
30			
40			fs
50			
60	L ms	SiL	
70			SiL
80			
90			
100			
110			
120			
130			

- Textural variations within a same series are small and are linked to the regime of temporary rivers to which is due the deposition of material presenting an homogeneous texture.

- The textural variations between series are linked to the origin of sedimentation.

For instance, in Imi region can be observed for series 36, the existence of medium sand resulting from the disaggregation of Gesoma sandstone in the Duhun region.

The fine sands of series 38 (Madiso temporary river) also originate from this region.

Conversely, series 37 is typically derived from weathered Mustahil limestone.

Therefore, no clay exists in the texture and the following consequences may be observed :

- For series 36 and 37 the non-clayey texture consisting of silty loam determines very unfavourable conditions as regards water infiltration in soils.

- For series 36 , the very permeable soil is due to the presence of medium sandy elements.

4.1.1.3.2. Mean chemical characteristics and variations between series

Mean profile

Depth cm	CO_3Ca %	Organic matter %	pH 1/2,5	Saturation extract conductivity mmhos/cm	K^+ me /100 g	Saturation extract Na Cl °/oo of soil	Saturation extract $SO_4Ca2\ H_2O$ °/oo of soil	Total $P_2\ O_5$ °/oo
0-30	21	0,7	8,1	3,0	0,8	0,11	1,03	1,2
30 +	22	0,5	8,0	14,0	1,3	2,87	2,13	2,4

- The organic matter content is low owing to the fact that the surface is not subject to temporary river flooding.

- Soils are composed of 21 to 22 % of limestone and pH is about 8,0.

- Exchangeable potassium content is high.

- The total phosphorus content has a medium value at the surface and is high in the depth.

Conductivity rapidly increases with depth and reaches rather high values. However, the sodium chloride content has a medium value.

Variations between the series

These variations are very low. Great differences only exist as regards the conductivity of the saturation extract :

Conductivity of the saturation extract mmhos/cm

Depth cm	Series 36	Series 37	Series 38
0 - 30	3,0	3,0	3,0
30 +	2,0	12,0	28,0

For the Imi "sandy" series(36), conductivity is very low in depth and conversely, in series 38 it largely increases in depth : 28 mmhos/cm, this owing to the influence of the Madiso water table during the rainy season and to its soluble salt content.

Conclusions

Consequently, the general characters of these soils are :

- a texture with dominant fine and non-clayey elements, high infiltration capacity or very low permeability.

- a low and variable conductivity for series 36 (Imi) but a high conductivity for series 38 (Madiso).

4.1.2. Vertic soils with powdery gypsum : series 39-40-41-42

These soils are formed on the brown alluvia of the Wabi, on yellowish-red alluvia of temporary rivers and on the Wabi yellowish-brown alluvia overlaying red basaltic alluvial deposits.

They are characterised by vertic features appearing in the depth and linked to a clayey texture with shrinkage cracks and slickensides in some places.

4.1.2.1. On brown alluvia of the Wabi Shebelle.

Series 39 is not largely spread in the plain to the North West of Gode near the Madiso temporary river. On the contrary, series 40 largely spreads in Gode plain and in the plain to the North-West of Kelafo, downstream from Didjinober hill.

4.1.2.1.1. Morphological and textural characteristics

Type profile : series 40, profile n° 6-61, 6 km away from the Wabi, to the South East of Gode; some graminea tufts.

0-10 cm : Brown (10 YR 5/3); silty loam; subangular blocky structure tending to single grained structure; friable; powdery; short and uniform transition to :

10-30 cm : Dark brown (10 YR 4/3); silty loam; shrinkage cracks in all directions delimiting medium, friable and weakly developed subangular blocky fragments; numerous rootlets, friable; short and undulated transition :

30-75 cm : Dark yellowish-brown (10 YR 4/4); clay; shrinkage cracks in all directions delimiting medium to coarse subangular blocky fragments; quite friable; very few rootlets; gradual transition to :

75-180 cm : Dark brown (10 YR 4/3); clay; small shrinkage cracks in all directions delimiting coarse angular blocky fragments with some horizontal slickensides; no rootlets; some gypsum crystals; compact.

The 30 first centimeters consist of silty loam but, in the depth, the profile is mainly composed of clay.

The structure is weakly developed at the surface and is subangular blocky. In the depth a "superstructure" of subangular blocky type becoming gradually coarser and delimited by vertical and oblique shrinkage cracks, confers a certain friability to the horizons. The slickensides are distinct in some places but only affect the horizontal sides of fragments.

The gypsum accumulation is still weak and forms crystals in the depth.

Compared textural characteristics of series 39 and 40 :

Depth cm	Series	
	39	40
10	SiL	SiL
20		
30		
40	SiC	
50		C
60		
70		
80		
90	Sic C	
100		C
110		
120		
130		
140	Sic	
150		
Type profile		6-61

The textural differences between these series are small. However series 39 is less clayey and richer in fine silt.

In both series can be seen a silty loam horizon at the surface and approximately 10 cm thick.

Gypsum accumulation forming crystals is observed below 60 cm.

4.1.2.1.2. Chemical characteristics

They are almost similar in there two series. The average values are given in the following table.

Depth cm	CO_3Ca %	Organic matter %	pH 1/2,5	Saturation extract conductivity mmhos/cm	K^+ me/100g	Na^+ me/100g	Saturation extract: Na Cl °/°° of soil	Saturation extract: $SO_4Ca,2\ H_2O$ °/°° of soil	Total P_2O_5 ‰
0-10	21	1,1	8,3	1,5	1,2	0,5	0,05	0,45	2,4
10-60	21	1,0	8,1	4,5	0,8	0,7	0,16	1,37	2,1
60 +	21	0,5	8,0	11,0	0,5	1,4	1,6	2,20	2,2

The organic matter content is low and corresponds to the contents usually observed in soils in semi arid climates.

- An average of 20 % of calcium carbonate in the soils with a p H slightly above 8,0.

- High content of exchangeable potassium.

- High total phosphorus content.

- Low conductivity of saturation extract at the surface, and relatively high conductivity in the depth. However, chloride contents are still rather low.

4.1.2.2. On yellowish-red alluvia of temporary rivers (series 41)

This series consists of yellowish-red soils with silty loam and clay formed on the recent alluvia of temporary rivers, from Imi to Kelafo and stretching along these rivers for a generally short distance of about 100 to 200 m and sometimes more (2 km, to the South of Kelafo lake) as well as in the lower part of alluvial fans of temporary rivers (in particular : South of Gode plain).

The vegetative cover consists of a thicket of thorny shrubs of Acacia and Commiphora type. The graminea carpet is dense.

Type profile : n° 6-218, 4 km to the South West of Kelafo. Rough and broken up microrelief with large cracks.

0 - 20 cm : Reddish - yellow - brown (7,5 YR 5/6); silty loam; medium to fine well-developed subangular blocky structure; powdery and unstable aggregates; many small shrinkage cracks; friable; short and uniform transition to :

20 - 100 cm : Reddish - yellow (5 YR 6/8); silty loam and clay; big subvertical shrinkage cracks (1 to 3 cm) delimiting large friable subangular fragments tending to a single-grained structure; compact; some gypsum crystals; some rootlets; gradual transition to :

100 cm + : Yellowish - red (5 YR 5/8); clay; small shrinkage cracks; small flat angular fragments; massive and very compact; numerous small gypsum crystals, very few or no rootlets.

4.1.2.2.1. Mean morphological and textural characteristics

Depth cm	Serie 41
10	SiC
20	
30	
40	SiC
50	
60	
70	C
Type profile	6-218

Reddish-yellow to yellowish-red soil with a texture of silty loam to silty clay loam forming a 20 cm thick layer. However, the texture is always clayey in the depth.

The structure is characterized by a general cracking of the profile when dry, these cracks going in all directions and delimiting subangular blocks, the size of which increases as they are deeper.

The latter are still friable with a powdery single-grained structure in horizons 0 to 60 cm.

In the depth, the structure becomes massive and tends to become a prismatic structure and this appears at the surface in the form of a gilgai microrelief. Slickensides seldom exist.

- The gypsum accumulation is for more distinct than in the previously described series. It appears at approximately a 60 cm depth in the clay horizon, but always as a powdery accumulation (separate crystals).

4.1.2.2.2. Mean chemical characteristics

Depth cm	CO_3Ca %	Organic matter %	pH 1/2,5	Saturation extract conductivity mmhos/cm	K^+ me/100 g	Na^+ me/100g	E^+SP	Saturation extract: Na Cl °/oo of soil	Saturation extract: $SO_4Ca,2H_2O$ °/oo of soil	Total P_2O_5 °/oo
0-10	32	0,6	8,2	1,0	0,9	0,1	2	0,01	0,30	1,9
10-60	32	0,5	8,2	0,5	0,5	0,1	2	0,01	0,17	1,7
60 +	27	0,4	8,1	28	0,5	10,4	10,4	6,3	1,72	1,7

The organic matter content is very low despite the important thicket cover. In fact, vegetation is only active for a short period in the year and the litter of Acacia and Commiphora is not very abundant and is soon mineralized.

- Large quantities of calcium carbonate in the soils and pH approximately : 8,2.

- Exchangeable potassium contents are high.

- Total phosphorus contents are also high.

Soluble salts

The chloride accumulation in the depth is high 6,3 % of soil. Besides, alcalinization below 60 cm depth can be observed and E.S.P. is above 10. However, alcalinization is low owing to the presence of abundant sulphates : the gypsum content of the saturation extract shows that after this extraction, gypsum supplies still exist in the soils.

Conclusion

The existence in soils of abundant chlorides constitute a major difficulty for soil reclamation, as the toxicity level may soon be reached in the upper horizons if drainage is insufficient. In fact, as will be seen further on, these soils should not be used for agricultural purposes and should be separated from the Wabi Shebelle alluvial soils by a drainage "belt".

4.1.2.3. Yellowish-brown alluvia of the Wabi Shebelle overlaying red basaltic alluvia : series 42

This series only covers a 320 ha. area approximately between the basalt hills and the river, 25 km to the North West of Gode.

4.1.2.3.1. Morphological and textural characteristics

These yellowish - brown soils consist of silty loam to red clay. Their texture is distinctly discontinuous on the level of the overlap contact, at about 120 cm depth.

Depth cm	Serie 42	
10		
20		
30		
40	SiL	Wabi Shelle alluvia
50		
60		
70		
80		
90	SiL	
100		
110		
120		Basaltic alluvia
130		
140		
150		

The structure in the higher level is subangular blocky tending to a single-grained structure. But in the higher level vertic characters appear with cracks and some slickensides.

4.1.2.3.2. Chemical characteristics

- Medium organic matter content is about 1,3 %.

- Limestone content is low with 13 to 16 %.

- pH : 8,3.

- Medium total phosphorus contents.

- Conductivity is low as well as the soluble salt content.

Depth cm	CO_3Ca %	Organic matter %	pH 1/2,5	Saturation extract conductivity mmhos/cm	Saturation extract		Total P_2O_5 °/oo
					Na Cl °/oo of soil	$SO_4Ca,2H_2O$ °/oo of soil	
0-60	13	1,3	8,5	2,0	0,1	0,6	1,1
60-120	15	0,7	8,5	2,0	0,1	0,6	1,0
120 +	16	0,4	8,4	2,0	0,1	0,6	1,1

4.2. Soils with gypsum crusts : series 43 to 47

Soils with gypsum crusts exist in :

- The lower parts of alluvial fans of temporary rivers in the outskirts of the Wabi Shebelle from Imi to Burkur.

- The slopes of basalt hills between Gode and Imi which do not extend far.

- The yellowish - brown Wabi Shebelle alluvia between Gode and Didjinober hill.

The genesis of gypsum crusts is described in Chapter II A.

4.2.1. Soils on colluvia derived from basaltic formations,series 43

This series is composed of red soils with sandy clay loam to clay with gypsum crust at about a 60 cm depth on the debris slopes of basaltic hills between the Madiso temporary river and Gode, on the Northern bank of the Wabi Shebelle. The soil structure is generally single-grained at the surface,but becomes prismatic at a medium depth just above the gypsum capping. This gypsum capping is very friable and consists of light red gypsum crystals. The weakly developed basalt pebbles are numerous throughout the whole profile. Many small runoff gullies run across the soil surface which is unfit for any soil-reclamation purpose. Moreover, analyses show :

- a high conductivity of saturated paste : 22 mmhos/cm.

- Sodium chloride contents exceeding 2 % of soil just above the gypsum capping which is crust.

4.2.2. Soils on the yellowish-red alluvia of temporary rivers : series 44 - 45 - 46.

These series are formed in the lower parts of alluvial fans of temporary rivers from Imi to Burkur. They largely spread along the Northern bank of the Wabi Shebelle between Madiso and Didjinober hill. The global area measured on the map exceeds 50 000 ha.

4.2.2.1. Morphological and textural characteristics :

Type profiles

Series 44 : Type profile: n° 6-181 : alluvia of temporary rivers near the Water Resources camp recently subject to land clearing.

0 - 30 cm : Light red; clay loam; subangular blocky structure tending to a single-grained structure; dry very friable and powdery; dense root network; small limestone black and white pebbles; gradual transition to :

30 - 80 cm : Red clay; medium to fine well developed subangular blocky structure; relatively humid; compact; few small and hard weakly developed pebbles; a few rootlets; gradual transition to :

80 - 125 cm : Deep red; clay; massive and very compact;relatively humid; saline; no rootlets; gradual transition to :

125 - 185 cm : Deep red; clay; massive and compact with progressive accumulation in the depth of gypsum crystals forming a mass; no rootlets.

Series 45 : Type profile: 6-317 North of Mustahil plain; alluvial fans of temporary rivers; some small halophyte plants.

0 - 8 cm : Grey fine sand : weakly developed angular blocky structure tending to a single-grained structure ; numerous white sodium chloride crystals; gradual and steady transition to :

8 - 35 cm : Yellowish-brown: sandy clay loam; single-grained structure; 20 to 30 % of gravels with some fine limestone pebbles saline but no visible sodium chloride crystals; humid and friable; some dead rootlets; distinct and steady transition to :

35 - 75 cm : Fine and many-coloured; light greyish-red and dark grey soils; loam; many gypsum crystals; single-grained structure; humid and friable; progressive and steady transition to :

75 - 150 cm : Well contrasted multicoloured: grey (gypsum crystals) and light red clay single grained structure; some fine limestone pebbles; humid and friable; no rootlets; sudden transition to :

150 cm : Saline,compact gypsum crust giving friable fragments.

Profile observations

Gypsum crusts are formed progressively. The quantity of crystals increases from the medium part down to the base of the profile where they form a mass. This crust is usually massive but the fragments are always friable. Series 46 shows a specific example of crystals caught in the mass and forming small "sand roses" which are miniatures of those seen in deserts.

The single-grained structure in the upper horizons frequently presents a coarse prismatic character in the depth and small cracks. This is due to the temporary waterlogging caused by the gypsum crust.

Morphological and texture characteristics of the three series :

Depth	Series		
cm	44	45	46
0	SiL	SiL	L
10 20 30 40 50 60 70	SiL	SiC	SiC
80 90 100 110 120 130 140 150	gypsum crust	gypsum crust	gypsum crust
Type profile	6-181	6-317	

The texture varies from silty loam (series 44) to silty clay (series 45 and 46) but the upper horizon (0 - 10 cm) presents a silty loam, silty clay or loam texture.

This textural type determines :

- A powdery character in the surface horizon, but in the depth the horizon is compact to dry.

- The general permeability is low as can be observed from the presence of residual puddles which are still visible at the surface long after rainfall.

4.2.2.2. Mean chemical characteristics

Depth cm	CO_3Ca %	Organic %	pH 1/2,5	Saturation extract conductivity mmhos/cm	K^+ me/100g	Saturation extract Na Cl °/₀₀ of soil	Saturation extract $SO_4Ca,2\ H_2O$ °/₀₀ of soil
0-10*	25	0,9	8,1	1,6	0,6	0,02	0,62
10-70	26	0,6	8,0	2,9	0,5	0,11	1,03
70 +	35	0,3	8,1	24,0	1,1	5,6	2,54

* In the first horizon of series 45 which may be considered as a saline crust, the conductivity of the saturated paste is 143 mmhos/cm. The organic matter content is low : 0,9 % at the surface; the CO_3 Ca content varies from medium to high : 25 to 35 %; pH is close to 8,0 and indicates that there is no soil alkalinisation; exchangeable potassium is medium to high.

But the considerable increase of conductivity in the depth must be noted.

Conductivity of the saturation extract remains low, down to a 30 cm depth : 1,6 to 2,9 mmhos/cm, but it considerably rises in the depth and is 24 mmhos/cm at the level of the gypsum crust. This is mostly due to the increasing chloride concentration which is multiplied by 50 compared to the horizon situated immediately above and which reaches : 5,6 % of soil.

The sulphate content is close to the saturation degree below a 10 cm depth, and indicates that the sulphate supplies are important practically from the soil surface and deeper down.

The large quantities of chlorides contained in the depth of these soils constitute a major difficulty as regards soil reclamation. Moreover, the available boron content is very high : approximately 75 ppm, and this concentration is extremely toxic for most cultivated plants.

4.2.3. Soils on yellowish-brown alluvia of the Wabi Shebelle overlaying the yellowish red alluvia of temporary rivers Series 47

This series composed of yellowish-brown soils with sandy clay loam and yellowish-red clay spreads over 4 900 ha on the Northern bank of the Wabi Shebelle.

4.2.3.1. Morphological and textural characteristics

Type profile n° 6-182. situated 1 km to the South of the Water Resources camp.

Relatively dense graminea vegetation; some thorny shrubs.

0 - 15 cm : Greyish-brown (10 YR 5/2); fine sand; subangular blocky structure tending to a single-grained structure dry and loose; numerous rootlets; short steady transition to :

15 - 60 cm : Yellowish-brown (10 YR 5/4); fine sand; subangular blocky structure tending to a single-grained structure; loose and dry; many rootlets; some loam stratifications; distinct and steady transition to :

60 - 75 cm : Dark brown (10 YR 4/3); clay; medium to fine well-developed angular blocky pseudo-structure with dry friable conchoidal fracture; rootlets still exist; distinct and steady transition to :

75 cm + : Yellowish-red (5 YR 5/6); clay; massive; scarcely friable fragments giving a fine angular blocky structure; many gypsum crystals tending to form a crust; no rootlets; compact, dry.

Observations :

- The superimposition of the two types of alluvia : grey for the Wabi and red for those of temporary rivers, is delimited by the difference in the colouring below 75 cm.

The texture consists of :

. Fine sand for grey alluvia. However, the characters, of Wabi deposits being varied, not very thick clay layers can be observed from a 60 to 75 cm depth.

. Clay for the subjacent alluvia of temporary rivers

. The gypsum crust is more or less distinct. It is not very pronounced in the case of the profile above described, but it is very distinct to the East of Gode towards Machekoke village.

4.2.3.2. Mean chemical characteristics

Depth cm	CO_3Ca %	Organic matter %	pH 1/2,5	Saturation extract conductivity mmhos/cm	K^+ me/100g	Na^+ me/100g	Saturation extract		Total P_2O_5 ‰
							Na Cl ‰ of soil	$SO_4Ca,2H_2O$ ‰ of soil	
0-10	23	1,0	8,0	0,4		0,1	0,01	0,15	1,6
10-60	23	0,8	7,9	2,9		0,1	0,13	1,0	2,1
60 +	22	0,6	7,8	4,0			0,44	0,86	1,8

The organic matter content is very close to the average content in the considered zone : 1 % at the surface.

The calcium carbonate content has a medium value : 22 to 23 % and pH varies from 7,7 to 8,0.

The total phosphorus content is high.

Conductivity of the saturation extract though it increases with the depth, remains low : 4 mmhos/cm, with a low chloride content : 0,44 ‰ of soil.

These soils might consequently be irrigated, reservations being made as regards the depth of the gypsum crust (still 60 to 70 cm but more or less consolidated) as well as regards the available boron content which is also probably high.

5. MODERATELY ORGANIC HYDROMORPHIC SOILS : series 48 and 49

These soils only exist on the Wabi alluvia of flood zones. Their originality consists in an accumulation of organic matter which is quite unusual in this region (see chapter II C).

5.1. Soil series of the Wabi Shebelle plain : series 48

Consisting of brown clay soils, it spreads over more than 10 000 ha to the North of the Shebelle plain in a long-duration flood zone, downstream from Kelafo where the river divides into many never dry branches. Overflowing exceeds a 50 cm level during the floods but the water table is never below a 1 m, 5 depth during the minimum flow period with a capillary fringe less than 30 cm below the surface.

Vegetation mainly consists of *Cyperaceae* of Papyrus type but also of tall trees with ligneous thorns.

5.1.1. Morphological and textural characteristics

Type profile : n° 6-227, at 2 km from the old Kelafo - Mustahil track.

0 - 15 cm : Very dark grey (5 YR 3/1); silty clay; very organic, plastic and wet; numerous small roots and rootlets; short and slightly undulated transition to :

15 - 50 cm : Reddish-brown (5 YR 4/3); clay; plastic and wet ; numerous small roots and rootlets; angular fragments easily separated from the profile; some rootlets can still be found; short and uniform transition to :

50 cm + : Reddish-brown (5 YR 4/3) with red stripes (2,5 YR 4/6) ; small very clayey gypsum crystals ; wet ; plastic ; angular fragments which can be easily separated from the profile; some rootlets.

Observations :

Very clayey texture throughout the profile, in relation with the alluvial deposition by slow flow.

- The structure is not well defined, the whole profile being usually wet. The whole soil is plastic and sticky; in some cases the pseudo-structure linked to the type of alluvial deposits, gives the horizons a very friable character.

- After a 50 cm depth, gypsum crystals can often be observed and in some places, brick-red manganese blots.

5.1.2. Chemical characteristics

Depth cm	CO_3Ca %	Organic matter %	pH 1/2,5	Saturation extract conductivity mmhos/cm	K^+ me/100g	Na^+ me/100g	Saturation extract: Na Cl °/oo of soil	Saturation extract: $SO_4Ca,2\ H_2O$ °/oo of soil	Total P_2O_5 ‰
0-15	14	11,0	7,9	3,9	1,2	0,8	0,04	1,51	2,6
15-50	17	1,5	8,0	3,2	0,4	0,9	0,07	1,03	2,0
50 +	16	0,8	8,1	3,6	0,7	0,7	0,09	1,03	2,0

- Accumulation of organic matter is high : 11 % for 15 cm, but it suddenly falls to 1,5 % and less in the depth. This surface humus concentration is due to the quick mineralization of the latter which soon disappears under a large and permanent addition of organic matter.

- Calcium carbonate content is low and pH is close to 8,0.

- Medium to high exchangeable potassium content.

- Total phosphorus : high content.

- Conductivity of saturated paste throughout the profile is less than 4 mmhos/cm.

- Sodium chloride content is low and the gypsum content shows that powdery gypsum supplies exist in the soils.

5.2. Soil series of the Mustahil plain : series 49

It consists of brown clay soils and stretches over 1 800 ha in the Northern part of Mustahil plain under a dense graminea vegetation. The water level is 50 cm high during the floods. However, in the dry season the ground-water level is 2 meters below the surface and the capillary fringe at 80 cm below the surface.

5.2.1. Morphological and textural characteristics

Type profile n° 6 273 at 4 km to the North of the Wabi, Mustahil plain, dense vegetation of tall graminea.

0 - 7 cm : Dark grey (10 YR 4/1); clay-organic; medium to fine, well-developed crumb-structure ; numerous rootlets; distinct and uniform transition to :

7cm - 45 cm : Yellowish-brown (10 YR 5/4); loam; small 1/2 mm subvertical shrinkage cracks; fine to medium friable subangular blocky fragments giving a fine to medium subangular blocky structure tending to a single-grained structures; humid and friable; many rootlets; gradual and uniform transition to :

45 - 90 cm : Yellowish - brown (10 YR 5/4); clay;friable flattened angular fragments giving a fine weakly developed sub-angular blocky structure; many rootlets; progressive transition to :

90 cm + : Light yellowish-brown (10 YR 6/4); clay with many yellow translucent gypsum crystals; medium angular fragments; humid with slickensides; still numerous rootlets.

Observations :

Clay predominates in the texture but this does not exclude the presence of horizons with loam, linked to the nature of alluvial deposits.

In clay horizons, the structure is well developed and crumbly at the surface, and coarse angular blocky with depth. In loam and silty loam horizons, the structure is scarcely developed and subangular blocky tending to a single-grained structure.

In the depth can be observed an accumulation of numerous gypsum crystals which do not form a mass. The size of these yellowish translucent crystals is 1 mm, and they are round like lenses.

5.2.2. Chemical characteristics

Depth	CO_3Ca	Organic matter	pH	Saturation extract conductivity	K^+	Saturation extract		Total P_2O_5
						Na Cl °/oo	$SO_4Ca,2(H_2O)$	
cm	%	%	1/2,5	mmhos/cm	me/100g	of soil	°/oo of soil	°/oo
0-10	23	6,6	7,7	2,8	1,2	0,03	1,0	2,3
10-80	24	0,9	8,0	2,3	1,1	0,01	0,72	2,3
80 +	28	0,4	7,8	4,3	0,8	0,17	1,03	1,8

The organic matter content is high : 6,6 % in horizon 0 to 10 cm but it suddenly decreases below 10 cm. However, the content is lower than in the previously described series owing to shorter floods in Mustahil plain. This is confirmed by the fact that gramineaewith an annual vegetative cycle appear instead of big perennial cyperaceae.

Medium calcium carbonate : from 23 to 28 % and pH close to 7,8. High exchangeable potassium content, and high total phosphorus content. Conductivity of saturated paste increases with the depth but is never high.

Chloride concentration is low : 0,17 % in the depth. The gypsum concentration reveals the presence of gypsum supplies.

Conclusion :

These soils are suitable for land reclamation because of their high organic matter content and their low chloride concentration. However, many land clearing and levelling problems exist (see chapter on soil-reclamation). Furthermore, flood control is necessary until the regulation dam is built upstream from Imi.

6. SODIC SOILS

6.1. Sodic soils with saline efflorescences : series 50

These are red soils with loam to clay loam and a gypsum slab at a medium depth. They spread over more than 7 000 ha between Burkur and Ferfer on the red alluvia resulting from the junction of several temporary rivers which form a large alluvial fan.

The soil surface is not even as wind has formed small, 20 to 30 cm high mounds at the top of which mainly graw Urochondra setulosa. Salt efflorescences are frequently seen.

6.1.1. Morphological and textural characteristics

Type profile : n° 6-339 at 1,5 km to the North of the Burkur-Ferfer track. No vegetation. Saline efflorescences.

0 - 1 cm : Salt crust composed of fine soil mixed with sodium chloride. Short transition to :

1 - 7 cm : Red (2,5 YR 5/8); single-grained and slightly humid silty loam; friable; salty; gradual transition to :

7 - 45 cm : Red (2,5 YR 5/8); clay loam; single-grained; many salt "needles", humid; very friable; gradual transition to :

45 - 100 cm : Red (2,5 YR 5/8) clay to silty clay; medium angular blocky fragments giving a scarcely developed subangular blocky structures; salt "needles" and numerous salt crystals; distinct transition to :

100 - 140 cm : Light grey : weathering of gypsum in situ; many sodium chloride crystals; not very compact.

The texture usually consists of loam at the surface, and clay loam to loam at a medium depth.

The fine subangular blocky structure is usually well developed when the texture is sufficiently clayey. It is massive and 10 cm thick in some places at the surface, owing to a beginning of alkalinization of the upper horizon (see chapter II A paragraph 3.3.).

The existence of a shallow gypsum slab about 40 cm below the surface or sometimes deeper (1,2 m to 1,8 m) depends on the thickness of alluvial deposits. This slab is of geologic origin and belongs to the main gypsum formation.

A double system of salt accumulation : exists in these soils, i.e. :

- a gypsum accumulation just above the gypsum slab and due to a dissolution-precipitation process.

- a great sodium chloride concentration forming efflorescences at the soil surface and "salt needles" below.

Very often the soil presents an "oily" aspect. Stains at the surface are due to the hygroscopicity of sodium chloride crystals.

6.1.2. Chemical characteristics

Depth	CO_3Ca	Organic matter %	pH 1/2,5	Saturation extract conductivity mmhos/cm	K + me/100 g	E S P	1:2 extract		1:10 extract		1 : 2 and 1:10 extract	Total P_2O_5 ‰
%	%						Na Cl ‰ of soil	$SO_4Ca,2H_2O$ ‰ of soil	Na Cl ‰ of soil	$SO_4Ca,2H_2O$ ‰ of soil	CO3NaH	
0-1-7	15,6	0,7	8,3	84	4,8	5	33,6	8,2	11,6	22,5	0	0,95
7-45	18,5	0,5	8,4	126	3,1	3	51,0	10,0	23,0	17,2	0	0,92
45-100	16,7	0,5	8,5	80	3,0	3	24,9	6,7	11,8	4,0	0	1,10
100^+	20,0	0,4	8,5	56	1,5	3	15,8	6,2	8,2	16,5	0	1,10

- Organic matter content is low right from the surface.
- A medium calcium carbonate content : less than 20 %.
- pH close to 8,4 is alkali but less than in the pH in which alkalinization processes clearly exist (see table above).
- Very high exchangeable potassium percentage.
- Total phosphorus content is low.
- Conductivity of saturation extract is very high but a reconstruction as an hypothesis of the salts in 1 : 2 extract and 1 : 10 extract reveals that :
- Sodium chloride is very abundant : it can be found in large quantities in 1 : 10 extract.
- Gypsum also exists in large quantities. The inverted proportions of sodium chloride and gypsum in 1 : 10 extract is due to the fact that most of the very soluble sodium chloride disappeared in 1 : 2 extract, whereas less soluble gypsum can be found in a relatively larger quantity in the more diluated 1 : 10 extract. .
- The fact that no acid sodium carbonate is formed implies that there is no soil alkalinization. However, in some cases (see chapter II 3.3), alkalinization takes place in the first 10 centimetres of soils and is revealed on the field by the existence of a very compact upper horizon, and in analyses, by the presence of acid sodium carbonate in a very small quantity (0,025 ‰ of soil). But this process is always limited by the

presence of abundant Ca^{++} ions due to gypsum and limestone which prevents the fixation of Na^{+} ions on the absorbing complex.

Consequently, there is no fundamental objection in theory to soil reclamation by a preliminary unsalting achieved through flooding, and by the installation of a suitable drainage system.

Nevertheless, irrigation of these soils is not advisable owing to the following reasons:

- Large non-saline areas exist in the vicinity.

- Serious risks that the soil should contaminate the drainage water of scarcely saline Wabi alluvial soils and even the Wabi water.

- It would be more advisable to use these soils as natural grazing grounds which would prove very useful during the rainy season for livestock and wild animals.

IV. RECLAMATION OF THE SOILS OF THE LOWER VALLEY BY IRRIGATION

A. CLASSIFICATION OF SOILS FOR IRRIGATION PURPOSES

Three classes of soils are distinguished as regards their fitness for irrigation :

Class I : Very suitable soils for irrigation

Class II : Not very suitable for irrigation

Class III: Non-irrigable.

The appreciation of soil quality for irrigation in class I and class II mainly rests on the respective situation of these two classes.

Class I represents the Wabi alluvia and a small part of the alluvia of temporary rivers (series 1 and 10) which are very slightly saline in the depth and cannot easily be contaminated by runoff water from the Ogaden hills.

Class II consists of the alluvia of temporary rivers and saline soils. Situated in the outskirts of the valley, they are saline in depth but can also be easily contaminated by water containing chlorides from the gypsum environment when rainfall occurs in this zone.

Class III is situated in the stony zones around plateaus, slopes and glacis. This class also includes the dune soils of the Wabi Shebelle valley.

Unfavourable factors for irrigation are indicated in the map; i.e. :

R : Abundant coarse elements;
T : Steep slopes;

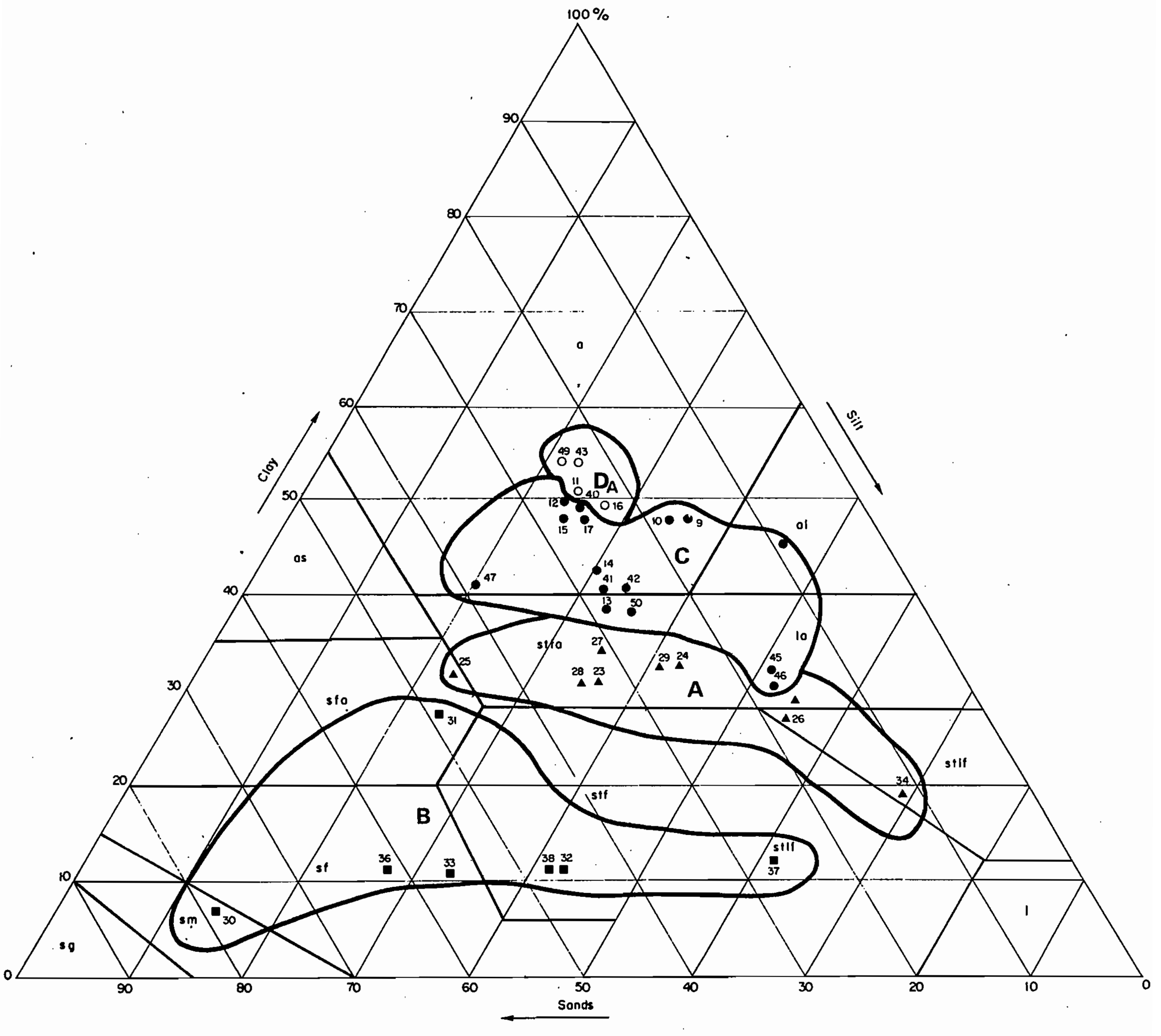


TABLE 5 - Soil series classified in textural sub-classes ABCD$_A$ - Classes I and II

U : Limestone or gypsum surface slab;
W : Depth of soil below 50 cm;
Y : Dunes.

1. Subdivisions of classes I and II

Each of these classes is divided into a subclass according to a textural criterium :

Sub-class A : 25 to 40 % of clay
Sub-class B : less than 25 % of clay
Sub-class C : more than 40 % of clay
Sub-class DA : more than 40 % of flooded clay.

The triangle of textures (table 5) shows the textural distribution of the different series within each sub-class. Soils being classed according to their texture in each series (even for vertisols and hydromorphic soils which are clay soils) but also according to the parent material, the overlapping corresponds to the classification of soils in irrigable zones (see table 6).

The following correspondences are established :

Classification of soils for irrigation purposes		Pedologic classification Level of soil family
Class	Sub-class	
I	A	Soils with powdery gypsum on Wabi brown alluvia
	B	Soils with powdery gypsum on yellowish brown alluvia of Wabi
	C	Vertisols on brown alluvia of Wabi and reddish brown alluvia of temporary rivers
	DA	Vertisols and hydromorphic soils on brown alluvia of Wabi
II	B	Powdery gypsum soils on yellowish red alluvia of temporary rivers
	C	Vertic powdery gypsum soils on yellowish-red alluvia of temporary rivers

Table 6 : Correspondences of classes and sub-classes of irrigable soils and pedologic classification.

Consequently, each sub-class has its own specific characters as regards permeability, water-holding capacity, drainage and finally different cultivation fitness.

2. Factors changing the quality of the soils as to the fitness for irrigation.

In each sub-class symbols are assigned to the series and indicate modifications as to the fitness for irrigation of each series, taking into account the texture, salinity, microrelief of the soil and its depth. Following features have been noted on the 1/50.000 map.

2.1. Drainage and soil salinity

These are two very important factors as regards soil reclamation and they are studied in detail in the following chapter.

2.2. Soil texture : St

The permeability of some series in class II (series 44-45-46) is very low and the texture varies from silty loam to silty clay. This is probably due to the existence of numerous flat limestone particles the size of silt which prevents penetration of water.

2.3. Microrelief : m and M :

m : this microrelief is not very even and requires a slight levelling of vertisols and vertic soils which are characterised by rolling lands, 1 m. long and 10 cm high with, in some places, collapse holes, some of them 80 cm deep.

M : Uneven microrelief which requires important levelling It is characterised by the existence of numerous flood ramifications in the alluvial fans of temporary rivers.

As to strongly-flooded soils of class I (series 16-48-49), the existence of flood channels is not taken into consideration as the latter may eventually be used as natural drainage channels.

2.4. Depth of soil P :

The soils of class I which may be irrigated, do not contain any coarse elements, and no limestone and gypsum slab or crust exist. Consequently, no limit has to be considered as regards the depth of this class.

As to class II, the acceptable depth limit for irrigation varies from 1 m to 50 cm below which soils may be considered as non-irrigable.

2.5. Topography

Class I : Topographic conditions are very favourable :

- The Wabi tributaries never cross the alluvial plain but remain in the outskirts (dejection zone)

- There are no termitaries.

- Slopes are not steep : less than 1 % which reduces the work but presents some difficulties as regards the necessity of a sufficient declivity for irrigation and drainage canals.

Class II : Slopes are steeper : approximately 2 to 3 % and soils are cut into ribbons by the gullies of runoff water from temporary rivers.

2.6. Character and density of vegetative cover and fitness of soils for land clearing

This factor was not mentioned in the map legend as it varies within the same series. However, it plays an important part as regards the cost of the irrigation project. Here, will only be considered the types of associated vegetation and their important consequences as regards the land clearing work to be undertaken.

2.6.1. Character and density of vegetative cover for each series

Sub-class A :

Series 23 : Dense fringing forest with Tamarix and other tall trees;

Series 24 to 27 : Discontinuous and very loose graminea cover;

Series 28 : Dense thicket with medium size shrubs;

Series 29 : Not very dense shrubs;

Series 34 : Dense bushes along the abandoned Wabi channel, palmgrove stretching along 100 to 200 m.

Sub-class B :

Series 30 : Dense forest with Tamarix palm trees or tall Acacias

Series 31 : Dense bushes at Imi or sparse bushes South of Imi (Northern bank of the Wabi).

Series 32 : Discontinuous and very loose graminea cover.

Series 33 : Dense forest with Tamarix tall Acacias and dense thickets at Kelafo; dense forest with palm-trees at Mustahil.

Sub-class C :

Series 9 : Dense forest with tall Acacias

Series 10 : Dense vegetation of small thorny plants.

Series 11 : Scattered bushes and some tall Acacias, dense gramineae at Gode, Imi, along the Madiso (Northern bank of the Wabi) and at Kugno.

Series 12 : Dense gramineae: Gode; dense graminea and small thorny bushes North of Gode.

Series 13 : Dense gramineae.

Series 14 : Dense gramineae and some tall Acacias

Series 15 : Forest with tall Acacias, undergrowth with gramineae and very dense small Cyperaceae.

Series 16 : Tall gramineae and very dense rushes with some trees and bushes along flood channels.

Series 17 : Dense gramineae with some tall Acacias (Shebelle plain), dense bushes at the South Eastern end of the Shebelle plain).

Series 39 : Vegetation consisting of a sparse and discontinuous graminea cover at Gode and North of Gode.

Series 40 : Sparse bushes.

Series 42 : Discontinuous gramineae and some small thorny bushes.

Sub-class D_A :

Series 48 : Tall Cyperaceae alternated with small Juncaceae and, in largely flooded zones, tall thorny trees.

Series 49 : Tall gramineae and dense rushes.

Class II :

Sub-class B :

Series 36 : Discontinuous gramineae cover, scattered bushes.

Series 37 : Dense vegetation of small thorny plants and bushes.

Series 38 : Tall Acacias and undergrowth of fairly dense bushes.

Sub-class C :

Series 41 : Small thorny plants.

Series 44 : Dense, small thorny plants and Commiphora

Series 45 : Small thorny plants and dense Commiphora, halophyte vegetation.

Series 46 : Dense small thorny plants.

Series 47 : Discontinuous gramineae cover and some small thorny plants.

Series 50 : Sparse vegetation of halophyte type only.

2.6.2. Vegetative cover and its consequences on land clearing

The importance of the land clearing to be undertaken for soil-reclamation has been codified from 1 to 10, function of the increasing expense. Table 7 summarizes the types of vegetative cover and indicates the clearing work to be undertaken for each series. The fitness of soil series for irrigation decreases from the beginning to the end of the table.

3. Classification of the various series according to the factors modifying or preventing irrigation

This classification is a reproduction of the classification on the map at 1/50.000 of "cultural fitness of soils".

Class I

Sub-class I A

I A ds series 24- 25- 26
I A DS series 23- 27- 28- 29

Sub-class I B

I B ds series 30 - 32 - 33 - 34
I B DS series 31

Sub-class I C

I C sm series 9 - 10 - 12 - 13 - 14 - 15 - 17 - 39 - 40 - 42

Sub-class I D A

I D A D Sm series 11 - 16 - 48 - 49

Class II

Sub-class II B

II B dm series 36 - 37 - 38

Sub-class II C

II CD sm series 41 - 47
II CDSGM series 44 - 45 - 46
II CDSP series 50

Class III

Sub-class

III Y series 8
III RU series 1 - 2 - 4
III RT series 3 - 5 - 7 - 18 - 19 - 22 - 35 - 43
III U series 6
III W series 2

TABLE 7

FITNESS OF SOILS FOR LAND CLEARING IN VIEW OF IRRIGATION

Fitness for land-clearing	Type of vegetative cover	Land clearing work	Cartographical units	
			Class I	Class II
1	Discontinuous gramineae	Light ploughing.	24-25-26-27	36-50
2	Tall dense gramineae	Burning, if possible, and deep ploughing.	11 (Kugno) -12(Gode) 13	37
3	Dense gramineae and small scarce thorny plants	Uprooting of bushes by traction and light ploughing.	9 (between Gode and Kugno southern bank) 12Northern Gode	47
4	Sparse bushes	Digging up of bushes and light ploughing	40-12(between Gode and Imi southern bank)	
5	Dense small thorny plants	Uprooting of shrubs and light ploughing	10	37-41-44-45
6	Dense gramineae and some tall Acacia	Uprooting of tall trees and deep ploughing	11-14-17 (Shebelle plain)	
7	Juncaceae	Burning if possible and deep ploughing	16-49	
8	Cyperaceae of Papyrus type	Crushing "disking" and burying by deep ploughing	48	
9	Dense bushes	Digging up roots, important levelling and light ploughing	17 (SE Shebelle plain) 29-31 34 (Shebelle plain) 39 (Northern Gode)	
10	Tree vegetation of Acacias and palm-trees and dense thicket with medium size trees	Digging up roots important levelling and ploughing	9-15-23-28-30-33-34-(ancient Wabi Shebelle natural levee) 48-(certain flood zones) of the Wabi Shebelle near the main Wabi channel).	

B. EXTENSION OF IRRIGABLE ZONES

1. Total irrigable area

The total surface of irrigable zones in the Wabi Shebelle Lower Valley between Imi and Ferfer is 353.416 ha.* This is the largest area corresponding to the irrigation possibilities defined in the soil map. It consists of :

Class I : 264.724 ha i.e.:75 % of the total area.

Class II : 88.692 ha i.e.:25 % of the total area.

1.1. Extension of sub-classes

Table 8 indicates the surface areas of sub-classes respectively on the Northern bank and on the Southern bank of the Wabi, and their total surface and percentage compared with the extension of the class.

	A		B		C		D_A	
	N. bank	S. bank	N. bank	S. bank	N. bank	S. bank	N. bank	S. bank
Class I : Total surface area 264.724 ha	25.018 ha	57.078 ha	20.834 ha	19.916 ha	45.988 ha	58.859 ha	13.012 ha	24.019 ha
Total of each sub-class	82.096 ha		40.750 ha		104.847 ha		37.031 ha	
% compared with the total surface area of class I	31 %		15,4 %		39,6 %		14 %	
Class II : Total surface area 88.692 ha			N. bank 6.920 ha	S. bank 6.171 ha	N. bank 46.313 ha	S. bank 29.288 ha		
Total area of each sub-class			13.091 ha		75.601 ha			
			14,8 %		85,2 %			

TABLE 8 : Surface of soil sub-classes

*Planimetry on the soil map.

1.2. Extension of series in each sub-class

The following table indicates the extension of each series on either side of the Wabi, its total surface and the percentage to which the latter corresponds in the surface of the sub-class to which it belongs.

Table 9 : Extension of irrigable soil series

	Sub-class	Series	Surface in ha N. bank	Surface in ha S. bank	Surface in ha for each series	% in the sub class
CLASS I	A	24	10.274	12.619	22.893	27,9
		25		4.582	4.582	5,6
		26		9.094	9.094	11,0
		34	1.433	10.560	11.990	14,7
		23	3.148	3.059	6.207	7,5
		27		1.327	1.327	1,7
		28	3.808	9.000	12.808	15,6
		29	6.355	6.837	13.192	16,0
	B	30	3.246	4.529	7.775	18,9
		32	15.603	13.967	29.570	72,1
		33	770	1.690	2.460	6,0
		31	1.215		1.215	3,0
	C	9	5.990	9.371	15.361	14,6
		10	3.297		3.297	3,1
		12	14.101	3.681	17.782	16,9
		13	4.190		4.190	4,0
		14	2.604	4.801	7.405	7,1
		15	7.555	192	7.747	7,4
		17		31.143	31.143	29,7
		39	2.909	1.384	4.293	4,1
		40	5.025	8.287	13.312	12,7
		42	317		317	0,4
	D_A	11	8.255	14.814	23.069	62,3
		16	1.000		1.000	2,7
		48	2.007	8.803	10.810	29,2
		49	1.750	402	2.152	5,8
CLASS II	B	36	2.717	862	3.579	27,3
		37	3.386	5.309	8.695	66,4
		38	817		817	6,3
	C	41	3.044	8.320	11.364	15,1
		47	4.898		4.898	6,5
		44	4.985	918	5.903	7,8
		45	4.077	15.288	19.365	25,6
		46	21.862	4.762	26.624	35,2
		50	7.447		7.447	9,8

TABLE 10 : SURFACE OF LARGE IRRIGABLE ZONES

	Total Surface (ha)	NORTHERN BANK of soil sub-classes (ha)					Total Surface (ha)	SOUTHERN BANK of soil sub-classes (ha)				
		I A	I B	I C	I D_A	II B		I A	I B	I C	I D_A	II B
A- Imi zone	3.516	284	2.142		1.090							
B- Kugno zone							9.921	5.007	2.318	1.432		1.162
C- See map	5.651	464	1.732									
D- See map							8.649	1.307	1.417	957	4.851	127
E- S.E. Madiso	7.162	357	2.561	3.744	500							
F- S.E. Madiso	10.393	575	1.592	6.561	1.665							
G- N.W. Gode	25.887	4.037	2.480	13.740	5.630							
H- Gode area							54.951	14.498	12.190	10.563	7.700	
I- Kelafo Didjinober	26.304	5.982	13.842	6.460								
J- Southern Kelafo							2.401	582		1.819		
K- Northern Shebelle							60.504	20.740	30.539	9.205		
L- Northern Shebelle	3.965		1.958	2.007								
M- Mustahil plain	3.620	100	770		2.750							
N- S.W. Burkur							14.163	4.262	4.901			
O- Burkur	8.899	7.042		1.857								

TOTAL : 245.986 ha

2. Delimitation and extension of large areas in view of irrigation

Large areas were delimited for hydro-agricultural development, on the map at 1/50.000. Their total surface area is 245.986 and they are indicated on the map by the letters A to O.

These areas only include the soils of class I which are very favourable for irrigation except in zones B and D. To the latter can also be added some soils of class II in order to facilitate the eventual execution of a general irrigation network.

As the total surface of these zones largely exceeds the possibilities of irrigation by the river, the selection of zones or of parts of zones will be decided upon by the competent authorities who will take into account the economic and political local conditions. Nevertheless it would also be useful to consider, when selecting these areas, the main crops to be cultivated, the latter varying from one zone to the other according to the sub-class to which the soil belongs and also to the land-clearing possibilities in these zones (see table on soil series).

Table 10 indicates the surface of each zone, the extension in each zone of the various sub-classes and their situation in regard to the Wabi. For an accurate delimitation of zones, see map.

C. MAIN CHARACTERISTICS OF SOILS IN THE LOWER VALLEY AS REGARDS IRRIGATION :

1. Salinity of soils :

The soil survey reveals that soluble salts consist mainly of sodium chloride and calcium sulphate (gypsum).

The sodium chloride content (the only toxic salt for plants) being well correlated with the conductivity of soil saturated paste, the latter only will be considered in the development study.

"Saline and Alkali Soils" (Agricultural Handbook n° 60, United States, Department of Agriculture) gives the following informations concerning the relation between the tolerance of plants and conductivity (table 11).

Saturated paste conductivity mmhos/cm	0 2	2 4	4 8	8 16	16
Effect of salinity on cultivated crops	Negligible salinity effect	Reduced crop produce	Low yield of many cultivated crops.	Only plants tolerant to salt have a normal yield	Only a few plants, very tolerant to salt, have a normal yield

Table 11 : Relation : plant tolerance to salinity and conductivity

The conductivity of the soil solution should not exceed a maximum value of 4 mmhos/cm in the area where a root system exists, in order to obtain a satisfactory yield of all cultivated crops.

	A		B		C		D_A	
	Depth	mmhos/cm	Depth	mmhos/cm	Depth	mmhos/cm	Depth	mmhos/cm
Class I	0-20 cm	2,6	0,10	1,7	0-30	2,1		3,3
	20-90	2,9	10-60	1,8	30-80	4,1		2,7
	90 cm +	11,9	60-100	3,6	80 cm +	7,7		5,4
			100 +	3,9				
Class II			0-30 cm	3	0-10 cm	1,3		
			30 cm	17,3	10-80 cm	9,2		
					80 cm +	24,5		

Table 12 : Mean conductivity of saturated paste mmhos/cm at 25 ° for classes I and II

These data concerning the conductivity of saturated paste of classes I and II suggests the following comments :

Class I :

- Only sub-class B has a conductivity less than 4 mmhos/cm below 1 m. depth.

- On the other hand, for sub-classes A, C and D_A the conductivity is greater than 4 mmhos/cm.

11,9 mmhos/cm below 90 cm for sub-class A.

7,7 mmhos/cm below 80 cm for sub-class C.

5,4 mmhos/cm below 90 cm for sub-class D_A.

These relatively high values concern a zone where many roots of trees and of annual or perennial plants can be found. It is therefore necessary to bring down the conductivity to approximately 4 mmhos/cm by drainage and leaching methods which will be described later.

Class II :

Conductivity is already very high at a small depth and this is incompatible with a high yield for most crops. In order to bring conductivity down to 4 mmhos, the necessary drainage and leaching work will have to be far more considerable than above described. Otherwise, the efficiency of one of those factors may be insufficient and leave the soil unfit for any type of cultivation.

2. Content of available boron in soils

Boron is absolutely necessary for the growth of plants but the required quantity is very low which indicates that the poverty - toxicity interval is very narrow.If measurements carried out in similar types of soils, in Rajasthan in India, (MOCHE V.B. and al. 1966) are compared, one may observe for instance :

- poverty in available boron for contents under 0,35 ppm.

- an excess of available boron when the content is greater than 1,5 ppm.

Nevertheless, the quantity of boron required by one plant may correspond to the limit of toxicity for another plant.

For instance, for citrus fruit trees and avocado trees, a boron excess is very unfavourable but it can be tolerated by plants such as cotton, wheat, barley and tomatoes.

The contents of water soluble boron were determined for several types of soils in the lower valley. The latter are all situated in the Gode region (see table 13).

Class and sub-class	I A		I B		I C		II C	
Series an n° of profile	25 6 - 11		32 6 - 17		11 6 - 20		44 6 - 181	
Depth cm	0-10	10-70	0-10	30-70	0-10	80-100	0-30	80-125
Available boron content in ppm	0-40	0,38	0,24	0,30	0,40	0,16	0,16	75,0

Table 13 : Available boron content (ppm) of some soils of Gode plain

For soils of class I, the contents of water-soluble boron seem to be very favourable for the growth of plants even if the latter scarcely tolerate an excess of boron. Considering the lower limit indicated above, a certain boron poverty could even exist. However, supposing this to be true, the poverty cannot be evaluated accurately for the present time. One could try incorporating borax to soils in the experiment plots of Gode.

But as regards soil analysed in class II and sampled in the red-soil regions of the Northern bank of the Wabi at Gode, the water-soluble boron content is very high : 75 ppm at an 80 cm. depth and considerably exceeds the toxicity level of all cultivated plants. This probably accounts for conkers and burns visible on the leaves of citrus trees at the old experimental Gode farm.

One may believe that all the soils derived from gypsum and limestone material (geological sedimentation of ancient sea) are also rich in available boron.

3. <u>Moisture equivalent and apparent specific gravity of soils</u>

The extent of irrigation to be undertaken may be calculated from these data.

3.1. <u>Moisture equivalent</u> : <u>M Eq</u>. is determined by the difference of the moisture percentage between pF 4,2 and pF 2,5. The quantity of water soon available for irrigated plants corresponds to 75 % of the moisture equivalent.

3.2 <u>Apparent density</u> : Ad was measured on the field by the cylinder sampling method. Results may be considered as valid as regards sandy soils and medium clayey soils but they are questionable for vertisols (sub-class IC). In this particular case, only measurements carried out on a large enough irrigated area, for instance 100 m2, can give more valid results.

In both cases, the results are given in compensated values for a 70 cm thick layer (annual plants), and for a 120 cm thick layer (perennial plants).

These compensated values result from the addition of the moisture equivalents or apparent densities in the different horizons down to a given depth corresponding to the thickness of these horizons.

Sub-class	M. Eq. compensated for 70 cm	M. Eq. compensated for 120 cm	A B. compensated for 70 cm	A d. compensated for 120 cm
I A	13,4	13,2	1,24	1,30
I B	9,5	9,6	1,33	1,35
I C	14,9	14,7	1,32*	1,35*
I D_A	17,5	17,3	1,12	1,24

Table 14 : Moisture equivalent and apparent density of the various sub-classes of irrigable soils

*see following observations.

- Moisture equivalent, that is to say, which is still available for plants after the free drainage of the soils.

. medium for I A
. low for I B
. medium for I C
. medium to high for I D (see table 14).

Apparent density is usually the highest in soils where sand predominates (I.B.). For vertisols, the given value is probably rather high and must be measured again on an irrigated plot (see table 14).

4. Permeability :

Soil permeability is one of the most important factors to be known in view of irrigation as it determines the soil drainage possibilities. The quantity of salt contained in a soil is of minor importance if the latter is sufficiently permeable and if the water used enables to wash away the excess of salt.

Permeability tests were carried out using the well-known double cylinder method and this was repeated three times at each site.

12 measurements were undertaken on the series of class I at representative sites selected in the Kugno, Gode and Kelafo zones. The results are given in table 15.

Sub-class	Permeability on dry soil	Permeability on humid soil		Permeability
		cm/h	cm/24 h	
A	3,3	2,0	48	Relatively permeable
B	4,1	3,0	72	Permeable
C	2,0	0,8	19,2	Scarcely permeable
D_A	2,0	0,8	19,2	Scarcely permeable

Table 15 : Permeability of soils of various sub-classes of irrigable soils

Convenient conditions for irrigation correspond to the data comprised between the figures indicated for permeability of dry soil and those given for permeability of humid soil. For instance, for a 10 hours irrigation, runoff lasts one hour at the infiltration rate on dry soil, and 9 hours at the infiltration rate on humid soil.

The data on permeability calls forth some comments :

- The permeability of the different sub-classes seems directly linked to the soil-texture. For instance sandy soils of class B are permeable whereas soils with a medium texture and belonging to class A are relatively permeable and those of sub-classes C and D_A (clay soils) are scarcely permeable.

- Thus, these provide interesting informations as to the importance of drainage installations to be undertaken for each sub-class (see table 15).

- The data on permeability obtained by using the cylinder method does not replace full-size measurements carried out on the field. This is also true for most soils which in fact consist of interstratified profiles with a variable permeability, particularly for vertisols which present swelling and shrinkage features with cracks deeply affecting the permeability.

5. Drainage

Soil drainage is necessary in order :

- to bring down, when irrigation begins, the amount of toxic salts to an acceptable quantity.

- to avoid the eventual secondary salinization of soil by irrigation water.

- to keep saline phreatic water at a low level.

A general drainage system in irrigated zones is therefore absolutely necessary. The suggestions to be made further below concerning tile-drain spacing and the depth of drains, correspond to the results of experience acquired in other similar regions in the world. In fact, the utilization of these data is generally a complex affair in which several factors which could not be measured must be considered.

5.1. Tile-drain spacing

This spacing is in relation to the soil permeability which has been defined above for each sub-class, but is also linked to the non-existence or existence of an impervious horizon for the series. For this reason, a light drainage : d and a drainage D have been distinguished on the soil map (see table 16)

Sub-class	Series	Drainage symbol on the map	Spacing of open drains
I-A	24-25-26-34	d	150 m
	23-27-28-29	D	100 m
I-B	30-32-33	d	150 m
	31	D	100 m
I-C	9-10-12-13-14-15-17-39-40-42	D	80 ← → 100 m
I-D_A	11-16-18-49	D	80 ← → 100 m

Table 16 : Symbols concerning drainage and tile-drain spacing for different sub-classes of irrigable soils.

A tile-drain spacing of 100 m for sub-classes C and D_A would be more convenient. Taking into account the low permeability of these two sub-classes, the evolution of chloride content in the root zone of cultivated crops should be controlled.

5.2. Depth of drains

The thickness of the drained and "decontaminated" soil-layer, that is to say with a conductivity under or equal to 4 mmhos/cm, depends on the type of cultivation.

For annual plants with short roots or perennial plants with a not very important root system, a decontaminated layer from 0,8 m to 1 meter deep is sufficient. A 1,5 meters depth is necessary for trees.

Consequently, for annual plants, the drains should be 1,3 m deep and for trees : 1,8 m deep, this being understood for a medium depth of tertiary drains. These drainage depths may seem considerable but they are only reasonable if a progressive salt contamination on large areas is to be avoided in the years to come, which otherwise would require the installation of deeper drains, to say nothing of the waste of water used for leaching and of the reduced yield of crops (see table 17).

Type of cultivated crop	Decontaminated layer	Depth of tertiary drains
Annual or perennial crops with not very important rooting	0,8 - 1 m	1,3 m
Trees	1,5 m	1,8 m

Table 17 : Depth of drainage

5.3. Protection of irrigated zones from saline contamination originating from the surroundings of the valley

Soils of class II, are often saline in the depth but that is also true in the outskirts of the valley for many soils of class III.

It is therefore necessary to protect the soils of class I against the salt contamination which occurs during rainfall in Ogaden and is due to the gypsum environment.

In the case of large irrigation areas, it will only be necessary to complete the natural drain already existing in contact with the alluvia of the Wabi and of the temporary rivers, and in this way to avoid the risk of flooding of irrigable zones by saline water (see other details in chapter I C 3).

6. Necessity of wind screens

The dry wind which constantly blows in the Lower Valley at a mean velocity of 3,6 m/s throughout the year, largely increases evaporation. This explains the great difference (double) observed between evaporation measured on evaporation pan or calculated potential evapotranspiration (see chapter paragraph 5).

Apart from the fact that cultivated plants are damaged by the mechanical and physiological action of strong wind (intense evaporation regime of leave stomas) it is also responsible for the waste of a large quantity of water though the exact amount cannot be estimated accurately as experimental data are lacking.

It is therefore necessary before undertaking an irrigation device, first of all to plant wind-screens consisting of trees with a rapid growth (Cassia, Tamarix, etc...)

A wind-screen protects crops along a distance equal to 20 times its height. For instance, a 10 m. high wind-screen protects crops stretching along a 200 m distance about.

It would be advisable :

- To place wind-screens every 100 m along the tertiary channels in S.E. - N.W. directions in other words, perpendicularly to the direction of dominant winds.

- 5 years later, it should be possible, if necessary, to remove one wind-screen out of two in order to bring the spacing between two of them to 200 m.

Two important principles must be applied :

- The wind-screen must be sufficiently supplied with water without finding it in the cultivated zone.

- The wind-screen must not be too thick and must only reduce the wind velocity as a too sudden barrier would in fact cause whirlwinds which might be even more damageable for crops than wind itself.

D. QUALITY OF IRRIGATION WATER LEACHING REQUIREMENTS

Only Wabi water will be used for irrigation as ground water from drillings is very saline.

The two following cases will be studied :

- Quality of the Wabi water supplied either by pumping or diversion before constructing the regulation dam.

- Quality of the Wabi water once the regulation dam is constructed.

- Richards' method (1954) set up by the laboratory for saline soils, classifies irrigation waters taking into account two characteristics of water :

- Salinity hazard (C), linked to the conductivity which indicates the salinity hazard in regard to the soil and which is based upon water conductivity expressed in mmhos/cm.

- Sodium Alkali Hazard (S) in regard to the absorbing complex of the soil to be irrigated, expressed in S A R (Sodium absorption ratio).

$$SAR = \frac{Na^{+}}{\sqrt{\frac{Ca^{++} + Mg^{++}}{2}}} \quad \text{ionic data in me/l}$$

By combining these two factors, irrigation waters may be classified.

The hypothetic reconstruction by the Bazilevitch method of salts existing in water in the ionic form, accounts for an eventual reprecipitation of a determined type of salt in irrigated soils.

1. Quality of Wabi Shebelle water used for irrigation by pumping or diversion before constructing dam II bis

Hydrological data reveal that the regime of the Wabi presents three different types :

- Low water regime

- Regime of high water or floods originating from the High Plateaus

- Regime of peak floods corresponding to rainfall in Ogaden

Tables 17 - 18 - 19 show that only the water salinity (C) varies, but the sodium alkali hazard (S) does not vary much and remains low.

Table 18 : Low water

Localisation	mmhos /cm	pH	CO_3H^-	Cl^-	SO_4^{--}	K^+	Na^+	Ca^{++}	Mg^{++}	Σ A	Σ C	SAR	ESP	Water classes
IMI	0,736	7,6	2,70	0,68	3,33	0,12	1,13	2,9	2,27	6,71	6,42	0,71	0,	$C_2 - S_1$
GODE	0,777	7,6	2,49	0,95	4,10	0,12	1,03	4,0	2,27	7,54	7,42	0,77		$C_2 - S_1$
KELAFO	0,777	7,3	2,59	0,97	4,69	0,14	1,43	4,40	2,37	8,25	8,33	0,77		$C_2 - S_1$

Table 19 : High water of floods from the High Plateaus

Localisation	mmhos/cm	Na^+	Ca^{++}	Mg^{++}	SAR	Water classes
HAMARO	0,310	0,5	1,8	0,9	0,3	$C_2 - S_1$

Table 20 : Floods corresponding to rainfall in Ogaden

Localisation	mmhos/cm	Na^+	Ca^{++}	Mg^{++}	SAR	Water classes
GODE	1,980	9,3	9,1	1,4	4,0	$C_3 - S_1$

1.1. Sodium alkali hazard : table 21

The S A R varies from 0,3 to 4 and water can be classified in : S_1. This water has a low sodium content and may be used for soils, the probability being small that a large quantity of exchangeable sodium should form. This is all the more certain as large quantities of calcium exist in the soils (carbonates and especially gypsum) thus reducing to a minimum the sodium alkali hazard.

1.2. Secondary salinity hazard due to irrigation water

The previous tables show that conductivity in the global salinity of water considerably varies : from 1 to 6 depending on the hydrological regime.

- Low and high waters may be classified in C_2 (see table 21), i.e. : with medium saline water. This type of water may be used if a minimum drainage is undertaken. However for plants with a moderate salt-tolerance, it is not necessary to control the salinity which is in relation to the water.

- Flood water due to rainfall in Ogaden is classified in C_3 (see table 21) or very saline water. Even if special methods are applied, plants with a good salt-tolerance must be selected.

Secondary salinity hazard is important in the case of flood water from Ogaden. Consequently irrigation using this type of water must absolutely be avoided. Nevertheless, floods do not last more than a day or two and conductivity soon comes down to a similar value to that observed for low flow. These instructions can generally be easily followed as this period corresponds to the rainy season in the Lower Valley during which the water requirements of plants are low.

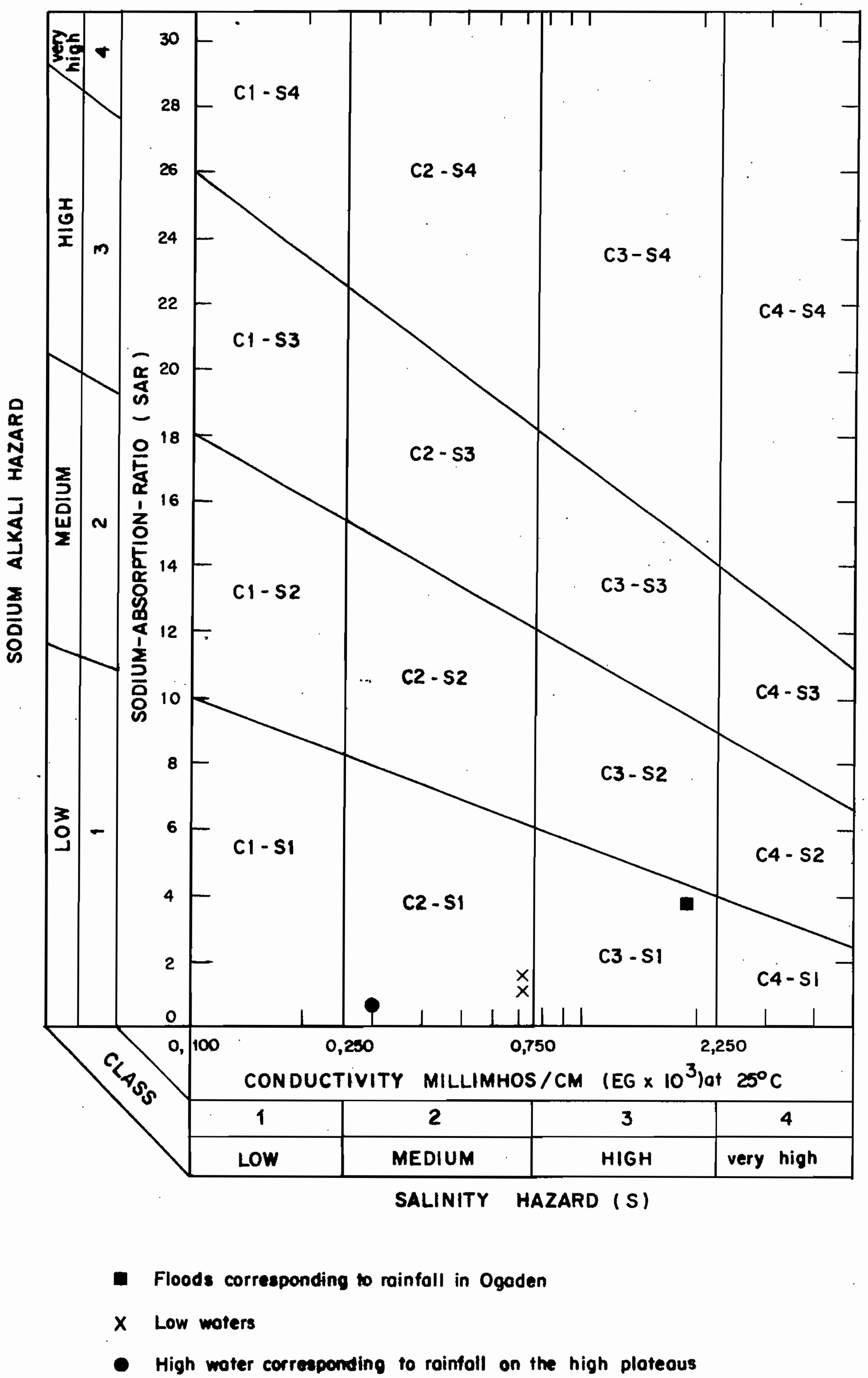


TABLE 21. Classification of Wabi Shebelle water for irrigation (from Agricultural handbook 60, USDEPT of Agriculture.)

1.3. Boron content in irrigation water

It has already been noted that boron is vital to the growth of plants but the required quantity is small.

Analyses of low-water samples reveal that the boron content is : 0,09 ppm. This is a very low content and Wabi water may be classified as very favourable irrigation water , even for plants which do not tolerate an excess of boron.

1.4. Salts from irrigation water which are likely to concentrate in soils if drainage conditions are poor

Salt exists in the ionic form in water and soil solutions.

However, if soil solutions are concentrated at a certain depth (usually corresponding to the root zone) owing to the lack of soil drainage (irrigation too unfrequent, insufficient quantity of water or poor drainage system), ions are combined together and precipitated in the form of salt.

If conditions are identical during a long enough period, the content of precipitated toxic salts may rise to values affecting not only the yield but even the survival of crops.

The Bazilevitch method enables to undertake an hypothetic reconstruction of salts from the ions existing in the solution and, in this particular case, to foresee the types of salts which might be accumulated in the soils by irrigation water. This has been done for Wabi low water (see table 22).

Salts / pH	$(CO_3H)_2Ca$ in the form : CO_3 Ca	$(CO_3H)_2Mg$ in form : CO_3 Mg	CO_3H Na in form of CO_3 Na_2	$SO_4Ca,2H_2O$	SO_4Mg	Cl Na
7,3	0,16	0,021	0,016	0,196	0,15	0,058

Table 22 : Salts of irrigation water which are likely to concentrate in soils, in g/l.

The acid calcium carbonate $(CO_3H)_2Ca$ which is precipitated in the form of calcium carbonate CO_3 Ca and gypsum SO_4 Ca, 2 H_2 0 are neutral salts as regards crops.

The other salts only may be considered as toxic when concentrations are too high :

The magnesium bicarbonate $(CO_3H)_2$ Mg and acid sodium carbonate CO_3 H Na contents are very low.

Furthermore, magnesium sulphate (SO_4 Mg), which is a very toxic salt, may appear when drainage conditions are poor. Its hypothetic content in irrigation water is relatively high.

This is also true for sodium chloride (Cl Na) with low but not negligible contents which are likely to accumulate.

1.5. Leaching requirement

It is therefore necessary to keep down in the root zone the toxic salt concentration of the soil solution (in particular magnesium sulphate and sodium chloride) so that it may be compatible with a normal growth of plants. This concentration is linked to the conductivity of drainage water which passes through the root zone and depends on the crop tolerance to toxic salts. Consequently, it determines the quantity of water which must percolate outside the root zone. This corresponds to the leaching requirement

$$\text{Leaching requirement (L.R.)} = \frac{\text{Conductivity of irrigation water Ciw}}{\text{Conductivity of drainage water Cdw}} \times 100$$

Irrigation water	Ciw mmhos/cm	Cdw mmhos/cm	LR %	Cdw mmhos/cm	LR %
Low water	0,770	4	20	8	9,5
High water	0,310	4	8	8	4
Ogaden floods	1,980	4	49	8	24,5

Table 23 : Conductivity of irrigation water and leaching requirement (L.R.)

In table 23, two maximum values for the conductivity of drainage water : Cdw = 4 and 8 mmhos/cm and the corresponding L.R. are indicated.

For most of the plants suggested in the list concerning the cultural fitness of soils, Cdw should be less than 4 mmhos/cm in order to correspond to the best crop yielding conditions as regards salinity.

This means that :

The percentage of water drained outside the root zone must correspond during irrigation to :

- 19 % for low flow.
- 8 % for high flow.
- 49 % for flood water from Ogaden.

Irrigation with the latter type of water requires drainage corresponding to approximately half the water used. This is scarcely compatible with rational irrigation conditions : important utilization of power and eventual leaching of fertilizers.

Otherwise, for the other two types of water, the leaching requirement is relatively low : 1/5 at most of the water used.

For calculations, and in order to have a large enough security range when undertaking irrigation projects, a leaching requirement of 20 % will be taken into account.

2. Quality of Wabi Shebelle water used for irrigation once the storage dam is constructed.

The question is to determine the quality of the water of the storage dam, once the latter is full. One may reasonably think :

- That the quantity of salts (especially chlorides) dissolved at the level of the wetted part of the reservoir will be small as this part of the reservoir is mainly constituted by the geologic limestone formation of Kebri Dahar where saline gypsum stratifications seldom exist.

- That the Wabi tributaries which directly flow into the reservoir, in the part comprised between the dam and the Wabi-Daketa junction, and which drain a large zone (approximately 2.600 km2) of gypsum formations, will bring a certain amount of chlorides in this region during the rainy season.

- Consequently, the quality of irrigation water should not change nor its qualitative composition : these waters may still be classified in C_2 S_1 like the present low and medium waters.

- The leaching requirement only could possibly vary though it would remain under 20 % (data corresponding to present low water).

Estimated data :

For calculations in the scheme outlines and preliminary projects on irrigation, should be looked upon :

- a conductivity of 0.750 mmhos/cm
- a leaching requirement of 20 %.

E. SOIL FERTILITY (See table 24)

When optimum irrigation and drainage conditions are fulfilled, the crop yield depends on the fertility of soil. The elements determining soil fertility are :

- Organic matter
- Nitrogen, phosphorus, potassium, sulphur (major elements)
- Trace elements (minor elements).

1. Organic matter

Humus, besides its favourable effect on the hydrologic budget of soil, also contains major elements and trace-elements which are easily available for the plant growth. This is particularly true for nitrogen and phosphorus.

In the Lower Valley, as was already seen, the organic matter content in the soil is linked to pedoclimatic conditions:

In non-flooded zones, the content is low : about 1°/₀ or less.

In weakly flooded zones, a medium content (2,4 %) can be observed.

In long-duration flood zones, only the content is high and may exceed 8 %.

Humus belongs to the calcic mull type, that is to say that it is soon mineralized in the soil and its level decreases rapidly if it is not progressively reconstituted.

When soil is irrigated, the percentage (2 % or above) of organic matter is sufficient. This can be obtained by returning to the soil crop residues leys, etc....

In the table joined to this report, the levels of organic matter are classified as follows :

Content of organic matter	Level
Less than 1,5 %	Low
from 1,5 to 3 %	Medium
Greater than 3 %	High

2. Nitrogen

In the Wabi Shebelle Lower Valley the contents of total nitrogen are correlative to the organic matter content.

These contents are usually very low (less than 1 °/₀₀), they are medium in soils IC and high in organic soils (IDA).

The fertility scale concerning nitrogen is, as follows :

Nitrogen content	Fertility level :
Less than 1 °/oo	Low
From 1 °/oo to 1,5 °/oo	Medium
Above 1,5 °/oo	High

The nitrogen content only, has a relative value and must be compared to the phosphorus content in order to determine if the nutritional balance between these two components is consistent with a suitable growth of crops (see ratio $\frac{\text{Total N}}{\text{Total } P_2 O_5}$)

3. Phosphorus

The measurement of total phosphorus allows to know the phosphorus percentage in soil. Part of this total phosphorus can be used by plants : this is available phosphorus.

In the soils of the Lower Valley, where the average calcium carbonate percentage is 20 %, it is difficult to appreciate the level of available phosphorus. Most of the phosphorus appears in fact as tricalcic phosphorus, scarcely soluble in water.

However, there is always a high total phosphorus level. Moreover, limestone is divided up in fine grains the size of silt. A weak but progressive solubilization of tricalcic phosphorus may therefore occur under irrigation and be utilized for crops.

Available phosphorus may be estimated as corresponding to 1/20 of the total phosphorus content.

The fertility scale corresponding to total phosphorus is as follows, i.e. :

Total phosphorus in °/oo ($P_2 O_5$)	Fertility
Less than 0,50 °/oo	Low
From 0,50 to 1,50 °/oo	Medium
Greater than 1,50 °/oo	High

4. Potassium :

Potassium exists in soils in three forms :

A complex form : constituting a fine net between thin mineral slabs (muscovite and biotite).

A form fixed in clay of montmorillonitic type; potassium tends to migrate from the external sides to the internal sides of clay layers. This feature is known under the name of potassium retrogression and potassium is then only very slightly exchangeable. This fixed form is most often observed in vertisols.

An exchangeable form fixed on the external sides of clay layers and directly available plants.

A balance exists between these three forms, the two first types constituting the potassium storage.

The soils of the Lower Valley are always rich or very rich in potassium.

The fertility scale accepted for potassium is the following :

K in me/100 g of soil	Fertility
Less than 0,2	Low
From 0,2 to 0,4	Medium
Greater than 0,4	High

5. Utilization of ratio : $\frac{\text{Total N °/}_{\circ\circ}}{\text{Total } P_2O_5 \text{ °/}_{\circ\circ}}$

This ratio gives indications concerning the nutritional balance between phosphorus and nitrogen as regards crops.

It was used for the first time by DABIN from O.R.S.T.O.M. on acid soils or soils with neutral pH, in West Africa.

In the soils of the Wabi Lower Valley where the medium calcium carbonate content is 20 %, one may consider that the efficiency of total phosphorus is reduced by half as far as plants are concerned (see paragraph 2). Consequently the following ratio may be used :

$N / P_2O_5 > 2,5$: soils very poor in phosphorus.

$N / P_2O_5 < 1$: soils very poor in nitrogen.

If the ratio value falls between these two extreme values, the nutritional balance is favourable but plants then depend on the contents of each of these elements in soil.

In all the irrigable soils of the Lower Valley, nitrogen is very scarce.

The nitrogen content is high in I A, I B, I C, and medium in I D A.

6. Sulphur :

In the Lower Valley the soils cannot be poor in sulphur as they contain large quantities of gypsum (SO_4Ca, $2H_2O$).

7. Trace-elements :

Trace-elements are absolutely necessary for nutrition as they are diastase or vitamin catalysers. Consequently, on the one hand, requirements are very moderate and on the other hand, the toxicity level is reached very soon.

For instance, as regards soils II B and II C in the outskirts of the Lower Valley, the available boron content is very high and is greater than 75 ppm in the Gode area. This value largely exceeds the toxicity critical level which may be accepted for many cultivated crops. (See details in chapter IV, C 2).

8. Types of fertilizers advised for irrigated zones

The soils of the Lower Valley are very poor in nitrogen and rich in phosphorus and potassium. The fertilizers which must be added will therefore mainly consist of carriers of nitrogen. Further below are indicated the types of phosphorus and potassium carriers that could possibly be used.

Nitrogen carriers :

- Urea is very useful because of its strong concentration and because it can be easily stored to be utilized in the Lower Valley. However some reservations must be made :

- To convert urea into ammonia nitrogen, a suitable biologic activity in the soil is necessary, in other words, the humus content must correspond at least to 2 %.

- If such is not the case, urea is not hydrolysed and may be washed away from the root absorption zone.

- Ammonium sulphate is strongly advised as it has the particular advantage of acidifying the soil, which is very favourable for the limestone soils of the Lower Valley and in particular, allows a better assimilation of phosphorus.

- Ammonium nitrate is also a suitable fertilizer but cannot be be recommended here as its storage requires some safety measures.

Nitrogen carriers are generally used in two ways :

- Basal dressing before a cultivation cycle.
- Fractional adding, in proportion with the needs of plants.

TABLEAU 24 : FERTILITY LEVEL OF SOILS - Major elements NPK and deficiencies

Sub-class	Depth cm	Organic matter %	N °/oo	Total P in P_2O_5 °/oo	Kme/100 g	Total N in P_2O_5 °/oo	Poverty
I A	0-20	1,0 L	0,50 L	1,8 E	1,5 E	0,33	Very poor in nitrogen
	20-90	0,8 L	0,38 L	1,6 E	0,4 M-E	0,23	
	90 +	0,4 L	0,20 L	1,6 E	0,8 E	0,25	
I B	0-10	1,3 L	0,54 L	1,3 E	3,8 E	0,41	Very poor in nitrogen
	10-60	1,2 L	0,57 L	1,4 E	3,6 E	0,40	
	60-100	0,9 L	0,43 L	1,5 E	3,1 E	0,28	
	100 +	0,5 L	0,24 L	1,9 E	1,0 E	0,13	
I C	0-30	2,4 M	1,20 M	1,9 E	1,4 E	0,62	Very poor in nitrogen
	30-80	1,0 L	0,50 L	1,8 E	0,9 E	0,27	
	80 +	0,8 L	0,40 L	1,8 E	0,7 E	0,22	
I D_A	0-10	8,8 E	4,15 E	2,4 E	1,2 E	1,70	Moderately poor in nitrogen
	10-80	0,9 L	0,43 L	2,2 E	0,8 E	0,22	

Scales :

Scale	O.M. %	N °/oo	Total P_2O_5 °/oo	Kme / 100 g
Low (L)	< 2	< 1	< 0,25	< 0,2
Medium (M)	2-3	1-1,5	0,25-0,75	0,2-0,4
High (H)	> 3	> 1,5	> 0,75	> 0,4

Carriers of phosphorus

If phosphorus is required in soil, lime-superphosphate or better still, ammonium phosphate can be supplied, but the latter is more expensive.

Carriers of potassium

The soils have a high content of potash. Nevertheless if a potassium deficiency occurred it could be adjusted by adding potassium sulphate.

Using potassium chloride is not advisable as this fertilizer contains a non-negligible residue of sodium chloride, the removal of which in irrigated soils, is already a serious problem.

F. CULTURAL FITNESS OF SOILS

All the required conditions being met for an optimum potential yield of the soil, namely :

- salinity less than 4 mmhos/cm,
- adjusted nitrogen poverty,

the cultural fitness of soils may be directly correlated with the texture (and eventually with the structure as regards vertisols), this texture directly influencing the depth of root penetration and consequently, the volume of reclaimed soil.

Class I : Very favourable soils for irrigation

I A : Soils favourable for most tropical crops in a semi-arid climate

Series 23 - 24 - 25 - 26 - 27 - 28 - 29.

These soils with a medium silty loam texture (see chapter III B paragraph 4 - 1.1.1.), consist in fact of fine interstratifications of fine sand and clay.

After ploughing, the upper horizons allow a good penetration of the root system of annual plants. Furthermore, thin clay interstratifications allow the roots of perennial plants and trees to penetrate deeply.

Class I B : Suitable soils for tropical fruit-trees, citrus-trees, pineapples, tomatoes (for juice), vegetables, maize, sorghum, wheat, groundnut and other oil seeds, forage gramineae.

Series 30 - 31 - 32 - 33 - 34.

These fine sandy soils, consisting of silty loam to loam and fine sand, therefore with a light texture (see chapter III B, paragraph 4. 1.1.2.), exist on the actual or ancient natural levees of the Wabi.

They can be easily ploughed, are sound from a physiosanitary point of view owing to a quick infiltration of irrigation water and are very favourable for the cultivation of vegetables, tomatoes, pineapple (for juice) cereals such as maize, sorghum, wheat, oil seeds, in particular sesame as well as ground nuts which grow well in light and warm soils. Forage gramineae can also be cultivated for livestock-raising.

A good penetration of the root-system is favourable for the cultivation of trees which require an important volume of soil for proper growth : tropical fruit-trees and citrus.

<u>Class I C</u> : <u>Suitable soils for sugar cane, cotton artificial pastures, maize, sorghum, wheat, fibre plants, oil plants</u>

Series 10 - 12 - 13 - 14 - 15 - 17.

These are vertic soils and vertisols. Their texture is heavy, clayey and of montmorillonitic type. The moisture-capacity is relatively high and the exchangeable capacity or field capacity of fertilizing elements is also high (see chapter II B and chapter III B). But the most interesting feature is the existence at the surface of a 20 to 40 cm thick very friable "grumosolic" horizon, facilitating the cultural practices and the rooting and aeration of the root system of plants. But the swelling process and the formation of large shrinkage cracks due to dessication, are very unsuitable for perennial plants with a deep rooting, for instance : fruit trees and citrus.

With an adequate drainage system (see chapter III B, C5) the following crops may be cultivated : sugar cane, cotton, artificial pastures, maize, sorghum, wheat and fibre plants, especially ramie. Oil plants also grow well on these soils. However, the cultivation of groundnut is not advisable.

<u>Class I D_A</u> : <u>Suitable soils for sugar cane, cotton and rainfed rice</u>

Series 11 - 16 - 48 - 49

Apart from series 11 which can also be observed in the Northern Gode and Gode areas, these soils are particularly developed in the Shebelle plain between Kelafo and Mustahil and in the Mustahil plain. They are episodically flooded (series 11), or permanently flooded or under the influence of shallow ground-water. On the soil grows a dense gramineae or cyperaceae vegetation.

- These are clay and organic soils except for series 11, forming a 10 to 20 cm thick layer (see chapter III B, paragraph 2 and 5). Once they are reclaimed, these soils are very suitable for the cultivation of cotton, sugar cane and especially for rainfed rice during periodical flooding.

<u>Class II</u> : <u>Scarcely suitable soils for irrigation</u>

It is altogether unadvisable to irrigate these soils, owing to the risk of chloride contamination of the soils of class I. Furthermore, toxicity corresponding to a boron excess may occur and is wholly unfavourable for the cultivation of fruit trees and citrus. However, if irrigation proved to be absolutely necessary because of the too limited extent of soils of class I in the development area, the following crops could be cultivated there, i.e. :

<u>Class II B</u> : <u>Possible crops</u> : pineapple and tomatoes (juice) vegetables, maize, sorghum, wheat, groundnut and other oil seeds.

Series 36 - 37 - 38.

<u>Class II C</u> : <u>Possible crops</u>...... sugar cane, cotton, artificial pastures, maize, sorghum, wheat, fibre plants, oil plants.

Series 41 - 44 - 45 - 46 - 47 - 50.

CONCLUSION :

The Lower Valley of the Wabi Shebelle from Imi to Ferfer presents original features which allow considering this region as a specific entity in the Ogadenian context.

The Wabi Shebelle is the only river in Ogaden with a permanent flow. The Valley has a semi-arid climate of Ogadenian type, but the pedoclimate is modified in many areas by temporary or permanent floodings from the river.

The Wabi Shebelle flows along an almost straight fault following a North-West-South East direction, with here and there some small limestone outcrops from Imi to Gode. This fault is marked by the tilted limestone beds in the Kelafo region.

This depression is partly filled in by yellowish red alluvia derived from neighbouring calcareous gypsum formations outcropping in the surroundings of the Valley.

In the latter, they are covered with a thick layer of brown to yellowish - brown alluvial deposits transported by the Wabi Shebelle and derived mostly from weathered basalt and granite (in a small proportion) of the High Plateaus.

The river's alluvial deposits are alternated on either bank and form a series of crescents widening as one goes from the North-West to the South-East.

The drainage system presents a very particular aspect : most of the Wabi Shebelle tributaries, between Imi and Ferfer, which are in fact but ephemeral streams (rivers with a temporary flow), do not reach the main river but end up in alluvial fans at the limit of the Valley.

Soils : 50 soils series are mapped on the soil map at 1/50 000.

These are calcareous soils (average : 20 %) with powdery lime.

On the contrary, gypsum and sodium chloride are solubilized and are deposited once more in suitable parts of the area.

The soluble salt content (gypsum and sodium chloride) varies according to the type of alluvial deposits.

- on the brown to yellowish-brown alluvia of the Wabi Shebelle, the sodium chloride content is low as well as the gypsum content.

- on the reddish-yellow alluvia of temporary rivers, the sodium chloride and gypsum contents are usually high and available boron also exists in large quantities.

Layers of coarse elements are non-existent in the Wabi Shebelle alluvia.

Utilization of soils for irrigation purposes :

Irrigation soils have been classified in three categories :

Class I :

Very favourable for irrigation; on brown to yellowish-brown Wabi Shebelle alluvia and reddish-brown alluvia of temporary rivers, spreading over 264.724 ha.

Class II :

Not very favourable for irrigation; on reddish-yellow alluvia of temporary rivers spreading over 88.692 ha.

Class III :

Non-irrigable, and consisting in stony soils or in soils with limestone or gypsum slabs derived from flats, slopes and hills in the outskirts of the Valley.

These three soil classes are studied in detail in this report, but only the characteristics of the class are described here as its extent exceeds the irrigation potentials of the Wabi Shebelle.

This class includes three sub-classes corresponding to different textures (as for class II).

Sub-class A : Sandy soils
Sub-class B : Medium textured soils
Sub-class C : Clay soils (vertisols and vertic soils)
Sub-class D_A : Organic soils

The data on texture, permeability, apparent density and drainage have been studied. They condition in particular the irrigation methods and cultural fitness of soils.

However, the fertility of soils does not vary much from one sub-class to the other.

The main factor limiting fertility is nitrogen, as potassium and phosphorus contents are high.

The soluble salt content is usually low but the sodium chloride concentration in the soil solution may soon reach the toxicity critical level for many cultivated crops if the drainage system and the leaching requirement of soils are not taken into account.

The available boron content is low in soils of class I and keeps within compatible limits for a suitable growth of plants. But as regards the soils of class II, they reach considerably high values which are very unfavourable for most plants.

The alkali hazard or risk of a modification of the physical qualities of plants is low considering that a large quantity of calcium is fixed on the absorbing complex and in the soil solution.

The quality of irrigation water is determined in the present conditions for different hydrologic regimes characterizing the river during the year, as well as for the water of the storage dam, once it is constructed. The water of the river belongs to the type of water with a medium salinity hazard and a low alkali hazard, consequently it is very favourable for irrigation if the proposed leaching requirement is taken into account.

Finally, the soils of the Lower Valley of the Wabi Shebelle between Imi and Ferfer seem to be very favourable for irrigation (Class I):

- The soils are deep, well supplied with potassium and phosphorus, but as in most semi-arid regions, they are very poor in nitrogen and this will be compensated for by adding carriers of nitrogen.

- Management by irrigation is made easier as reclamation work is not considerable (except for the Kelafo - Shebelle area), ana as termitaries and temporary rivers joining the river do not exist in the selected areas.

Nevertheless, the successful execution of a general irrigation project depends on the application of the following instructions :

- Installation of an efficacious general drainage system to protect the irrigation areas from saline contaminations originating from the gypsum surroundings (outskirts of the valley).

- To keep rules indicated in this report concerning the drainage and leaching of soils, in order to prevent any saline concentration in the soil root zone.

- To plant wind-screens in order to check the evapotranspiration of plants, consequently, to limit water-consumption and reduce the capillary rise of salts as well as the mechanical effects of wind on vegetation.

BIBLIOGRAPHY :

MOCHE (U.B.) and al. quoted by AUBERT (H.) and PINTA (M.), 1971 Trace elements in soils. ORSTOM, Paris.

RICHARDS (L.A.) edit. 1954, Diagnosis and improvement of saline and alkali soils. Agricultural handbook n° 60 U.S. Department Agric. 160 p.

Plate I

The Wabi Shebelle alluvial plain (near KELAFO)

- One must note the very distinct contact limit between the brown alluvial deposits of the Wabi and the yellowish red alluvial deposits of the temporary rivers

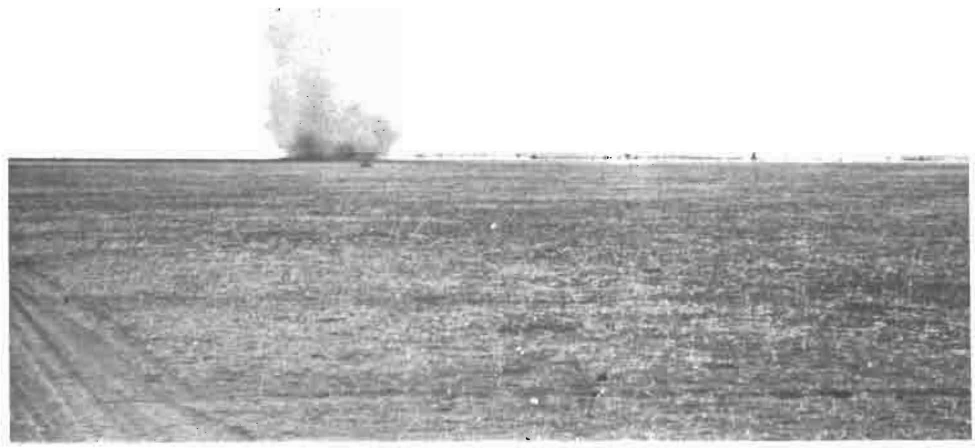
Flood zone
(SHEBELLE plain)

Plate II

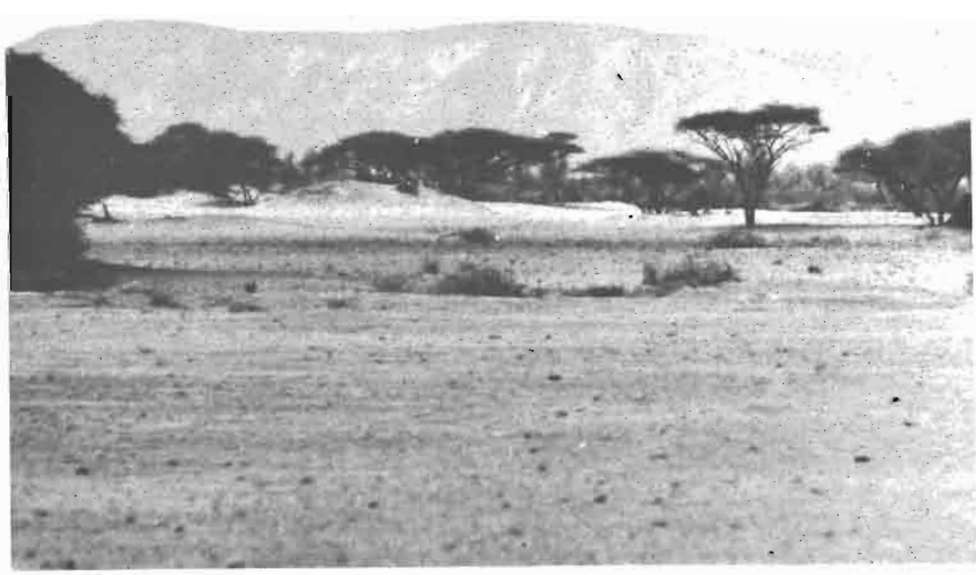
Fringing forest with *Tamarix nilotica* on the convex banks of the river (near GODE)

Fringing forest with *Hyphaene thebaïca* on the natural levees of the river (surroundings of MUSTAHIL)

Plate III _

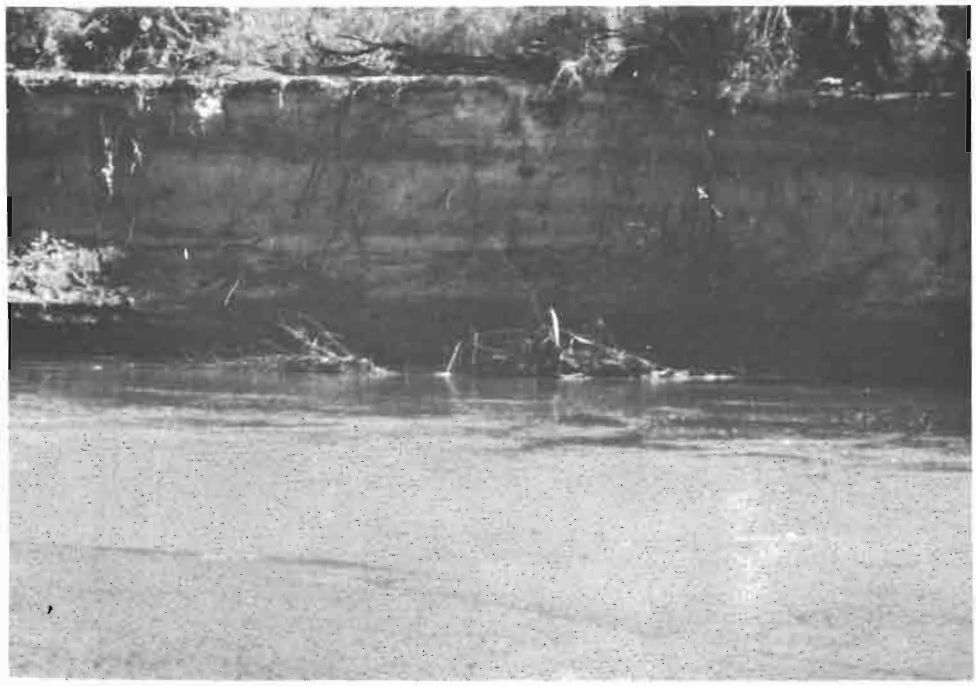


Dust column due to a whirlwind
(GODE plain, Southern bank of the river)



Dune formations with tall Acacias
(GODE plain, Southern bank of the river)

Plate IV



Interstratified soil with predominating sand
from the natural levee (IMI region)

Grumosolic limestone vertisol (MUSTAHIL region)

- the diffuse gypsum accumulation in crystals
  must also be noted

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ብሔራዊ የውሃ ሀብት ልማት ኮሚሽን መሥሪያ ቤት

IMPERIAL ETHIOPIAN GOVERNMENT

NATIONAL WATER RESOURCES COMMISSION

ETHIOPIA - FRANCE COOPERATIVE PROGRAM

WABI SHEBELLE SURVEY

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FRENCH MINISTRY OF FOREIGN AFFAIRS

NATIONAL WATER RESOURCES COMMISSION

BCEOM-ORSTOM-EDF IGN-BDPA

V

The Soils of the Lower Valley of the Wabi Shebelle

Eleven maps at 1 / 50 000

JANUARY 1973

CONTENTS

THE SOIL OF THE LOWER VALLEY OF THE WABI-SHEBELLE

የኢትዮጵያ ንጉሠ ነገሥት መንግሥት
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V

SOILS MAP - CARTE DES SOLS

Lower Valley - Basse Vallée

BURKUR

ORSTOM

JANUARY 1973
MAP N° 1

SOILS FEATURES FAVOURING IRRIGATION
APTITUDES DES SOLS A L'IRRIGATION

1ST CLASS - VERY SUITABLE SOILS FOR IRRIGATION
CLASSE I - SOLS TRES FAVORABLES A L'IRRIGATION

I A - for all tropical crops in arid zone.
pour toutes cultures tropicales de zone aride.

- I A d s: 24, 25, 26
- I A D S: 23, 27, 28, 29

I B - for tropical fruit-trees, citrus, pine-apples, tomatoes (juice) vegetables, maize, sorghum, wheat, groundnuts, other oilseeds, forages (graminea).
pour arbres fruitiers tropicaux, agrumes, ananas, tomates (jus), cultures légumières, maïs, sorgho, blé, arachide, autres oléagineux, graminées fourragères.

- I B d s: 30, 32, 33, 34
- I B D S: 31

I C - for sugar-cane, cotton, artificial pastures, maize, sorghum, wheat, textile fiber plants, oilseeds.
pour canne à sucre, coton, pâturages artificiels, maïs, sorgho, blé, plantes à fibres, plantes à huile.

- I C D s m: 9, 10, 12, 13, 14, 15, 17, 39, 40, 42

I D_A - for sugar-cane, coton, hill rice.
pour canne à sucre, coton, riz pluvial.

- I D_A D S m: 11, 16, 48, 49

2ND CLASS - LOW SUITABILITY FOR IRRIGATION
CLASSE II - SOLS PEU FAVORABLES A L'IRRIGATION

II B - possible crops : tropical fruit-trees, citrus, pine-apples, tomatoes (juice) vegetables, maize, sorghum, wheat, groundnuts, other oilseeds.
cultures possibles : arbres fruitiers tropicaux, agrumes, ananas, tomates (jus), cultures légumières, maïs, sorgho, blé, arachide, autres oléagineux.

- II B d m: 36, 37, 38

II C - possible crops : sugar-cane, cotton, artificial pastures, maize, sorghum, wheat, textile fiber plants.
cultures possibles : canne à sucre, coton, pâturages artificiels, maïs, sorgho, blé, plantes à fibres textiles.

- II C D S m: 41, 47
- II C D S G M: 44, 45, 46
- II C D S P: 50

3RD CLASS - UNSUITABLE FOR IRRIGATION
CLASSE III - SOLS NON IRRIGABLES

- III Y: 8
- III R U: 1, 2, 4
- III R T: 3, 5, 7, 18, 19, 22, 35, 43
- III U: 6
- III W: 20, 21

EXPLANATION OF THE SYMBOLS
SIGNIFICATION DES SYMBOLES

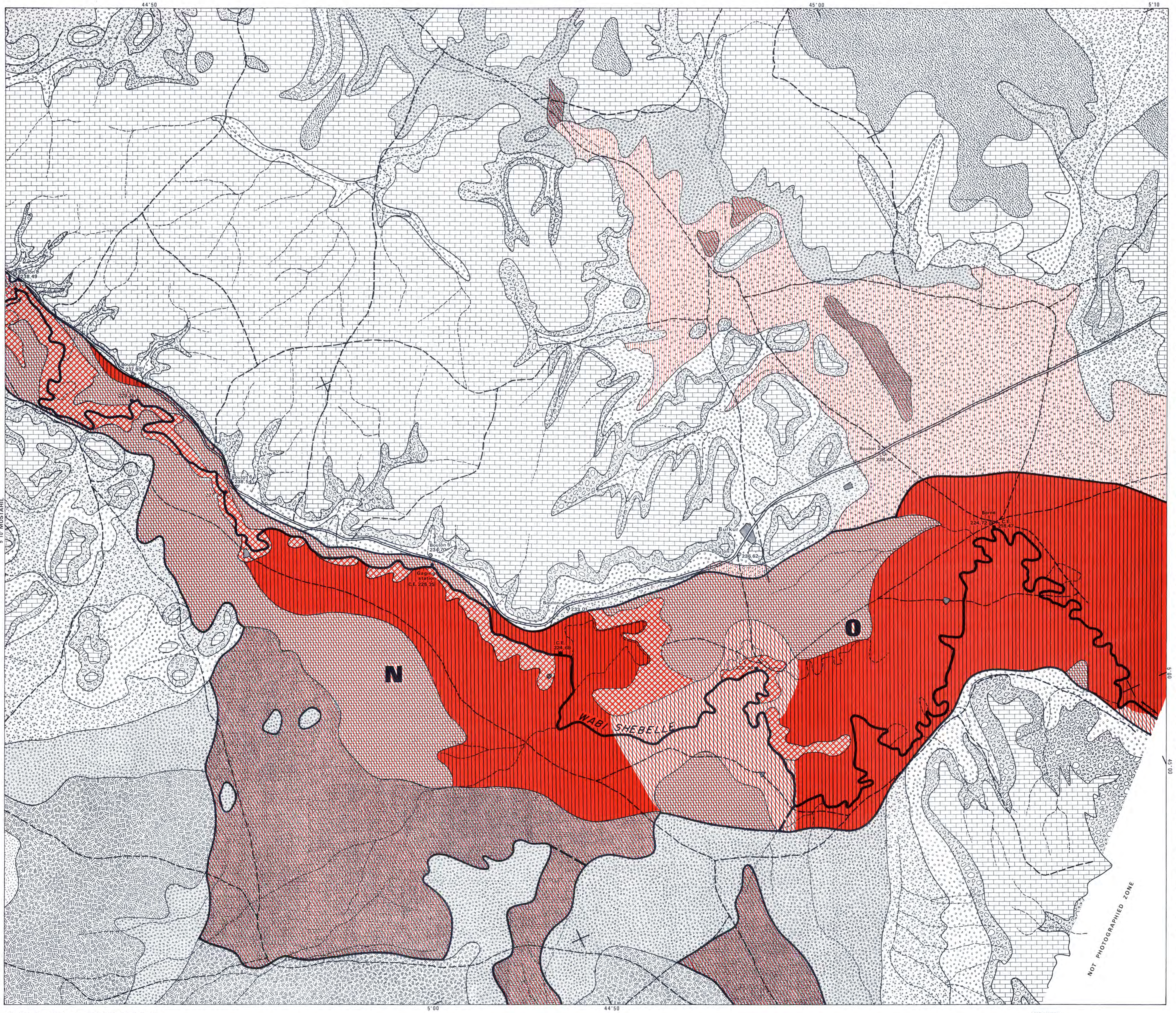
Factors changing the quality of the soils suitable for irrigation.
Facteurs altérant les qualités des sols irrigables.

- **d** Slight drainage necessary / *Drainage léger nécessaire*
- **D** Drainage necessary on a larger scale / *Drainage important nécessaire*
- **s** Weak salinity in the depth / *Salure faible en profondeur*
- **S** High salinity affecting the whole soil. / *Salure forte affectant l'ensemble du sol*
- **G** Fine non-clayey texture unsuitable for irrigation / *Granulométrie fine non argileuse, défavorable à l'irrigation*
- **m** Slighty broken micro-relief requiring very slight leveling / *Microrelief peu uniforme nécessitant des planages très légers*
- **M** Broken micro-relief requiring a great deal of leveling / *Microrelief peu uniforme necessitant des planages importants*
- **P** Depth of the soil less than 1 m / *Profondeur du sol inférieure à 1 m*

Symbols concerning non irrigable soils.
Symboles concernant les sols non irrigables.

- **R** Abundant coarse elements / *Eléments grossiers abondants*
- **T** Steep slopes / *Pentes fortes*
- **U** Superficial limestone or gypsum flags / *Dalles calcaire ou gypseuse superficielles*
- **W** Depth of soil less than 50 cm / *Profondeur du sol inférieure à 50 cm*
- **Y** Dunes / *Dunes*

N



Planimetric sketch executed from the mosaics of 1964-67 aerial photos.
Esquisse planimétrique éxecutée d'après les mosaïques photographiques de 1964-67.

INDEX SHEET

11 IMI WEST	10 IMI	9 IMI EAST	8 MADISO	7 GODE WEST	6 GODE	5 GODE EAST	4 KELAFO	3 MUSTAHIL WEST	2 MUSTAHIL	1 BURKUR

— Limits of irrigable soils - 1st Class / *Limite des sols irrigables - Classe 1*

A Indication of large irrigable zones / *Indication des grandes zones irrigables*

Scale 1: 50 000° approximate

Mile 1 ¾ ½ ¼ 0 1 2 3 Miles
M 1000 500 0 1 2 3 4 5 Km.

Fa Flooded area (highly) / *Zone fortement inondable*

C.E. Water level / *Cote d'eau*

⊙ Bench-mark / *Boulon, borne*

ABREVIATIONS

m.S.	Medium sand	L.	Loam
sm	*sableux à sables moyens*	stf	*sableux à sables très fins*
m.f.S.	Medium and fine sand with predominance of medium sand	S.i.L.	Silty loam
smsf	*sableux à sables moyens et sables fins*	stfl	*sablo-limoneux à sables très fins*
f.S.	Fine sand	C.L.	Clay loam
sf	*sableux à sables fins*	stfa	*sablo-argileux à sables très fins*
c.m.S.	Coarse and medium sand with predominance of coarse sand	S.i.C.L.	Silty clay loam
sgsf	*sableux à sables grossiers et sables fins*	la	*limono-argileux*
f.c.S.	Fine and coarse sand	C.S.i.C.	Clay - Silty clay
sfsg	*sableux à sables fins et sables grossiers*	astfl	*argilo-sablo-limoneux à sables très fins*
f.m.S.	Fine and medium sand	S.i.C.	Silty clay
sfsm	*sableux à sables fins et sables moyens*	al	*argilo-limoneux*
S.L.L.	Sandy loam to loam	C.	Clay
sfstf	*sableux à sables fins et sables très fins*	a	*argileux*
S.C.L.	Sandy clay loam		
sfa	*sablo-argileux à sables fins*		

LEGEND OF THE SOILS MAP
LEGENDE DE LA CARTE PEDOLOGIQUE

WEAKLY DEVELOPED SOILS *SOLS PEU EVOLUES*
XEROSOLS *XERIQUES*
GYPSEOUS SOILS Derived from marl and gypsum
GYPSEUX Issus des marnes gypseuses

1 Yellowish-gray soils L. with superficial gypsum flag : LARGE FLATS (IMI, KELAFO, MUSTAHIL, BURKUR).
Sols gris-jaune stf en place à dalle de gypse superficielle GRANDS FLATS : IMI, KELAFO, MUSTAHIL, BURKUR.

2 Yellowish-gray soils SiL, with a gypsum flag at 50 cm depth on COLLUVIA : LARGE FLATS (IMI, KELAFO, MUSTAHIL, BURKUR).
Sols gris-jaune stfl à dalle de gypse enterrée à 50 cm sur COLLUVIONS : GRANDS FLATS (IMI, KELAFO, MUSTAHIL, BURKUR).

NON CLIMATIC SOILS *NON CLIMATIQUES*
LITHIC ERODED SOILS WITH POWDERY LIME Derived from marl and gypsum
SOLS D'EROSION LITHIQUES A CALCAIRE DIFFUS Issus des marnes gypseuses

3 Yellowish-gray soils SiL, with superficial gypsum flag : LOWER HILLS.
Sol gris-jaune stfl en place à dalle de gypse superficielle : COLLINES BASSES.

4 Whitish-yellow soils L. shallow with gypsum flag on COLLUVIA : DEBRIS-SLOPE of the LOWER HILLS.
Sols jaune-blanc stf à dalle de gypse peu profonde sur COLLUVIONS : DEBRIS-SLOPES sous les COLLINES BASSES.

Derived from limestone *Issus des calcaires*

5 Yellowish-red soils L. to CL, with limestone fragments and calcareous nodules on COLLUVIA : TALUS below the BLUFF of the LIMESTONE PLATEAUS.
Sols rouge-jaune stf à stfa à debris et nodules calcaires sur COLLUVIONS. TALUS sous les CORNICHES des PLATEAUX CALCAIRES.

6 Red soils SiL with gypsum flag at 20 cm depth on COLLUVIA : GODE area (DEBRIS SLOPE) and FERFER area (PLATEAUS).
Sols rouges stfl à dalle de gypse à 20 cm de profondeur sur COLLUVIONS : environs de GODE (DEBRIS-SLOPE) et de FERFER (PLATEAUX).

Derived from basalts *Issus des basaltes*

7 Pale-brown soils SL to L. very stony on WEATHERED Basalt BOULDERS : HILLS.
Sols brun-clair sf à stf très caillouteux sur ALTERATION en BOULE des basaltes : COLLINES.

SOILS DEVELOPED ON WIND BLOWN MATERIAL WITH POWDERY LIMESTONE.
SOLS D'APPORTS EOLIENS A CALCAIRE DIFFUS

8 Yellow soils SL to L. on DUNES : GODE area.
Sols jaune sf à stf sur DUNES : environs de GODE.

VERTISOLS AND VERTIC SOILS *VERTISOLS ET SOLS VERTIQUES*
WITH CURVED STRUCTURE *A STRUCTURE ARRONDIE*
BROWN OR REDDISH BROWN VERTISOLS WITH POWDERY LIME AND POWDERY GYPSUM IN THE DEPTH.
VERTISOLS BRUNS A BRUN-ROUGE A CALCAIRE DIFFUS ET CRISTAUX DE GYPSE EN PROFONDEUR

On RED-BROWN oued ALLUVIA derived from limestone
Sur ALLUVIONS BRUN-ROUGE d'oued issues des calcaires

9 Reddish-brown vertisols, grumosolic on 40 cm C. to SiC with powdery gypsum at 100 cm depth, easily flooded : oued Bu-Y ALLUVIA.
Vertisols brun-rouge grumosoliques sur 40 cm a. à al à cristaux de gypse vers 100 cm. inondables : ALLUVIONS de l'oued Bu-Y.

On BROWN oued ALLUVIA derived from basalts
Sur ALLUVIONS BRUNES d'oued issus des basaltes

10 Brown to red vertisols, grumosolic on 40 cm C. to SiC, with powdery gypsum at 40 cm depth, easily flooded : oued ALLUVIA : North West GODE area.
Vertisols bruns à rouges grumosoliques sur 40 cm a. à al. à cristaux de gypse à plus de 40 cm, inondables : ALLUVIONS d'oued : Nord Ouest GODE.

On BROWN ALLUVIA of the Wabi Shebelle *Sur ALLUVIONS BRUNES du Wabi Shebelle*
GODE - I M I series. *Séries IMI-GODE*

11 Brown vertisols grumosolic on 30 cm C. with little powdery gypsum below 60 cm, easily flooded.
Vertisols bruns grumosoliques sur 30 cm a. quelques cristaux de gypse à partir de 60 cm. inondables.

12 Brown vertic soils grumosolic on 30 cm C. little powdery gypsum below 30 cm.
Sols bruns vertiques grumosoliques sur 30 cm. a. quelques cristaux de gypse à partir de 30 cm.

13 Brown vertic soils grumosolic on 20 cm SiC. to C. with powdery gypsum in depth.
Sols bruns vertiques grumosoliques sur 20 cm stfl à a. à cristaux de gypse en profondeur.

KELAFO - MUSTAHIL - BURKUR series. *Séries KELAFO-MUSTAHIL-BURKUR*

14 Brown vertisols, grumosolic on 30 cm SiC to C. with powdery gypsum below 90 cm, seldom flooded.
Vertisols bruns grumosoliques sur 30 cm astfl à a. avec cristaux de gypse à plus de 90 cm, faiblement inondables.

15 Reddish-brown vertisols, grumosolic on 20 cm C. with powdery gypsum below 100 cm (KELAFO only).
Vertisols brun-rouge grumosoliques sur 20 cm a. avec cristaux de gypse à plus de 100 cm (KELAFO seulement).

16 Brown vertisols, grumosolic on 30 cm C. with powdery gypsum below 80 cm, very easily flooded (MUSTAHIL plain).
Vertisols bruns grumosoliques sur 30 cm a. avec nombreux cristaux de gypse à plus de 80 cm, fortement inondables : (plaine de MUSTAHIL).

17 Brown vertic soils, grumosolic on 20 cm C. with powdery gypsum below 80 cm, seldom flooded (SHEBELLE plain).
Sols bruns vertiques grumosoliques sur 20 cm a. avec cristaux de gypse à plus de 80 cm, faiblement inondables: (plaine de SHEBELLE).

SOILS WITH CALCAREOUS DIFFERENCIATION
SOLS A DIFFERENCIATION CALCAIRE
WITHOUT MELANIC HORIZON *SANS HORIZON MELANIQUE*
WITH POWDERY LIME : MODAL *A CALCAIRE DIFFUS : MODAUX*
COLLUVIA derived from limestone *COLLUVIONS issues des calcaires*

18 Yellowish-red soils fS with many limestone debris and pebbles : DEBRIS SLOPE below the LIMESTONE PLATEAUS (GODE to BURKUR).
Sols rouge-jaune sf riches en débris calcaires peu émoussés : DEBRIS-SLOPE sous les PLATEAUX CALCAIRES (GODE à BURKUR).

19 Yellowish-red soils mfs, with limestone and basaltic pebbles : HILLOCKS of the LARGE ALLUVIAL FANS (IMI).
Sols rouge-jaune smsf à galets calcaires et basaltiques: PETITS MAMELONS des GRANDS CONES de DEJECTION (IMI).

WITH NODULES *A AMAS ET NODULES*
Derived from limestone *Issus des calcaires*

20 Yellowish-red soils SiL to L. with calcareous nodules : LIMESTONE PLATEAUX (GODE to BURKUR).
Sols rouge-jaune stfl à stf, à nodules calcaires en place : PLATEAUX CALCAIRES (GODE à BURKUR).

Derived from sandstone *Issus des grès*

21 Red soils SL-L with calcareous nodules : LOWER PLATEAUS (IMI).
Sols rouges sfstf à amas et nodules calcaires, en place : BAS PLATEAUX (IMI).

On ancient oued ALLUVIA *Sur anciennes ALLUVIONS d'oued*

22 Yellowish-red soils CmS, with calcareous pebbles often cemented in conglomerate near the surface : HILLOCKS in the LARGE ALLUVIAL FANS (GODE).
Sols rouge-jaune sgsf à galets calcaires souvent soudés en conglomérat à faible profondeur : MAMELONS des GRANDS CONES de DEJECTION (GODE).

SOILS WITH GYPSEOUS DIFFERENCIATION
SOLS A DIFFERENCIATION GYPSEUSE
WITH POWDERY GYPSUM : MODAL *A GYPSE DIFFUS : MODAUX*
On BROWN ALLUVIA of the Wabi Shebelle
Sur ALLUVIONS BRUNES du Wabi Shebelle
I M I - GODE series *Séries IMI-GODE*

23 Brown soils SiC weakly organic/fs (ANCIENT MEANDERS of the Wabi Shebelle.
Sols bruns al. faiblement humifères/st : (MEANDRES MORTS du WABI SHEBELLE).

24 Brown to yellowish-brown soils SiL to SiC in depth.
Sols bruns à brun-jaune stfl à al. en profondeur.

25 Brown soils C/fs (GODE).
Sols bruns a./sf (GODE).

26 Brown soils SiL to C. in depth (GODE).
Sols bruns stfl à a. en profondeur : (GODE).

27 Brown soils CL (GODE).
Sols bruns stfa (Gode).

South KELAFO - MUSTAHIL - BURKUR series *Séries Sud KELAFO-MUSTAHIL-BURKUR*

28 Brown soils C/brownish-yellow L. seldom flooded to easily flooded (KELAFO).
Sols bruns a./jaune-brunâtre stf, peu inondables à inondables (KELAFO).

29 Brown soils SiL to C. in depth.
Sols bruns stfl à a. en profondeur.

On BROWNISH - YELLOW ALLUVIA of the Wabi Shebelle
Sur ALLUVIONS JAUNE-BRUN du Wabi Shebelle
I M I - North GODE series *Séries IMI-Nord GODE*

30 Brownish-yellow soils fcS : BANKS of the Wabi Shebelle.
Sols jaune-brun à sfsg : BOURRELETS de BERGE du Wabi Shebelle.

31 Brownish-yellow fS/C.
Sols jaune-brun sf/a.

I M I - North GODE - KELAFO series *Série IMI-Nord GODE-KELAFO*

32 Brownish-yellow soils SiL to fS : RECENT or ANCIENT BANKS of the Wabi Shebelle.
Sols jaune-brun stfl-sf : BOURRELETS de BERGE du Wabi Shebelle ACTUELS ou ANCIENS.

South KELAFO - MUSTAHIL - BURKUR series *Séries Sud KELAFO-MUSTAHIL-BURKUR*

33 Brownish-yellow soils SiL to fmS in depth : BANKS of the Wabi Shebelle.
Sols jaune-brun stfl à sfsm en profondeur : BOURRELETS de BERGE du Wabi Shebelle.

34 Brownish-yellow soils SiL to SiL-C in depth.
Sols jaune-brun stfl à stfla en profondeur.

On REDDISH - YELLOW oued ALLUVIA *Sur ALLUVIONS JAUNE-ROUGE des oueds*

35 Reddish-yellow soils fS to L. with pebbles in the depth often salty : ALLUVIAL FANS : HIGHER position (GODE to BURKUR).
Sols jaune-rouge sf à stf à galets en profondeur, souvent salés : ALLUVIONS des CONES de DEJECTION : position HAUTE (GODE à BURKUR).

36 Reddish-yellow soils L. and mS ALLUVIAL FANS (IMI).
Sols jaune-rouge stf et sm : ALLUVIONS des CONES de DEJECTION (IMI).

37 Reddish-yellow soils SiL : RECENT ALLUVIA of the larger oueds.
Sols jaune-rouge stfl : ALLUVIONS RECENTES des grands oueds.

38 Reddish-yellow soils fS-SiL : RECENT ALLUVIA of the larger oueds (MADISO).
Sols jaune-rouge sf-stfl : ALLUVIONS RECENTES des grands oueds (MADISO).

WITH POWDERY GYPSUM : VERTIC *A GYPSE DIFFUS : VERTIQUES*
On BROWN ALLUVIA of the Wabi Shebelle *Sur ALLUVIONS BRUNES du Wabi Shebelle*
North GODE serie *Série Nord GODE*

39 Brown soils with SiC predominance.
Sols bruns à dominance al.

GODE - KELAFO serie *Série GODE-KELAFO*

40 Brown soils C.
Sols bruns a.

On YELLOWISH - RED oued ALLUVIA *Sur ALLUVIONS ROUGE-JAUNE des Oueds*

41 Yellowish-red soils SiL to C. : RECENT ALLUVIA of the smaller oueds.
Sols rouge-jaune stfl à a. : ALLUVIONS RECENTES des petits oueds.

On Wabi Shebelle YELLOWISH - BROWN ALLUVIA over RED basaltic ALLUVIA
Sur ALLUVIONS BRUN-JAUNE du Wabi Shebelle recouvrant les ALLUVIONS ROUGES basaltiques.

42 Yellowish-brown soils SiL/red C. (GODE).
Sols brun-jaune stfl/rouge a. : (GODE).

WITH GYPSEOUS CRUST : MODAL *ENCROUTES : MODAUX*
From RED COLLUVIA derived from basalts *Sur COLLUVIONS ROUGES issues des basaltes*

43 Red soils SCL to C. with gypseous crust at 60 cm depth : DEBRIS SLOPE below the basaltic HILLS (GODE North GODE).
Sols rouges sfa à a. à croûte de gypse vers 60 cm : DEBRIS-SLOPE des COLLINES de basalte (GODE-Nord GODE).

From YELLOWISH - RED oued ALLUVIA *Sur ALLUVIONS ROUGE-JAUNE des oueds*

44 Yellowish-red soils L. to SiL, with gypsum crust at 70 cm depth, salty in depth : ALLUVIAL FANS LOWER position (GODE).
Sols rouge-jaune stf à stfl, à croûte de gypse vers 70 cm, salés en profondeur : ALLUVIONS des CONES de DEJECTION position BASSE, (GODE).

45 Yellowish-red soils SiL to SiCL, with gypsum crust at 70 cm depth, salty near the surface : ALLUVIAL FANS LOWER position (GODE to BURKUR).
Sols rouge-jaune stfl à la. à croûte de gypse à 70 cm, salés à faible profondeur : ALLUVIONS des CONES de DEJECTION position BASSE (GODE à BURKUR).

46 Yellowish-red soils L. to SiC, with gypsum accumulation "SAND ROSE" type : ALLUVIAL FANS LOWER position (IMI-GODE).
Sols rouge-jaune stf à al. à accumulation de gypse sous forme de ROSE des SABLES : ALLUVIONS des CONES de DEJECTION position BASSE (IMI-GODE).

On Wabi Shebelle YELLOWISH - BROWN ALLUVIA over YELLOWISH - RED oued ALLUVIA
Sur ALLUVIONS BRUN-JAUNE du Wabi Shebelle recouvrant les ALLUVIONS ROUGE-JAUNE des oueds

47 Yellowish-brown soils SCL/yellowish-red C. (GODE).
Sols brun-jaune sfa/rouge-jaune a. (GODE).

HYDROMORPHIC SOILS *SOLS HYDROMORPHES*
MEDIUM ORGANIC *MOYENNEMENT ORGANIQUES*
HUMIC GLEY WITH POWDERY LIME *HUMIQUES A GLEY A CALCAIRE DIFFUS*
On BROWN ALLUVIA of the Wabi Shebelle *Sur ALLUVIONS BRUNES du Wabi Shebelle*
SHEBELLE plain serie *Série de la plaine de SHEBELLE*

48 Brown soils C. very easily flooded (PAPYRUS area).
Sols bruns a. fortement inondables (zone à PAPYRUS).

MUSTAHIL plain serie *Série de la plaine de MUSTAHIL*

49 Brown soils C. very easily flooded (GRAMINEA area).
Sols bruns a. fortement inondables (zone à GRAMINEES).

SODIC SOILS *SOLS SODIQUES*
WITH NON DEGRADED STRUCTURE *A STRUCTURE NON DEGRADEE*
SALINE SOILS WITH SALT EFFLORESCENCES *SOLS SALINS A EFFLORESCENCES SALINES*
On RED oued ALLUVIA *Sur ALLUVIONS ROUGES d'oued*

50 Red soils SiL to C. with gypsum flag at medium depth (BURKUR-FERFER).
Sols rouges stfl à a. à dalle de gypse à moyenne profondeur (BURKUR-FERFER).

IMPERIAL ETHIOPIAN GOVERNMENT
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ETHIOPIA - FRANCE COOPERATIVE PROGRAM

WABI SHEBELLE SURVEY

IN COLLABORATION WITH

FRENCH MINISTRY OF FOREIGN AFFAIRS — NATIONAL WATER RESOURCES COMMISSION — BCEOM, ORSTOM, EDF IGN, BDPA

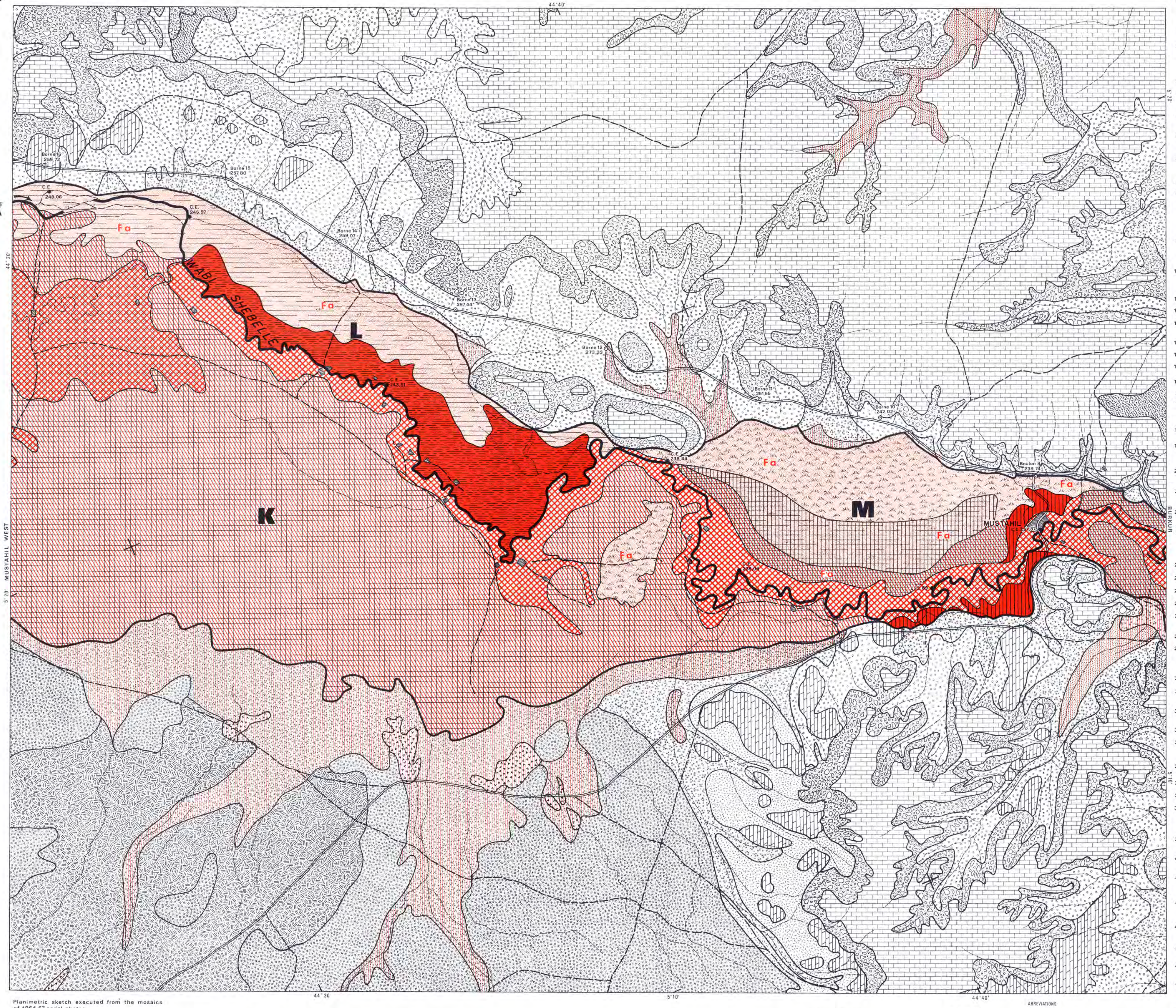
V

SOILS MAP - CARTE DES SOLS

Lower Valley - Basse Vallée

MUSTAHIL

JANUARY 1973
MAP N° 2



SOILS FEATURES FAVOURING IRRIGATION
APTITUDES DES SOLS A L'IRRIGATION

1ST CLASS - VERY SUITABLE SOILS FOR IRRIGATION
CLASSE I - SOLS TRES FAVORABLES A L'IRRIGATION

I A - for all tropical crops in arid zone.
pour toutes cultures tropicales de zone aride.

- I A d s: 24, 25, 26
- I A D S: 23, 27, 28, 29

I B - for tropical fruit-trees, citrus, pine-apples, tomatoes (juice) vegetables, maize, sorghum, wheat, groundnuts, other oilseeds, forages (graminea).
pour arbres fruitiers tropicaux, agrumes, ananas, tomates (jus), cultures légumières, maïs, sorgho, blé, arachide, autres oléagineux, graminées fourragères.

- I B d s: 30, 32, 33, 34
- I B D S: 31

I C - for sugar-cane, cotton, artificial pastures, maize, sorghum, wheat, textile fiber plants, oilseeds.
pour canne à sucre, coton, pâturages artificiels, maïs, sorgho, blé, plantes à fibres, plantes à huile.

- I C D s m: 9, 10, 12, 13, 14, 15, 17, 39, 40, 42

I D_A - for sugar-cane, coton, hill rice.
pour canne à sucre, coton, riz pluvial.

- I D_A D S m: 11, 16, 48, 49

2ND CLASS - LOW SUITABILITY FOR IRRIGATION
CLASSE II - SOLS PEU FAVORABLES A L'IRRIGATION

II B - possible crops : tropical fruit-trees, citrus, pine-apples, tomatoes (juice) vegetables, maize, sorghum, wheat, groundnuts, other oilseeds.
cultures possibles : arbres fruitiers tropicaux, agrumes, ananas, tomates (jus), cultures légumières, maïs, sorgho, blé, arachide, autres oléagineux.

- II B d m: 36, 37, 38

II C - possible crops : sugar-cane, cotton, artificial pastures, maize, sorghum, wheat, textile fiber plants.
cultures possibles : canne à sucre, coton, pâturages artificiels, maïs, sorgho, blé, plantes à fibres textiles.

- II C D S m: 41, 47
- II C D S G M: 44, 45, 46
- II C D S P: 50

3RD CLASS - UNSUITABLE FOR IRRIGATION
CLASSE III - SOLS NON IRRIGABLES

- III Y: 8
- III R U: 1, 2, 4
- III R T: 3, 5, 7, 18, 19, 22, 35, 43
- III U: 6
- III W: 20, 21

EXPLANATION OF THE SYMBOLS
SIGNIFICATION DES SYMBOLES

Factors changing the quality of the soils suitable for irrigation.
Facteurs altérant les qualités des sols irrigables.

- d — Slight drainage necessary / *Drainage léger nécessaire*
- D — Drainage necessary on a larger scale / *Drainage important nécessaire*
- s — Weak salinity in the depth / *Salure faible en profondeur*
- S — High salinity affecting the whole soil / *Salure forte affectant l'ensemble du sol*
- G — Fine, non-clayey texture, unsuitable for irrigation

LEGEND OF THE SOILS MAP
LEGENDE DE LA CARTE PEDOLOGIQUE

WEAKLY DEVELOPED SOILS *SOLS PEU EVOLUES*

NON CLIMATIC SOILS *NON CLIMATIQUES*

VERTISOLS AND VERTIC SOILS *VERTISOLS ET SOLS VERTIQUES*

SOILS WITH CALCAREOUS DIFFERENCIATION *SOLS A DIFFERENCIATION CALCAIRE*

SOILS WITH GYPSEOUS DIFFERENCIATION *SOLS A DIFFERENCIATION GYPSEUSE*

HYDROMORPHIC SOILS *SOLS HYDROMORPHES*

SODIC SOILS *SOLS SODIQUES*

Planimetric sketch executed from the mosaics of 1964-67 aerial photos.
Esquisse planimétrique exécutée d'après les mosaïques photographiques de 1964-67.

INDEX SHEET

Limits of irrigable soils, 1st Class
Limite des sols irrigables, Classe I

A — Indication of large irrigable zones
Indication des grandes zones irrigables

Scale 1: 50 000 approximate

Fa — Flooded area (highly)
Zone fortement inondable

C.E. — Water level
Cote d'eau

Bench-mark
Bouton, borne

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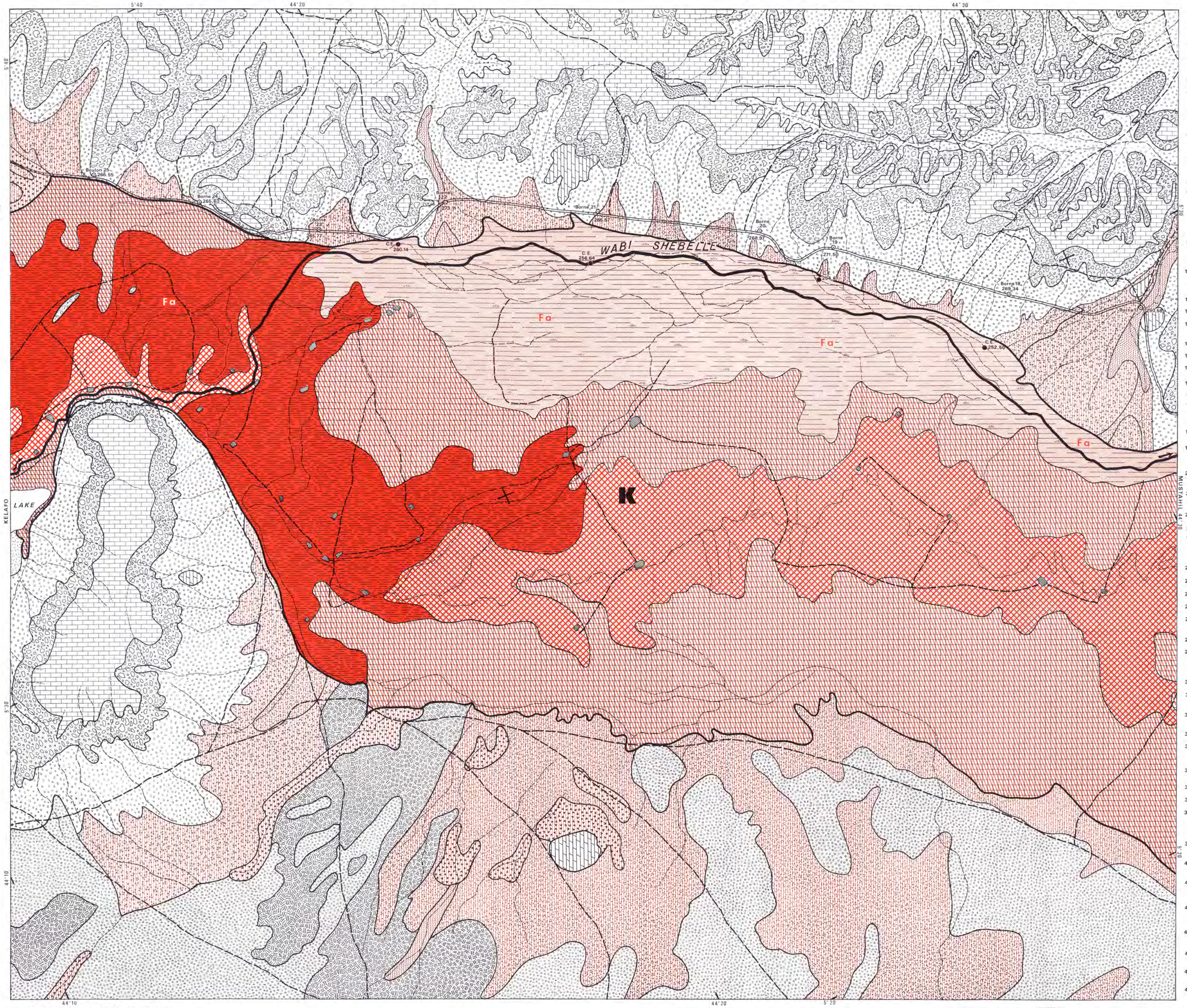
V

SOILS MAP - CARTE DES SOLS

Lower Valley - Basse Vallée

MUSTAHIL WEST

JANUARY 1973
MAP N°3



Planimetric sketch executed from the mosaics of 1964.67 aerial photos.
Esquisse planimétrique exécutée d'après les mosaïques photographiques de 1964.67.

INDEX SHEET

IMI WEST 11	IMI 10	IMI EAST 9	MADISO 8	GODE WEST 7	GODE 6	GODE EAST 5	KELAFO 4	MUSTAHIL WEST 3	MUSTAHIL 2	BURKUR 1

Limits of irrigable soils _ 1st Class
Limite des sols irrigables _ Classe 1

A — Indication of large irrigable zones
Indication des grandes zones irrigables

Scale 1: 50 000 approximate

Mile 1 ¾ ½ ¼ 0 1 2 3 Miles
M 1000 500 0 1 2 3 4 5 Km.

Fa — Flooded area (highly)
Zone fortement inondable

C.E. — Water level
Cote d'eau

Bench-mark
Boulon, borne

SOILS FEATURES FAVOURING IRRIGATION
APTITUDES DES SOLS A L'IRRIGATION

1ST CLASS - VERY SUITABLE SOILS FOR IRRIGATION
CLASSE I - SOLS TRES FAVORABLES A L'IRRIGATION

I A - for all tropical crops in arid zone.
pour toutes cultures tropicales de zone aride.

I A d s — 24, 25, 26
I A D S — 23, 27, 28, 29

I B - for tropical fruit-trees, citrus, pine-apples, tomatoes (juice) vegetables, maize, sorghum, wheat, groundnuts, other oilseeds, forages (graminea).
pour arbres fruitiers tropicaux, agrumes, ananas, tomates (jus), cultures légumières, maïs, sorgho, blé, arachide, autres oléagineux, graminées fourragères.

I B d s — 30, 32, 33, 34
I B D S — 31

I C - for sugar-cane, cotton, artificial pastures, maize, sorghum, wheat, textile fiber plants, oilseeds.
pour canne à sucre, coton, pâturages artificiels, maïs, sorgho, blé, plantes à fibres, plantes à huile.

I C D s m — 9, 10, 12, 13, 14, 15, 17, 39, 40, 42

I D_A - for sugar-cane, coton, hill rice.
pour canne à sucre, coton, riz pluvial.

I D_A D S m — 11, 16, 48, 49

2ND CLASS - LOW SUITABILITY FOR IRRIGATION
CLASSE II - SOLS PEU FAVORABLES A L'IRRIGATION

II B - possible crops : tropical fruit-trees, citrus, pine-apples, tomatoes (juice) vegetables, maize, sorghum, wheat, groundnuts, other oilseeds.
cultures possibles : arbres fruitiers tropicaux, agrumes, ananas, tomates (jus), cultures légumières, maïs, sorgho, blé, arachide, autres oléagineux.

II B d m — 36, 37, 38

II C - possible crops : sugar-cane, cotton, artificial pastures, maize, sorghum, wheat, textile fiber plants.
cultures possibles : canne à sucre, coton, pâturages artificiels, maïs, sorgho, blé, plantes à fibres textiles.

II C D S m — 41, 47
II C D S G M — 44, 45, 46
II C D S P — 50

3RD CLASS - UNSUITABLE FOR IRRIGATION
CLASSE III - SOLS NON IRRIGABLES

III Y — 8
III R U — 1, 2, 4
III R T — 3, 5, 7, 18, 19, 22, 35, 43
III U — 6
III W — 20, 21

EXPLANATION OF THE SYMBOLS
SIGNIFICATION DES SYMBOLES

Factors changing the quality of the soils suitable for irrigation.
Facteurs altérant les qualités des sols irrigables.

- d — Slight drainage necessary / *Drainage léger nécessaire*
- D — Drainage necessary on a larger scale / *Drainage important nécessaire*
- s — Weak salinity in the depth / *Salure faible en profondeur*
- S — High salinity affecting the whole soil / *Salure forte affectant l'ensemble du sol*
- G — Fine non-clayey texture unsuitable for irrigation / *Granulométrie fine non argileuse défavorable à l'irrigation*
- m — Slighty broken micro-relief requiring very slight leveling / *Microrelief peu uniforme nécessitant des planages très légers*
- M — Broken micro-relief requiring a great deal of leveling / *Microrelief peu uniforme nécessitant des planages importants*
- P — Depth of the soil less than 1 m / *Profondeur du sol inférieure à 1 m*

Symbols concerning non irrigable soils.
Symboles concernant les sols non irrigables.

- R — Abundant coarse elements / *Eléments grossiers abondants*
- T — Steep slopes / *Pentes fortes*
- U — Superficial limestone or gypsum flags / *Dalles calcaire ou gypseuse superficielles*
- W — Depth of soil less than 50 cm / *Profondeur du sol inférieure à 50 cm*
- Y — Dunes / *Dunes*

N

LEGEND OF THE SOILS MAP
LEGENDE DE LA CARTE PEDOLOGIQUE

WEAKLY DEVELOPED SOILS *SOLS PEU EVOLUES*
XEROSOLS *XEROSOLIQUES*
GYPSEOUS SOILS Derived from marl and gypsum
GYPSEUX Issus des marnes gypseuses

1 Yellowish-gray soils L with superficial gypsum flag LARGE FLATS (IMI, KELAFO, MUSTAHIL, BURKUR).
Sols gris-jaune slf en place à dalle de gypse superficielle GRANDS FLATS (IMI, KELAFO, MUSTAHIL, BURKUR)

2 Yellowish-gray soils SiL with a gypsum flag at 50 cm depth on COLLUVIA LARGE FLATS (IMI, KELAFO, MUSTAHIL, BURKUR).
Sols gris-jaune slfl à dalle de gypse enterrée à 50 cm sur COLLUVIONS GRANDS FLATS (IMI, KELAFO, MUSTAHIL, BURKUR)

NON CLIMATIC SOILS *NON CLIMATIQUES*
LITHIC ERODED SOILS WITH POWDERY LIME Derived from marl and gypsum
SOLS D'EROSION LITHIQUES A CALCAIRE DIFFUS Issus des marnes gypseuses

3 Yellowish-gray soils SiL with superficial gypsum flag LOWER HILLS.
Sol gris-jaune slfl en place à dalle de gypse superficielle COLLINES BASSES

4 Whitish-yellow soils L shallow with gypsum flag on COLLUVIA DEBRIS-SLOPE of the LOWER HILLS.
Sols jaune-blanc slf à dalle de gypse peu profonde sur COLLUVIONS DEBRIS-SLOPES sous les COLLINES BASSES

Derived from limestone *Issus des calcaires*

5 Yellowish-red soils L to CL with limestone fragments and calcareous nodules on COLLUVIA TALUS below the BLUFF of the LIMESTONE PLATEAUS.
Sols rouge-jaune slf à slfa à débris et nodules calcaires sur COLLUVIONS. TALUS sous les CORNICHES des PLATEAUX CALCAIRES

6 Red soils SiL with gypsum flag at 20 cm depth on COLLUVIA GODE area (DEBRIS SLOPE) and FERFER area (PLATEAUS).
Sols rouges slfl à dalle de gypse à 20 cm de profondeur sur COLLUVIONS environs de GODE (DEBRIS-SLOPE) et de FERFER (PLATEAUX)

Derived from basalts *Issus des basaltes*

7 Pale brown soils SL to L very stony on WEATHERED Basalt BOULDERS HILLS.
Sols brun-clair sf à slf très caillouteux sur ALTERATION en BOULE des basaltes COLLINES

SOILS DEVELOPED ON WIND BLOWN MATERIAL WITH POWDERY LIMESTONE
SOLS D'APPORTS EOLIENS A CALCAIRE DIFFUS

8 Yellow soils SL to L on DUNES GODE area.
Sols jaune sf à slf sur DUNES environs de GODE

VERTISOLS AND VERTIC SOILS *VERTISOLS ET SOLS VERTIQUES*
WITH CURVED STRUCTURE *A STRUCTURE ARRONDIE*
BROWN OR REDDISH BROWN VERTISOLS WITH POWDERY LIME AND POWDERY GYPSUM IN THE DEPTH.
VERTISOLS BRUNS A BRUN-ROUGE A CALCAIRE DIFFUS ET CRISTAUX DE GYPSE EN PROFONDEUR
On RED-BROWN oued ALLUVIA derived from limestone
Sur ALLUVIONS BRUN-ROUGE d'oued issues des calcaires

9 Reddish-brown vertisols grumosolic on 40 cm C to SiC with powdery gypsum at 100 cm depth, easily flooded oued Bu-Y ALLUVIA.
Vertisols brun-rouge grumosoliques sur 40 cm a. à al à cristaux de gypse vers 100 cm inondables ALLUVIONS de l'oued Bu-Y

On BROWN oued ALLUVIA derived from basalts
Sur ALLUVIONS BRUNES d'oued issus des basaltes

10 Brown to red vertisols grumosolic on 40 cm C to SiC with powdery gypsum at 40 cm depth, easily flooded oued ALLUVIA North West GODE area.
Vertisols bruns à rouges grumosoliques sur 40 cm a. à al à cristaux de gypse à plus de 40 cm inondables ALLUVIONS d'oued Nord Ouest GODE

On BROWN ALLUVIA of the Wabi Shebelle *Sur ALLUVIONS BRUNES du Wabi Shebelle*
GODE - I M I series. *Séries IMI-GODE*

11 Brown vertisols grumosolic on 30 cm C with little powdery gypsum below 60 cm easily flooded.
Vertisols bruns grumosoliques sur 30 cm a. quelques cristaux de gypse à partir de 60 cm inondables

12 Brown vertic soils grumosolic on 30 cm C little powdery gypsum below 30 cm.
Sols bruns vertiques grumosoliques sur 30 cm a. quelques cristaux de gypse à partir de 30 cm

13 Brown vertic soils grumosolic on 20 cm SiC to C with powdery gypsum in depth.
Sols bruns vertiques grumosoliques sur 20 cm slfl à a à cristaux de gypse en profondeur

KELAFO - MUSTAHIL - BURKUR series. *Séries KELAFO-MUSTAHIL-BURKUR*

14 Brown vertisols grumosolic on 30 cm SiC to C with powdery gypsum below 90 cm, seldom flooded.
Vertisols bruns grumosoliques sur 30 cm aslfl à a. avec cristaux de gypse à plus de 90 cm faiblement inondables

15 Reddish-brown vertisols, grumosolic on 20 cm C with powdery gypsum below 100 cm (KELAFO only).
Vertisols brun-rouge grumosoliques sur 20 cm a. avec cristaux de gypse à plus de 100 cm (KELAFO seulement)

16 Brown vertisols grumosolic on 30 cm C with powdery gypsum below 80 cm, very easily flooded (MUSTAHIL plain).
Vertisols bruns grumosoliques sur 30 cm a. avec nombreux cristaux de gypse à plus de 80 cm fortement inondables (plaine de MUSTAHIL)

17 Brown vertic soils, grumosolic on 20 cm C with powdery gypsum below 80 cm, seldom flooded (SHEBELLE plain).
Sols bruns vertiques grumosoliques sur 20 cm a. avec cristaux de gypse à plus de 80 cm, faiblement inondables (plaine de SHEBELLE)

SOILS WITH CALCAREOUS DIFFERENCIATION
SOLS A DIFFERENCIATION CALCAIRE
WITHOUT MELANIC HORIZON *SANS HORIZON MELANIQUE*
WITH POWDERY LIME : MODAL *A CALCAIRE DIFFUS : MODAUX*
COLLUVIA derived from limestone *COLLUVIONS issues des calcaires*

18 Yellowish-red soils fS with many limestone debris and pebbles DEBRIS SLOPE below the LIMESTONE PLATEAUS (GODE to BURKUR).
Sols rouge-jaune sf riches en débris calcaires peu émoussés DEBRIS SLOPE sous les PLATEAUX CALCAIRES (GODE à BURKUR)

19 Yellowish-red soils mfs, with limestone and basaltic pebbles HILLOCKS of the LARGE ALLUVIAL FANS (IMI).
Sols rouge-jaune smsf à galets calcaires et basaltiques PETITS MAMELONS des GRANDS CONES de DEJECTION (IMI)

WITH NODULES *A AMAS ET NODULES*
Derived from limestone *Issus des calcaires*

20 Yellowish-red soils SiL to L with calcareous nodules LIMESTONE PLATEAUX (GODE to BURKUR).
Sols rouge-jaune slfl à slf à nodules calcaires en place PLATEAUX CALCAIRES (GODE à BURKUR)

Derived from sandstone *Issus des grès*

21 Red soils SL-L with calcareous nodules LOWER PLATEAUS (IMI).
Sols rouges sfslf à amas et nodules calcaires en place BAS PLATEAUX (IMI)

On ancient oued ALLUVIA *Sur anciennes ALLUVIONS d'oued*

22 Yellowish-red soils CmS, with calcareous pebbles often cemented in conglomerate near the surface HILLOCKS in the LARGE ALLUVIAL FANS (GODE).
Sols rouge-jaune sgsf à galets calcaires souvent soudés en conglomérat à faible profondeur MAMELONS des GRANDS CONES de DEJECTION (GODE)

SOILS WITH GYPSEOUS DIFFERENCIATION
SOLS A DIFFERENCIATION GYPSEUSE
WITH POWDERY GYPSUM : MODAL *A GYPSE DIFFUS : MODAUX*
On BROWN ALLUVIA of the Wabi Shebelle
Sur ALLUVIONS BRUNES du Wabi Shebelle
I M I - GODE series *Séries IMI-GODE*

23 Brown soils SiC weakly organic/fs (ANCIENT MEANDERS of the Wabi Shebelle.
Sols bruns al faiblement humifères/sf (MEANDRES MORTS du WABI SHEBELLE)

24 Brown to yellowish-brown soils SiL to SiC in depth.
Sols bruns à brun-jaune slfl à al en profondeur

25 Brown soils C/fs (GODE).
Sols bruns a/sf (GODE)

26 Brown soils SiL to C in depth (GODE).
Sols bruns slfl à a. en profondeur (GODE)

27 Brown soils CL (GODE).
Sols bruns slfa (Gode)

South KELAFO - MUSTAHIL - BURKUR series *Séries Sud KELAFO-MUSTAHIL-BURKUR*

28 Brown soils C/brownish-yellow L seldom flooded to easily flooded (KELAFO).
Sols bruns a/jaune-brunâtre slf peu inondables à inondables (KELAFO)

29 Brown soils SiL to C in depth.
Sols bruns slfl à a. en profondeur

On BROWNISH - YELLOW ALLUVIA of the Wabi Shebelle
Sur ALLUVIONS JAUNE-BRUN du Wabi Shebelle
I M I - North GODE series *Séries IMI-Nord GODE*

30 Brownish-yellow soils fcS BANKS of the Wabi Shebelle.
Sols jaune-brun à sfsg BOURRELETS de BERGE du Wabi Shebelle

31 Brownish-yellow fS/C.
Sols jaune-brun sf/a

I M I - North GODE - KELAFO series *Série IMI-Nord GODE-KELAFO*

32 Brownish-yellow soils SiL to fS RECENT or ANCIENT BANKS of the Wabi Shebelle.
Sols jaune-brun slfl sf BOURRELETS de BERGE du Wabi Shebelle ACTUELS ou ANCIENS.

South KELAFO - MUSTAHIL - BURKUR series *Séries Sud KELAFO-MUSTAHIL-BURKUR*

33 Brownish-yellow soils SiL to fmS in depth BANKS of the Wabi Shebelle.
Sols jaune-brun slfl à sfsm en profondeur BOURRELETS de BERGE du Wabi Shebelle

34 Brownish-yellow soils SiL to SiL-C in depth.
Sols jaune-brun slfl à slfa en profondeur

On REDDISH - YELLOW oued ALLUVIA *Sur ALLUVIONS JAUNE-ROUGE des oueds*

35 Reddish-yellow soils fS to L with pebbles in the depth often salty ALLUVIAL FANS HIGHER position (GODE to BURKUR).
Sols jaune-rouge sf à slf à galets en profondeur, souvent salés ALLUVIONS des CONES de DEJECTION position HAUTE (GODE à BURKUR)

36 Reddish-yellow soils L and mS ALLUVIAL FANS (IMI).
Sols jaune-rouge slf et sm ALLUVIONS des CONES de DEJECTION (IMI)

37 Reddish-yellow soils SiL RECENT ALLUVIA of the larger oueds.
Sols jaune-rouge slfl ALLUVIONS RECENTES des grands oueds

38 Reddish-yellow soils fS-SiL RECENT ALLUVIA of the larger oueds (MADISO).
Sols jaune-rouge sf-slfl ALLUVIONS RECENTES des grands oueds (MADISO)

WITH POWDERY GYPSUM : VERTIC *A GYPSE DIFFUS : VERTIQUES*
On BROWN ALLUVIA of the Wabi Shebelle *Sur ALLUVIONS BRUNES du Wabi Shebelle*
North GODE serie *Série Nord GODE*

39 Brown soils with SiC predominance.
Sols bruns à dominance al

GODE - KELAFO serie *Série GODE-KELAFO*

40 Brown soils C.
Sols bruns a

On YELLOWISH - RED oued ALLUVIA *Sur ALLUVIONS ROUGE-JAUNE des Oueds*

41 Yellowish-red soils SiL to C RECENT ALLUVIA of the smaller oueds.
Sols rouge-jaune slfl à a. ALLUVIONS RECENTES des petits oueds

On Wabi Shebelle YELLOWISH - BROWN ALLUVIA over RED basaltic ALLUVIA
Sur ALLUVIONS BRUN-JAUNE du Wabi Shebelle recouvrant les ALLUVIONS ROUGES basaltiques.

42 Yellowish-brown soils SiL/red C (GODE).
Sols brun-jaune slfl/rouge a. (GODE)

WITH GYPSEOUS CRUST : MODAL *ENCROUTES : MODAUX*
From RED COLLUVIA derived from basalts *Sur COLLUVIONS ROUGES issues des basaltes*

43 Red soils SCL to C with gypseous crust at 60 cm depth DEBRIS SLOPE below the basaltic HILLS (GODE North GODE).
Sols rouges sfa à a. à croûte de gypse vers 60 cm DEBRIS-SLOPE des COLLINES de basalte (GODE-Nord GODE)

From YELLOWISH - RED oued ALLUVIA *Sur ALLUVIONS ROUGE-JAUNE des oueds*

44 Yellowish-red soils L to SiL with gypsum crust at 70 cm depth, salty in depth ALLUVIAL FANS LOWER position (GODE).
Sols rouge-jaune slf à slfl à croûte de gypse vers 70 cm salés en profondeur ALLUVIONS des CONES de DEJECTION position BASSE (GODE)

45 Yellowish-red soils SiL to SiCL with gypsum crust at 70 cm depth, salty near the surface ALLUVIAL FANS LOWER position (GODE to BURKUR).
Sols rouge-jaune slfl à la. à croûte de gypse à 70 cm salés à faible profondeur ALLUVIONS des CONES de DEJECTION position BASSE (GODE à BURKUR)

46 Yellowish-red soils L to SiC with gypsum accumulation " SAND ROSE " type ALLUVIAL FANS LOWER position (IMI-GODE).
Sols rouge-jaune slf à al. à accumulation de gypse sous forme de ROSE des SABLES ALLUVIONS des CONES de DEJECTION position BASSE (IMI GODE)

On Wabi Shebelle YELLOWISH - BROWN ALLUVIA over YELLOWISH - RED oued ALLUVIA
Sur ALLUVIONS BRUN-JAUNE du Wabi Shebelle recouvrant les ALLUVIONS ROUGE-JAUNE des oueds

47 Yellowish-brown soils SCL/yellowish-red C (GODE).
Sols brun-jaune sfa/rouge-jaune a (GODE)

HYDROMORPHIC SOILS *SOLS HYDROMORPHES*
MEDIUM ORGANIC *MOYENNEMENT ORGANIQUES*
HUMIC GLEY WITH POWDERY LIME *HUMIQUES A GLEY A CALCAIRE DIFFUS*
On BROWN ALLUVIA of the Wabi Shebelle *Sur ALLUVIONS BRUNES du Wabi Shebelle*
SHEBELLE plain serie *Série de la plaine de SHEBELLE*

48 Brown soils C, very easily flooded (PAPYRUS area).
Sols bruns a. fortement inondables (zone à PAPYRUS)

MUSTAHIL plain serie *Série de la plaine de MUSTAHIL*

49 Brown soils C very easily flooded (GRAMINEA area).
Sols bruns a. fortement inondables (zone à GRAMINEES)

SODIC SOILS *SOLS SODIQUES*
WITH NON DEGRADED STRUCTURE *A STRUCTURE NON DEGRADEE*
SALINE SOILS WITH SALT EFFLORESCENCES *SOLS SALINS A EFFLORESCENCES SALINES*
On RED oued ALLUVIA *Sur ALLUVIONS ROUGES d'oued*

50 Red soils SiL to C with gypsum flag at medium depth (BURKUR-FERFER).
Sols rouges slfl à a. à dalle de gypse à moyenne profondeur (BURKUR-FERFER)

ABBREVIATIONS

የኢትዮጵያ ንጉሠ ነገሥት መንግሥት
ብሔራዊ የውሃ ሀብት ልማት ኮሚሽን መሥሪያ ቤት

IMPERIAL ETHIOPIAN GOVERNMENT
NATIONAL WATER RESOURCES COMMISSION

ETHIOPIA - FRANCE COOPERATIVE PROGRAM

WABI SHEBELLE SURVEY

IN COLLABORATION WITH

FRENCH MINISTRY OF FOREIGN AFFAIRS — NATIONAL WATER RESOURCES COMMISSION — BCEOM. ORSTOM. EDF IGN_BDPA

V

SOILS MAP - CARTE DES SOLS

Lower Valley - Basse Vallée

KELAFO

ORSTOM

JANUARY 1973
MAP N°4

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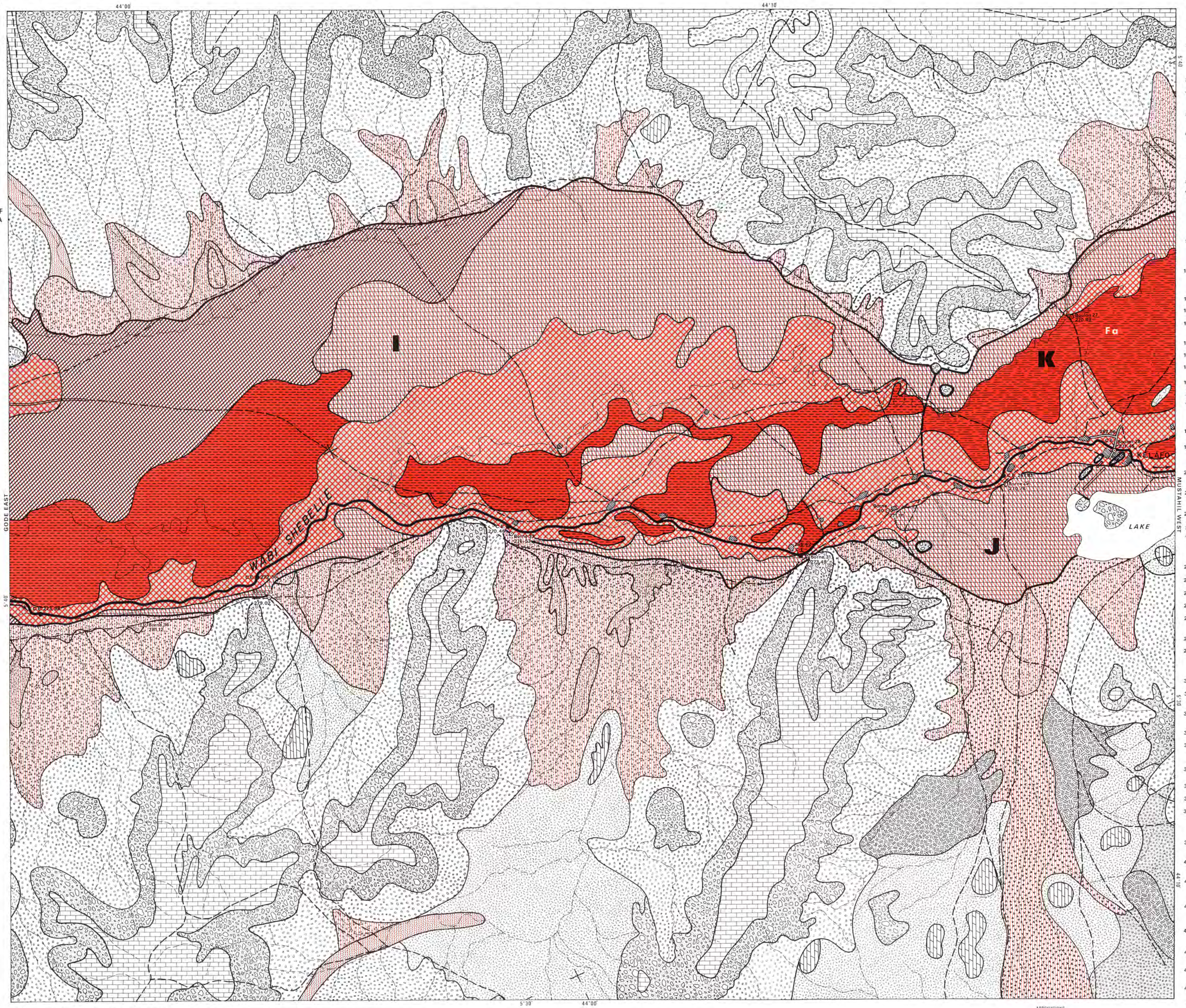


SOILS FEATURES FAVOURING IRRIGATION
APTITUDES DES SOLS A L'IRRIGATION

1ST CLASS - VERY SUITABLE SOILS FOR IRRIGATION
CLASSE I - SOLS TRES FAVORABLES A L'IRRIGATION

I A - for all tropical crops in arid zone.
pour toutes cultures tropicales de zone aride.

- I A d s: 24, 25, 26
- I A D S: 23, 27, 28, 29

I B - for tropical fruit-trees, citrus, pine-apples, tomatoes (juice) vegetables, maize, sorghum, wheat, groundnuts, other oilseeds, forages (graminea).
pour arbres fruitiers tropicaux, agrumes, ananas, tomates (jus), cultures légumières, maïs, sorgho, blé, arachide, autres oléagineux, graminées fourragères.

- I B d s: 30, 32, 33, 34
- I B D S: 31

I C - for sugar-cane, cotton, artificial pastures, maize, sorghum, wheat, textile fiber plants, oilseeds.
pour canne à sucre, coton, pâturages artificiels, maïs, sorgho, blé, plantes à fibres, plantes à huile.

- I C D s m: 9, 10, 12, 13, 14, 15, 17, 39, 40, 42

I D_A - for sugar-cane, coton, hill rice.
pour canne à sucre, coton, riz pluvial.

- I D_A D S m: 11, 16, 48, 49

2ND CLASS - LOW SUITABILITY FOR IRRIGATION
CLASSE II - SOLS PEU FAVORABLES A L'IRRIGATION

II B - possible crops : tropical fruit-trees, citrus, pine-apples, tomatoes (juice) vegetables, maize, sorghum, wheat, groundnuts, other oilseeds.
cultures possibles : arbres fruitiers tropicaux, agrumes, ananas, tomates (jus), cultures légumières, maïs, sorgho, blé, arachide, autres oléagineux.

- II B d m: 36, 37, 38

II C - possible crops : sugar-cane, cotton, artificial pastures, maize, sorghum, wheat, textile fiber plants.
cultures possibles : canne à sucre, coton, pâturages artificiels, maïs, sorgho, blé, plantes à fibres textiles.

- II C D S m: 41, 47
- II C D S G M: 44, 45, 46
- II C D S P: 50

3RD CLASS - UNSUITABLE FOR IRRIGATION
CLASSE III - SOLS NON IRRIGABLES

- III Y: 8
- III R U: 1, 2, 4
- III R T: 3, 5, 7, 18, 19, 22, 35, 43
- III U: 6
- III W: 20, 21

EXPLANATION OF THE SYMBOLS
SIGNIFICATION DES SYMBOLES

Factors changing the quality of the soils suitable for irrigation.
Facteurs altérant les qualités des sols irrigables.

- d — Slight drainage necessary / *Drainage léger nécessaire*
- D — Drainage necessary on a larger scale / *Drainage important nécessaire*
- s — Weak salinity in the depth / *Salure faible en profondeur*
- S — High salinity affecting the whole soil / *Salure forte affectant l'ensemble du sol*
- G — Fine non-clayey texture unsuitable for irrigation / *Granulométrie fine non argileuse défavorable à l'irrigation*
- m — Slighty broken micro-relief requiring very slight leveling / *Microrelief peu uniforme nécessitant des planages très légers*
- M — Broken micro-relief requiring a great deal of leveling / *Microrelief peu uniforme nécessitant des planages importants*
- P — Depth of the soil less than 1 m / *Profondeur du sol inférieure à 1 m*

Symbols concerning non irrigable soils.
Symboles concernant les sols non irrigables.

- R — Abundant coarse elements / *Eléments grossiers abondants*
- T — Steep slopes / *Pentes fortes*
- U — Superficial limestone or gypsum flags / *Dalles calcaire ou gypseuse superficielles*
- W — Depth of soil less than 50 cm / *Profondeur du sol inférieure à 50 cm*
- Y — Dunes / *Dunes*

N

Planimetric sketch executed from the mosaics of 1964-67 aerial photos.
Esquisse planimétrique exécutée d'après les mosaïques photographiques de 1964-67.

INDEX SHEET

IMI WEST 11	IMI 10	IMI EAST 9	MADISO 8	GODE WEST 7	GODE 6	GODE EAST 5	KELAFO 4	MUSTAHIL WEST 3	MUSTAHIL 2	BURKUR 1

— Limits of irrigable soils . 1st Class / *Limite des sols irrigables . Classe I*

A Indication of large irrigable zones / *Indication des grandes zones irrigables*

Scale 1: 50 000 approximate

Mile 1 ¾ ½ ¼ 0 1 2 3 Miles
M 1000 500 0 1 2 3 4 5 Km

Fa Flooded area (highly) / *Zone fortement inondable*

C.E. Water level / *Cote d'eau*

⊙ Bench-mark / *Boulon, borne*

ABREVIATIONS

m.S.	Medium sand	L.	Loam
sm	sableux à sables moyens	slf	sableux à sables très fins
m.f.S.	Medium and fine sand with predominance of medium sand	S.i.L.	Silty loam
smsf	sableux à sables moyens et sables fins	stff	sablo-limoneux à sables très fins
f.S.	Fine sand	C.L.	Clay loam
sf	sableux à sables fins	stfa	sablo-argileux à sables très fins
c.m.S.	Coarse and medium sand with predominance of coarse sand	S.i.C.L.	Silty clay loam
sgsf	sableux à sables grossiers et sables fins	la	limono-argileux
f.c.S.	Fine and coarse sand	C.S.i.C.	Clay - Silty clay
sfsg	sableux à sables fins et sables grossiers	astff	argilo-sablo-limoneux à sables très fins
f.m.S.	Fine and medium sand	S.i.C.	Silty clay
sfsm	sableux à sables fins et sables moyens	al	argilo-limoneux
S.L.L.	Sandy loam to loam	C.	Clay
sfstf	sableux à sables fins et sables très fins	a	argileux
S.C.L.	Sandy clay loam		
sfa	sablo-argileux à sables fins		

LEGEND OF THE SOILS MAP
LEGENDE DE LA CARTE PEDOLOGIQUE

WEAKLY DEVELOPED SOILS *SOLS PEU EVOLUES*
XEROSOLS *XERIQUES*

GYPSEOUS SOILS Derived from marl and gypsum
GYPSEUX Issus des marnes gypseuses

1 Yellowish-gray soils L. with superficial gypsum flag . LARGE FLATS (IMI, KELAFO, MUSTAHIL, BURKUR)
Sols gris-jaune stf en place à dalle de gypse superficielle GRANDS FLATS (IMI, KELAFO, MUSTAHIL, BURKUR)

2 Yellowish-gray soils SiL. with a gypsum flag at 50 cm depth on COLLUVIA . LARGE FLATS (IMI, KELAFO, MUSTAHIL, BURKUR)
Sols gris-jaune stff à dalle de gypse enterrée à 50 cm sur COLLUVIONS . GRANDS FLATS (IMI, KELAFO, MUSTAHIL, BURKUR)

NON CLIMATIC SOILS *NON CLIMATIQUES*
LITHIC ERODED SOILS WITH POWDERY LIME Derived from marl and gypsum
SOLS D'EROSION LITHIQUES A CALCAIRE DIFFUS Issus des marnes gypseuses

3 Yellowish-gray soils SiL. with superficial gypsum flag . LOWER HILLS
Sol gris-jaune stff en place à dalle de gypse superficielle . COLLINES BASSES

4 Whitish-yellow soils L. shallow with gypsum flag on COLLUVIA . DEBRIS-SLOPE of the LOWER HILLS
Sols jaune-blanc stf à dalle de gypse peu profonde sur COLLUVIONS . DEBRIS-SLOPES sous les COLLINES BASSES

Derived from limestone *Issus des calcaires*

5 Yellowish-red soils L. to CL. with limestone fragments and calcareous nodules on COLLUVIA TALUS below the BLUFF of the LIMESTONE PLATEAUS
Sols rouge-jaune stf à stfa à débris et nodules calcaires sur COLLUVIONS TALUS sous les CORNICHES des PLATEAUX CALCAIRES

6 Red soils SiL. with gypsum flag at 20 cm depth on COLLUVIA GODE area (DEBRIS SLOPE) and FERFER area (PLATEAUS)
Sols rouges stff à dalle de gypse à 20 cm de profondeur sur COLLUVIONS environs de GODE (DEBRIS-SLOPE) et de FERFER (PLATEAUX)

Derived from basalts *Issus des basaltes*

7 Pale-brown soils SL to L. very stony on WEATHERED Basalt BOULDERS . HILLS
Sols brun-clair sf à stf très caillouteux sur ALTERATION en BOULE des basaltes . COLLINES

SOILS DEVELOPED ON WIND BLOWN MATERIAL WITH POWDERY LIMESTONE.
SOLS D'APPORTS EOLIENS A CALCAIRE DIFFUS

8 Yellow soils SL to L. on DUNES . GODE area
Sols jaune sf à stf sur DUNES . environs de GODE

VERTISOLS AND VERTIC SOILS *VERTISOLS ET SOLS VERTIQUES*
WITH CURVED STRUCTURE *A STRUCTURE ARRONDIE*
BROWN OR REDDISH BROWN VERTISOLS WITH POWDERY LIME AND POWDERY GYPSUM IN THE DEPTH.
VERTISOLS BRUNS A BRUN-ROUGE A CALCAIRE DIFFUS ET CRISTAUX DE GYPSE EN PROFONDEUR

On RED-BROWN oued ALLUVIA derived from limestone
Sur ALLUVIONS BRUN-ROUGE d'oued issues des calcaires

9 Reddish-brown vertisols, grumosolic on 40 cm C. to SiC with powdery gypsum at 100 cm depth, easily flooded . oued Bu-Y ALLUVIA
Vertisols brun-rouge grumosoliques sur 40 cm a à al à cristaux de gypse vers 100 cm, inondables . ALLUVIONS de l'oued Bu-Y

On BROWN oued ALLUVIA derived from basalts
Sur ALLUVIONS BRUNES d'oued issus des basaltes

10 Brown to red vertisols, grumosolic on 40 cm C. to SiC. with powdery gypsum at 40 cm depth, easily flooded oued ALLUVIA . North West GODE area
Vertisols bruns à rouges grumosoliques sur 40 cm a à al à cristaux de gypse à plus de 40 cm inondables ALLUVIONS d'oued . Nord Ouest GODE

On BROWN ALLUVIA of the Wabi Shebelle *Sur ALLUVIONS BRUNES du Wabi Shebelle*
GODE - I M I series. *Séries IMI-GODE*

11 Brown vertisols grumosolic on 30 cm C. with little powdery gypsum below 60 cm . easily flooded
Vertisols bruns grumosoliques sur 30 cm a quelques cristaux de gypse à partir de 60 cm . inondables

12 Brown vertic soils grumosolic on 30 cm C. little powdery gypsum below 30 cm
Sols bruns vertiques grumosoliques sur 30 cm a quelques cristaux de gypse à partir de 30 cm

13 Brown vertic soils grumosolic on 20 cm SiC. to C. with powdery gypsum in depth
Sols bruns vertiques grumosoliques sur 20 cm stff à a, à cristaux de gypse en profondeur

KELAFO - MUSTAHIL - BURKUR series. *Séries KELAFO-MUSTAHIL-BURKUR*

14 Brown vertisols, grumosolic on 30 cm SiC to C. with powdery gypsum below 90 cm, seldom flooded
Vertisols bruns grumosoliques sur 30 cm astff à a, avec cristaux de gypse à plus de 90 cm faiblement inondables

15 Reddish-brown vertisols, grumosolic on 20 cm C. with powdery gypsum below 100 cm (KELAFO only)
Vertisols brun-rouge grumosoliques sur 20 cm a avec cristaux de gypse à plus de 100 cm (KELAFO seulement)

16 Brown vertisols, grumosolic on 30 cm C. with powdery gypsum below 80 cm, very easily flooded (MUSTAHIL plain)
Vertisols bruns grumosoliques sur 30 cm a, avec nombreux cristaux de gypse à plus de 80 cm fortement inondables (plaine de MUSTAHIL)

17 Brown vertic soils, grumosolic on 20 cm C. with powdery gypsum below 80 cm, seldom flooded (SHEBELLE plain)
Sols bruns vertiques grumosoliques sur 20 cm a, avec cristaux de gypse à plus de 80 cm, faiblement inondables (plaine de SHEBELLE)

SOILS WITH CALCAREOUS DIFFERENCIATION
SOLS A DIFFERENCIATION CALCAIRE

WITHOUT MELANIC HORIZON *SANS HORIZON MELANIQUE*
WITH POWDERY LIME : MODAL *A CALCAIRE DIFFUS : MODAUX*
COLLUVIA derived from limestone *COLLUVIONS issues des calcaires*

18 Yellowish-red soils fS with many limestone debris and pebbles DEBRIS SLOPE below the LIMESTONE PLATEAUS (GODE to BURKUR)
Sols rouge-jaune sf riches en débris calcaires peu émoussés DEBRIS-SLOPE sous les PLATEAUX CALCAIRES (GODE à BURKUR)

19 Yellowish-red soils mfS. with limestone and basaltic pebbles . HILLOCKS of the LARGE ALLUVIAL FANS (IMI)
Sols rouge-jaune smsf à galets calcaires et basaltiques PETITS MAMELONS des GRANDS CONES de DEJECTION (IMI)

WITH NODULES *A AMAS ET NODULES*
Derived from limestone *Issus des calcaires*

20 Yellowish-red soils SiL. to L. with calcareous nodules . LIMESTONE PLATEAUX (GODE to BURKUR)
Sols rouge-jaune stff à stf à nodules calcaires en place . PLATEAUX CALCAIRES (GODE à BURKUR)

Derived from sandstone *Issus des grès*

21 Red soils SL-L with calcareous nodules . LOWER PLATEAUS (IMI)
Sols rouges sfstf à amas et nodules calcaires en place . BAS PLATEAUX (IMI)

On ancient oued ALLUVIA *Sur anciennes ALLUVIONS d'oued*

22 Yellowish-red soils CmS. with calcareous pebbles often cemented in conglomerate near the surface HILLOCKS in the LARGE ALLUVIAL FANS (GODE)
Sols rouge-jaune sgsf à galets calcaires souvent soudés en conglomérat à faible profondeur MAMELONS des GRANDS CONES de DEJECTION (GODE)

SOILS WITH GYPSEOUS DIFFERENCIATION
SOLS A DIFFERENCIATION GYPSEUSE

WITH POWDERY GYPSUM : MODAL *A GYPSE DIFFUS : MODAUX*
On BROWN ALLUVIA of the Wabi Shebelle
Sur ALLUVIONS BRUNES du Wabi Shebelle
I M I - GODE series *Séries IMI-GODE*

23 Brown soils SiC weakly organic/fs (ANCIENT MEANDERS of the Wabi Shebelle
Sols bruns al faiblement humifères/sr . (MEANDRES MORTS du WABI SHEBELLE)

24 Brown to yellowish-brown soils SiL to SiC in depth
Sols bruns à brun-jaune stff à al en profondeur

25 Brown soils C/fs (GODE)
Sols bruns a/sf (GODE)

26 Brown soils SiL to C in depth (GODE)
Sols bruns stff à a en profondeur (GODE)

27 Brown soils CL (GODE)
Sols bruns sfa (Gode)

South KELAFO - MUSTAHIL - BURKUR series *Séries Sud KELAFO-MUSTAHIL-BURKUR*

28 Brown soils C/brownish-yellow L. seldom flooded to easily flooded (KELAFO)
Sols bruns a/jaune brunâtre stf, peu inondables à inondables (KELAFO)

29 Brown soils SiL to C in depth
Sols bruns stff à a en profondeur

On BROWNISH - YELLOW ALLUVIA of the Wabi Shebelle
Sur ALLUVIONS JAUNE-BRUN du Wabi Shebelle
I M I - North GODE series *Séries IMI-Nord GODE*

30 Brownish-yellow soils fcS . BANKS of the Wabi Shebelle
Sols jaune-brun à sfsg . BOURRELETS de BERGE du Wabi Shebelle

31 Brownish-yellow fS/C
Sols jaune-brun sf/a

I M I - North GODE - KELAFO series *Série IMI-Nord GODE-KELAFO*

32 Brownish-yellow soils SiL to fS . RECENT or ANCIENT BANKS of the Wabi Shebelle
Sols jaune-brun stff-sf . BOURRELETS de BERGE du Wabi Shebelle ACTUELS ou ANCIENS

South KELAFO - MUSTAHIL - BURKUR series *Séries Sud KELAFO-MUSTAHIL-BURKUR*

33 Brownish-yellow soils SiL to fmS in depth . BANKS of the Wabi Shebelle
Sols jaune-brun stff à sfsm en profondeur . BOURRELETS de BERGE du Wabi Shebelle

34 Brownish-yellow soils SiL to SiL-C in depth
Sols jaune-brun stff à stffa en profondeur

On REDDISH - YELLOW oued ALLUVIA *Sur ALLUVIONS JAUNE-ROUGE des oueds*

35 Reddish-yellow soils fS to L with pebbles in the depth often salty ALLUVIAL FANS . HIGHER position (GODE to BURKUR)
Sols jaune-rouge sf à stf à galets en profondeur, souvent salés ALLUVIONS des CONES de DEJECTION . position HAUTE (GODE à BURKUR)

36 Reddish-yellow soils L and mS ALLUVIAL FANS (IMI)
Sols jaune-rouge stf et sm . ALLUVIONS des CONES de DEJECTION (IMI)

37 Reddish-yellow soils SiL . RECENT ALLUVIA of the larger oueds
Sols jaune-rouge stff . ALLUVIONS RECENTES des grands oueds

38 Reddish-yellow soils fS-SiL . RECENT ALLUVIA of the larger oueds (MADISO)
Sols jaune-rouge sf-stff . ALLUVIONS RECENTES des grands oueds (MADISO)

WITH POWDERY GYPSUM : VERTIC *A GYPSE DIFFUS : VERTIQUES*
On BROWN ALLUVIA of the Wabi Shebelle *Sur ALLUVIONS BRUNES du Wabi Shebelle*
North GODE serie *Série Nord GODE*

39 Brown soils with SiC predominance
Sols bruns à dominance al

GODE - KELAFO serie *Série GODE-KELAFO*

40 Brown soils C.
Sols bruns a

On YELLOWISH - RED oued ALLUVIA *Sur ALLUVIONS ROUGE-JAUNE des Oueds*

41 Yellowish-red soils SiL to C. . RECENT ALLUVIA of the smaller oueds
Sols rouge-jaune stff à a . ALLUVIONS RECENTES des petits oueds

On Wabi Shebelle YELLOWISH - BROWN ALLUVIA over RED basaltic ALLUVIA
Sur ALLUVIONS BRUN-JAUNE du Wabi Shebelle recouvrant les ALLUVIONS ROUGES basaltiques

42 Yellowish-brown soils SiL/red C (GODE)
Sols brun-jaune stff/rouge a . (GODE)

WITH GYPSEOUS CRUST : MODAL *ENCROUTES : MODAUX*
From RED COLLUVIA derived from basalts *Sur COLLUVIONS ROUGES issues des basaltes*

43 Red soils SCL to C. with gypseous crust at 60 cm depth . DEBRIS SLOPE below the basaltic HILLS (GODE North GODE)
Sols rouges sfa à a à croûte de gypse vers 60 cm . DEBRIS-SLOPE des COLLINES de basalte (GODE Nord GODE)

From YELLOWISH - RED oued ALLUVIA *Sur ALLUVIONS ROUGE-JAUNE des oueds*

44 Yellowish-red soils L to SiL with gypsum crust at 70 cm depth, salty in depth . ALLUVIAL FANS LOWER position (GODE)
Sols rouge-jaune stf à stff à croûte de gypse vers 70 cm . salés en profondeur . ALLUVIONS des CONES de DEJECTION position BASSE (GODE)

45 Yellowish-red soils SiL to SiCL with gypsum crust at 70 cm depth, salty near the surface ALLUVIAL FANS LOWER position (GODE to BURKUR)
Sols rouge-jaune stff à la à croûte de gypse à 70 cm . salés à faible profondeur ALLUVIONS des CONES de DEJECTION position BASSE (GODE à BURKUR)

46 Yellowish-red soils L. to SiC, with gypsum accumulation " SAND ROSE " type . ALLUVIAL FANS LOWER position (IMI-GODE)
Sols rouge-jaune stf à al à accumulation de gypse sous forme de ROSE des SABLES ALLUVIONS des CONES de DEJECTION position BASSE (IMI-GODE)

On Wabi Shebelle YELLOWISH - BROWN ALLUVIA over YELLOWISH - RED oued ALLUVIA
Sur ALLUVIONS BRUN-JAUNE du Wabi Shebelle recouvrant les ALLUVIONS ROUGE-JAUNE des oueds

47 Yellowish-brown soils SCL/yellowish-red C (GODE)
Sols brun-jaune sfa/rouge-jaune a (GODE)

HYDROMORPHIC SOILS *SOLS HYDROMORPHES*
MEDIUM ORGANIC *MOYENNEMENT ORGANIQUES*
HUMIC GLEY WITH POWDERY LIME *HUMIQUES A GLEY A CALCAIRE DIFFUS*
On BROWN ALLUVIA of the Wabi Shebelle *Sur ALLUVIONS BRUNES du Wabi Shebelle*
SHEBELLE plain serie *Série de la plaine de SHEBELLE*

48 Brown soils C. very easily flooded (PAPYRUS area)
Sols bruns a, fortement inondables (zone à PAPYRUS)

MUSTAHIL plain serie *Série de la plaine de MUSTAHIL*

49 Brown soils C. very easily flooded (GRAMINEA area)
Sols bruns a, fortement inondables (zone à GRAMINEES)

SODIC SOILS *SOLS SODIQUES*
WITH NON DEGRADED STRUCTURE *A STRUCTURE NON DEGRADEE*
SALINE SOILS WITH SALT EFFLORESCENCES *SOLS SALINS A EFFLORESCENCES SALINES*
On RED oued ALLUVIA *Sur ALLUVIONS ROUGES d'oued*

50 Red soils SiL to C. with gypsum flag at medium depth (BURKUR-FERFER)
Sols rouges stff à a, à dalle de gypse à moyenne profondeur (BURKUR-FERFER)

የኢትዮጵያ ንጉሠ ነገሥት መንግሥት
ብሔራዊ የውሃ ሀብት ልማት ኮሚሽን መሥሪያ ቤት

IMPERIAL ETHIOPIAN GOVERNMENT

NATIONAL WATER RESOURCES COMMISSION

ETHIOPIA - FRANCE COOPERATIVE PROGRAM

WABI SHEBELLE SURVEY

IN COLLABORATION WITH

FRENCH MINISTRY OF FOREIGN AFFAIRS — NATIONAL WATER RESOURCES COMMISSION — BCEOM_ORSTOM_EDF IGN_BDPA

V

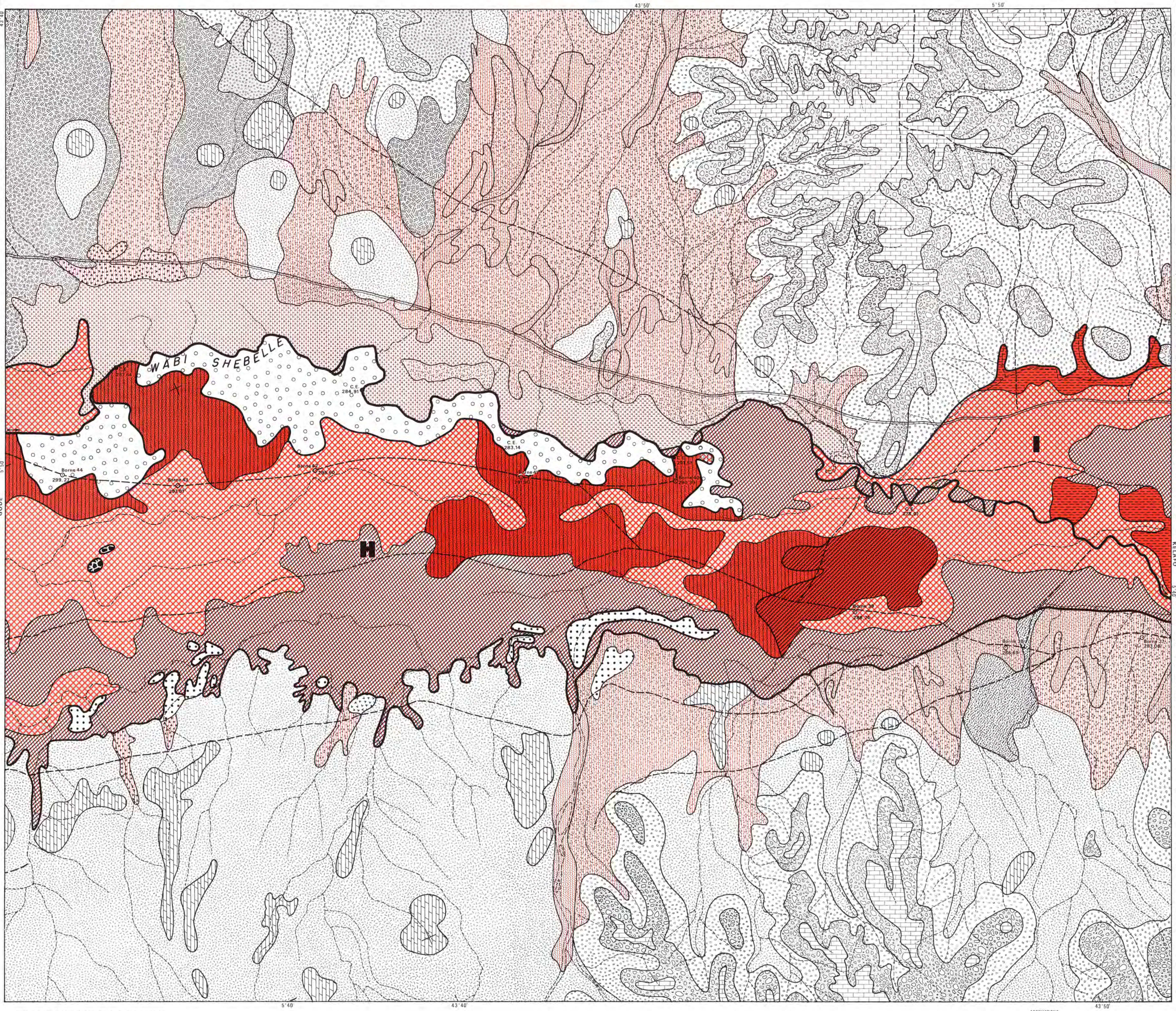
SOILS MAP - CARTE DES SOLS

Lower Valley - Basse Vallée

GODE EAST

ORSTOM

JANUARY 1973
MAP N°5



SOILS FEATURES FAVOURING IRRIGATION
APTITUDES DES SOLS A L'IRRIGATION

1ST CLASS - VERY SUITABLE SOILS FOR IRRIGATION
CLASSE I - SOLS TRES FAVORABLES A L'IRRIGATION

I A - for all tropical crops in arid zone.
pour toutes cultures tropicales de zone aride.

- I A d s: 24, 25, 26
- I A D S: 23, 27, 28, 29

I B - for tropical fruit-trees, citrus, pine-apples, tomatoes (juice) vegetables, maize, sorghum, wheat, groundnuts, other oilseeds, forages (graminea).
pour arbres fruitiers tropicaux, agrumes, ananas, tomates (jus), cultures légumières, maïs, sorgho, blé, arachide, autres oléagineux, graminées fourragères.

- I B d s: 30, 32, 33, 34
- I B D S: 31

I C - for sugar-cane, cotton, artificial pastures, maize, sorghum, wheat, textile fiber plants, oilseeds.
pour canne à sucre, coton, pâturages artificiels, maïs, sorgho, blé, plantes à fibres, plantes à huile.

- I C D s m: 9, 10, 12, 13, 14, 15, 17, 39, 40, 42

I D_A - for sugar-cane, coton, hill rice.
pour canne à sucre, coton, riz pluvial.

- I D_A D S m: 11, 16, 48, 49

2ND CLASS - LOW SUITABILITY FOR IRRIGATION
CLASSE II - SOLS PEU FAVORABLES A L'IRRIGATION

II B - possible crops : tropical fruit-trees, citrus, pine-apples, tomatoes (juice) vegetables, maize, sorghum, wheat, groundnuts, other oilseeds.
cultures possibles : arbres fruitiers tropicaux, agrumes, ananas, tomates (jus), cultures légumières, maïs, sorgho, blé, arachide, autres oléagineux.

- II B d m: 36, 37, 38

II C - possible crops : sugar-cane, cotton, artificial pastures, maize, sorghum, wheat, textile fiber plants.
cultures possibles : canne à sucre, coton, pâturages artificiels, maïs, sorgho, blé, plantes à fibres textiles.

- II C D S m: 41, 47
- II C D S G M: 44, 45, 46
- II C D S P: 50

3RD CLASS - UNSUITABLE FOR IRRIGATION
CLASSE III - SOLS NON IRRIGABLES

- III Y: 8
- III R U: 1, 2, 4
- III R T: 3, 5, 7, 18, 19, 22, 35, 43
- III U: 6
- III W: 20, 21

EXPLANATION OF THE SYMBOLS
SIGNIFICATION DES SYMBOLES

Factors changing the quality of the soils suitable for irrigation.
Facteurs altérant les qualités des sols irrigables.

- **d** Slight drainage necessary / *Drainage léger nécessaire*
- **D** Drainage necessary on a larger scale / *Drainage important nécessaire*
- **s** Weak salinity in the depth / *Salure faible en profondeur*
- **S** High salinity affecting the whole soil / *Salure forte affectant l'ensemble du sol*
- **G** Fine non-clayey texture unsuitable for irrigation / *Granulométrie fine non argileuse défavorable à l'irrigation*
- **m** Slighty broken micro-relief requiring very slight leveling / *Microrelief peu uniforme nécessitant des planages très légers*
- **M** Broken micro-relief requiring a great deal of leveling / *Microrelief peu uniforme nécessitant des planages importants*
- **P** Depth of the soil less than 1 m / *Profondeur du sol inférieure à 1 m*

Symbols concerning non irrigable soils.
Symboles concernant les sols non irrigables.

- **R** Abundant coarse elements / *Eléments grossiers abondants*
- **T** Steep slopes / *Pentes fortes*
- **U** Superficial limestone or gypsum flags / *Dalles calcaire ou gypseuse superficielles*
- **W** Depth of soil less than 50 cm / *Profondeur du sol inférieure à 50 cm*
- **Y** Dunes / *Dunes*

N

Planimetric sketch executed from the mosaics of 1964.67 aerial photos.
Esquisse planimétrique executée d'apres les mosaïques photographiques de 1964-67.

INDEX SHEET

11	10	9	8	7	6	5	4	3	2	1
IMI WEST	IMI	IMI EAST	MADISO	GODE WEST	GODE	GODE EAST	KELAFO	MUSTAHIL WEST	MUSTAHIL	BURKUR

Limits of irrigable soils _ 1st Class
Limite des sols irrigables _ Classe 1

A Indication of large irrigable zones
Indication des grandes zones irrigables

Scale 1: 50000 approximate

Mile 1 ¾ ½ ¼ 0 1 2 3 Miles
M 1000 500 0 1 2 3 4 5 Km

Fa Flooded area (highly) / *Zone fortement inondable*

C.E. Water level / *Cote d'eau*

⊙ Bench-mark / *Boulon, borne*

ABREVIATIONS

- m.S. Medium sand — *sm sableux à sables moyens*
- m.f.S. Medium and fine sand with predominance of medium sand — *smsf sableux à sables moyens et sables fins*
- f.S. Fine sand — *sf sableux à sables fins*
- c.m.S. Coarse and medium sand with predominance of coarse sand — *sgsf sableux à sables grossiers et sables fins*
- f.c.S. Fine and coarse sand — *sfsg sableux à sables fins et sables grossiers*
- f.m.S. Fine and medium sand — *sfsm sableux à sables fins et sables moyens*
- S.L.L. Sandy loam to loam — *sfstf sableux à sables fins et sables très fins*
- S.C.L. Sandy clay loam — *sfa sablo-argileux à sables fins*
- L. Loam — *stf sableux à sables très fins*
- Si.L. Silty loam — *sltf sablo-limoneux à sables très fins*
- C.L. Clay loam — *stfa sablo-argileux à sables très fins*
- Si.C.L. Silty clay loam — *la limono-argileux*
- C.Si.C. Clay Silty clay — *astf argilo-sablo-limoneux à sables très fins*
- Si.C. Silty clay — *al argilo-limoneux*
- C. Clay — *a argileux*

LEGEND OF THE SOILS MAP
LEGENDE DE LA CARTE PEDOLOGIQUE

WEAKLY DEVELOPED SOILS *SOLS PEU EVOLUES*

XEROSOLS *XERIQUES*

GYPSEOUS SOILS Derived from marl and gypsum
GYPSEUX Issus des marnes gypseuses

1. Yellowish-gray soils L with superficial gypsum flag LARGE FLATS (IMI, KELAFO, MUSTAHIL, BURKUR).
Sols gris-jaune stf en place à dalle de gypse superficielle GRANDS FLATS (IMI, KELAFO, MUSTAHIL, BURKUR).
2. Yellowish-gray soils SiL with a gypsum flag at 60 cm depth on COLLUVIA LARGE FLATS (IMI, KELAFO, MUSTAHIL, BURKUR).
Sols gris-jaune stll à dalle de gypse enterrée à 60 cm sur COLLUVIONS GRANDS FLATS (IMI, KELAFO, MUSTAHIL, BURKUR).

NON CLIMATIC SOILS *NON CLIMATIQUES*

LITHIC ERODED SOILS WITH POWDERY LIME Derived from marl and gypsum
SOLS D'EROSION LITHIQUES A CALCAIRE DIFFUS Issus des marnes gypseuses

3. Yellowish-gray soils SiL with superficial gypsum flag LOWER HILLS
Sol gris-jaune stll en place à dalle de gypse superficielle COLLINES BASSES
4. Whitish-yellow soils L shallow with gypsum flag on COLLUVIA DEBRIS-SLOPE of the LOWER HILLS
Sols jaune-blanc stf à dalle de gypse peu profonde sur COLLUVIONS DEBRIS-SLOPES sous les COLLINES BASSES

Derived from limestone *Issus des calcaires*

5. Yellowish-red soils L to CL with limestone fragments and calcareous nodules on COLLUVIA TALUS below the BLUFF of the LIMESTONE PLATEAUS.
Sols rouge-jaune stf à stfa à debris et nodules calcaires sur COLLUVIONS TALUS sous les CORNICHES des PLATEAUX CALCAIRES
6. Red soils SiL with gypsum flag at 20 cm depth on COLLUVIA GODE area (DEBRIS SLOPE) and FERFER area (PLATEAUS).
Sols rouges stll à dalle de gypse à 20 cm de profondeur sur COLLUVIONS environs de GODE (DEBRIS-SLOPE) et de FERFER (PLATEAUX)

Derived from basalts *Issus des basaltes*

7. Pale-brown soils SL to L very stony on WEATHERED Basalt BOULDERS HILLS.
Sols brun-clair sf à stf très caillouteux sur ALTERATION en BOULE des basaltes COLLINES

SOILS DEVELOPED ON WIND BLOWN MATERIAL WITH POWDERY LIMESTONE.
SOLS D'APPORTS EOLIENS A CALCAIRE DIFFUS

8. Yellow soils SL to L on DUNES GODE area
Sols jaune sf à stf sur DUNES environs de GODE

VERTISOLS AND VERTIC SOILS *VERTISOLS ET SOLS VERTIQUES*

WITH CURVED STRUCTURE *A STRUCTURE ARRONDIE*

BROWN OR REDDISH BROWN VERTISOLS WITH POWDERY LIME AND POWDERY GYPSUM IN THE DEPTH.
VERTISOLS BRUNS A BRUN-ROUGE A CALCAIRE DIFFUS ET CRISTAUX DE GYPSE EN PROFONDEUR

On RED-BROWN oued ALLUVIA derived from limestone
Sur ALLUVIONS BRUN-ROUGE d'oued issues des calcaires

9. Reddish-brown vertisols, grumosolic on 40 cm C to SiC with powdery gypsum at 100 cm depth, easily flooded oued Bu-Y ALLUVIA
Vertisols brun-rouge grumosoliques sur 40 cm a à al à cristaux de gypse vers 100 cm inondables ALLUVIONS de l'oued Bu-Y

On BROWN oued ALLUVIA derived from basalts
Sur ALLUVIONS BRUNES d'oued issus des basaltes

10. Brown to red vertisols grumosolic on 40 cm C to SiC with powdery gypsum at 40 cm depth, easily flooded oued ALLUVIA North West GODE area.
Vertisols bruns à rouges grumosoliques sur 40 cm a à al à cristaux de gypse à plus de 40 cm inondables ALLUVIONS d'oued Nord Ouest GODE

On BROWN ALLUVIA of the Wabi Shebelle *Sur ALLUVIONS BRUNES du Wabi Shebelle*
GODE - I M I series. *Séries IMI-GODE*

11. Brown vertisols grumosolic on 30 cm C with little powdery gypsum below 60 cm easily flooded.
Vertisols bruns grumosoliques sur 30 cm a quelques cristaux de gypse à partir de 60 cm inondables
12. Brown vertic soils grumosolic on 30 cm C little powdery gypsum below 30 cm.
Sols bruns vertiques grumosoliques sur 30 cm a quelques cristaux de gypse à partir de 30 cm
13. Brown vertic soils grumosolic on 20 cm SiC to C with powdery gypsum in depth
Sols bruns vertiques grumosoliques sur 20 cm stll à a à cristaux de gypse en profondeur

KELAFO - MUSTAHIL - BURKUR series. *Séries KELAFO-MUSTAHIL-BURKUR*

14. Brown vertisols, grumosolic on 30 cm SiC to C with powdery gypsum below 90 cm seldom flooded
Vertisols bruns grumosoliques sur 30 cm astll à a avec cristaux de gypse à plus de 90 cm faiblement inondables
15. Reddish-brown vertisols, grumosolic on 20 cm C with powdery gypsum below 100 cm (KELAFO only).
Vertisols brun-rouge grumosoliques sur 20 cm a avec cristaux de gypse à plus de 100 cm (KELAFO seulement).
16. Brown vertisols, grumosolic on 30 cm C with powdery gypsum below 80 cm, very easily flooded (MUSTAHIL plain)
Vertisols bruns grumosoliques sur 30 cm a avec nombreux cristaux de gypse à plus de 80 cm fortement inondables (plaine de MUSTAHIL)
17. Brown vertic soils, grumosolic on 20 cm C with powdery gypsum below 80 cm seldom flooded (SHEBELLE plain)
Sols bruns vertiques grumosoliques sur 20 cm a avec cristaux de gypse à plus de 80 cm faiblement inondables (plaine de SHEBELLE)

SOILS WITH CALCAREOUS DIFFERENCIATION
SOLS A DIFFERENCIATION CALCAIRE

WITHOUT MELANIC HORIZON *SANS HORIZON MELANIQUE*

WITH POWDERY LIME : MODAL *A CALCAIRE DIFFUS : MODAUX*

COLLUVIA derived from limestone *COLLUVIONS issues des calcaires*

18. Yellowish-red soils fS with many limestone debris and pebbles DEBRIS SLOPE below the LIMESTONE PLATEAUS (GODE to BURKUR)
Sols rouge-jaune sf riches en débris calcaires peu émoussés DEBRIS-SLOPE sous les PLATEAUX CALCAIRES (GODE à BURKUR)
19. Yellowish-red soils mfs, with limestone and basaltic pebbles HILLOCKS of the LARGE ALLUVIAL FANS (IMI)
Sols rouge-jaune smsf à galets calcaires et basaltiques PETITS MAMELONS des GRANDS CONES de DEJECTION (IMI)

WITH NODULES *A AMAS ET NODULES*

Derived from limestone *Issus des calcaires*

20. Yellowish-red soils SiL to L with calcareous nodules LIMESTONE PLATEAUX (GODE to BURKUR)
Sols rouge-jaune stll à stf à nodules calcaires en place PLATEAUX CALCAIRES (GODE à BURKUR)

Derived from sandstone *Issus des grès*

21. Red soils SL-L with calcareous nodules LOWER PLATEAUS (IMI).
Sols rouges sfstf à amas et nodules calcaires en place BAS PLATEAUX (IMI)

On ancient oued ALLUVIA *Sur anciennes ALLUVIONS d'oued*

22. Yellowish-red soils CmS, with calcareous pebbles often cemented in conglomerate near the surface HILLOCKS in the LARGE ALLUVIAL FANS (GODE).
Sols rouge-jaune sgsf à galets calcaires souvent soudés en conglomérat à faible profondeur MAMELONS des GRANDS CONES de DEJECTION (GODE)

SOILS WITH GYPSEOUS DIFFERENCIATION
SOLS A DIFFERENCIATION GYPSEUSE

WITH POWDERY GYPSUM : MODAL *A GYPSE DIFFUS : MODAUX*

On BROWN ALLUVIA of the Wabi Shebelle
Sur ALLUVIONS BRUNES du Wabi Shebelle
I M I - GODE series *Séries IMI-GODE*

23. Brown soils SiC weakly organic/fs (ANCIENT MEANDERS of the Wabi Shebelle.
Sols bruns al faiblement humifères/sr (MEANDRES MORTS du WABI SHEBELLE)
24. Brown to yellowish-brown soils SiL to SiC in depth.
Sols bruns à brun-jaune stll à al en profondeur
25. Brown soils C/fs (GODE)
Sols bruns a/sf (GODE)
26. Brown soils SiL to C in depth (GODE).
Sols bruns stll à a en profondeur (GODE)
27. Brown soils CL (GODE)
Sols bruns stfa (Gode)

South KELAFO - MUSTAHIL - BURKUR series *Séries Sud KELAFO-MUSTAHIL-BURKUR*

28. Brown soils C/brownish-yellow L seldom flooded to easily flooded (KELAFO)
Sols bruns a/jaune brunâtre stf peu inondables à inondables (KELAFO)
29. Brown soils SiL to C in depth
Sols bruns stll à a en profondeur

On BROWNISH - YELLOW ALLUVIA of the Wabi Shebelle
Sur ALLUVIONS JAUNE-BRUN du Wabi Shebelle
I M I - North GODE series *Séries IMI-Nord GODE*

30. Brownish-yellow soils fcS BANKS of the Wabi Shebelle
Sols jaune brun à sfsg BOURRELETS de BERGE du Wabi Shebelle
31. Brownish-yellow fS/C
Sols jaune brun sf/a

I M I - North GODE - KELAFO series *Série IMI-Nord GODE-KELAFO*

32. Brownish-yellow soils SiL to fS RECENT or ANCIENT BANKS of the Wabi Shebelle
Sols jaune brun stll-sf BOURRELETS de BERGE du Wabi Shebelle ACTUELS ou ANCIENS

South KELAFO - MUSTAHIL - BURKUR series *Séries Sud KELAFO-MUSTAHIL-BURKUR*

33. Brownish-yellow soils SiL to fmS in depth BANKS of the Wabi Shebelle
Sols jaune-brun stll à sfsm en profondeur BOURRELETS de BERGE du Wabi Shebelle
34. Brownish-yellow soils SiL to SiL-C in depth
Sols jaune brun stll à stlla en profondeur

On REDDISH - YELLOW oued ALLUVIA *Sur ALLUVIONS JAUNE-ROUGE des oueds*

35. Reddish-yellow soils fS to L with pebbles in the depth often salty ALLUVIAL FANS HIGHER position (GODE to BURKUR).
Sols jaune-rouge sf à stf à galets en profondeur, souvent salés ALLUVIONS des CONES de DEJECTION position HAUTE (GODE à BURKUR)
36. Reddish-yellow soils L and mS ALLUVIAL FANS (IMI)
Sols jaune-rouge stf et sm ALLUVIONS des CONES de DEJECTION (IMI)
37. Reddish-yellow soils SiL RECENT ALLUVIA of the larger oueds
Sols jaune-rouge stll ALLUVIONS RECENTES des grands oueds
38. Reddish-yellow soils fS-SiL RECENT ALLUVIA of the larger oueds (MADISO)
Sols jaune-rouge sf-stll ALLUVIONS RECENTES des grands oueds (MADISO)

WITH POWDERY GYPSUM : VERTIC *A GYPSE DIFFUS : VERTIQUES*

On BROWN ALLUVIA of the Wabi Shebelle *Sur ALLUVIONS BRUNES du Wabi Shebelle*
North GODE serie *Série Nord GODE*

39. Brown soils with SiC predominance
Sols bruns à dominance al

GODE - KELAFO serie *Série GODE-KELAFO*

40. Brown soils C
Sols bruns a

On YELLOWISH - RED oued ALLUVIA *Sur ALLUVIONS ROUGE-JAUNE des Oueds*

41. Yellowish-red soils SiL to C RECENT ALLUVIA of the smaller oueds
Sols rouge-jaune stll à a ALLUVIONS RECENTES des petits oueds

On Wabi Shebelle YELLOWISH - BROWN ALLUVIA over RED basaltic ALLUVIA
Sur ALLUVIONS BRUN-JAUNE du Wabi Shebelle recouvrant les ALLUVIONS ROUGES basaltiques.

42. Yellowish-brown soils SiL/red C (GODE)
Sols brun-jaune stll/rouge a (GODE)

WITH GYPSEOUS CRUST : MODAL *ENCROUTES : MODAUX*

From RED COLLUVIA derived from basalts *Sur COLLUVIONS ROUGES issues des basaltes*

43. Red soils SCL to C with gypseous crust at 60 cm depth DEBRIS SLOPE below the basaltic HILLS (GODE North GODE)
Sols rouges sfa à a à croûte de gypse vers 60 cm DEBRIS-SLOPE des COLLINES de basalte (GODE Nord GODE)

From YELLOWISH - RED oued ALLUVIA *Sur ALLUVIONS ROUGE-JAUNE des oueds*

44. Yellowish-red soils L to SiL with gypsum crust at 70 cm depth, salty in depth ALLUVIAL FANS LOWER position (GODE)
Sols rouge-jaune stf à stll à croûte de gypse vers 70 cm salés en profondeur ALLUVIONS des CONES de DEJECTION position BASSE (GODE)
45. Yellowish-red soils SiL to SiCL with gypsum crust at 70 cm depth salty near the surface ALLUVIAL FANS LOWER position (GODE to BURKUR).
Sols rouge-jaune stll à la à croûte de gypse à 70 cm salés à faible profondeur ALLUVIONS des CONES de DEJECTION position BASSE (GODE à BURKUR)
46. Yellowish-red soils L to SiC, with gypsum accumulation " SAND ROSE " type ALLUVIAL FANS LOWER position (IMI-GODE)
Sols rouge-jaune stf à al à accumulation de gypse sous forme de ROSE des SABLES ALLUVIONS des CONES de DEJECTION position BASSE (IMI GODE)

On Wabi Shebelle YELLOWISH - BROWN ALLUVIA over YELLOWISH - RED oued ALLUVIA
Sur ALLUVIONS BRUN-JAUNE du Wabi Shebelle recouvrant les ALLUVIONS ROUGE-JAUNE des oueds

47. Yellowish-brown soils SCL/yellowish red C (GODE)
Sols brun-jaune sfa/rouge jaune a (GODE)

HYDROMORPHIC SOILS *SOLS HYDROMORPHES*

MEDIUM ORGANIC *MOYENNEMENT ORGANIQUES*

HUMIC GLEY WITH POWDERY LIME *HUMIQUES A GLEY A CALCAIRE DIFFUS*

On BROWN ALLUVIA of the Wabi Shebelle *Sur ALLUVIONS BRUNES du Wabi Shebelle*
SHEBELLE plain serie *Série de la plaine de SHEBELLE*

48. Brown soils C, very easily flooded (PAPYRUS area).
Sols bruns a fortement inondables (zone à PAPYRUS)

MUSTAHIL plain serie *Série de la plaine de MUSTAHIL*

49. Brown soils C very easily flooded (GRAMINEA area).
Sols bruns a fortement inondables (zone à GRAMINEES)

SODIC SOILS *SOLS SODIQUES*

WITH NON DEGRADED STRUCTURE *A STRUCTURE NON DEGRADEE*

SALINE SOILS WITH SALT EFFLORESCENCES *SOLS SALINS A EFFLORESCENCES SALINES*

On RED oued ALLUVIA *Sur ALLUVIONS ROUGES d'oued*

50. Red soils SiL to C, with gypsum flag at medium depth (BURKUR-FERFER).
Sols rouges stll à a à dalle de gypse à moyenne profondeur (BURKUR-FERFER)

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ብሔራዊ የውሃ ሀብት ልማት ኮሚሽን መሥሪያ ቤት

IMPERIAL ETHIOPIAN GOVERNMENT

NATIONAL WATER RESOURCES COMMISSION

ETHIOPIA - FRANCE COOPERATIVE PROGRAM

WABI SHEBELLE SURVEY

IN COLLABORATION WITH

FRENCH MINISTRY OF FOREIGN AFFAIRS — NATIONAL WATER RESOURCES COMMISSION — BCEOM, ORSTOM, EDF IGN - BDPA

V

SOILS MAP - CARTE DES SOLS

Lower Valley - Basse Vallée

GODE

JANUARY 1973
MAP N°6

ORSTOM

ign

SOILS FEATURES FAVOURING IRRIGATION
APTITUDES DES SOLS A L'IRRIGATION

1ST CLASS - VERY SUITABLE SOILS FOR IRRIGATION
CLASSE I - SOLS TRES FAVORABLES A L'IRRIGATION

I A - for all tropical crops in arid zone.
pour toutes cultures tropicales de zone aride.

- I A d s — 24, 25, 26
- I A D S — 23, 27, 28, 29

I B - for tropical fruit-trees, citrus, pine-apples, tomatoes (juice) vegetables, maize, sorghum, wheat, groundnuts, other oilseeds, forages (graminea).
pour arbres fruitiers tropicaux, agrumes, ananas, tomates (jus), cultures légumières, maïs, sorgho, blé, arachide, autres oléagineux, graminées fourragères.

- I B d s — 30, 32, 33, 34
- I B D S — 31

I C - for sugar-cane, cotton, artificial pastures, maize, sorghum, wheat, textile fiber plants, oilseeds.
pour canne à sucre, coton, pâturages artificiels, maïs, sorgho, blé, plantes à fibres, plantes à huile.

- I C D s m — 9, 10, 12, 13, 14, 15, 17, 39, 40, 42

I D_A - for sugar-cane, coton, hill rice.
pour canne à sucre, coton, riz pluvial.

- I D_A D S m — 11, 16, 48, 49

2ND CLASS - LOW SUITABILITY FOR IRRIGATION
CLASSE II - SOLS PEU FAVORABLES A L'IRRIGATION

II B - possible crops : tropical fruit-trees, citrus, pine-apples, tomatoes (juice) vegetables, maize, sorghum, wheat, groundnuts, other oilseeds.
cultures possibles : arbres fruitiers tropicaux, agrumes, ananas, tomates (jus), cultures légumières, maïs, sorgho, blé, arachide, autres oléagineux.

- II B d m — 36, 37, 38

II C - possible crops : sugar-cane, cotton, artificial pastures, maize, sorghum, wheat, textile fiber plants.
cultures possibles : canne à sucre, coton, pâturages artificiels, maïs, sorgho, blé, plantes à fibres textiles.

- II C D S m — 41, 47
- II C D S G M — 44, 45, 46
- II C D S P — 50

3RD CLASS - UNSUITABLE FOR IRRIGATION
CLASSE III - SOLS NON IRRIGABLES

- III Y — 8
- III R U — 1, 2, 4
- III R T — 3, 5, 7, 18, 19, 22, 35, 43
- III U — 6
- III W — 20, 21

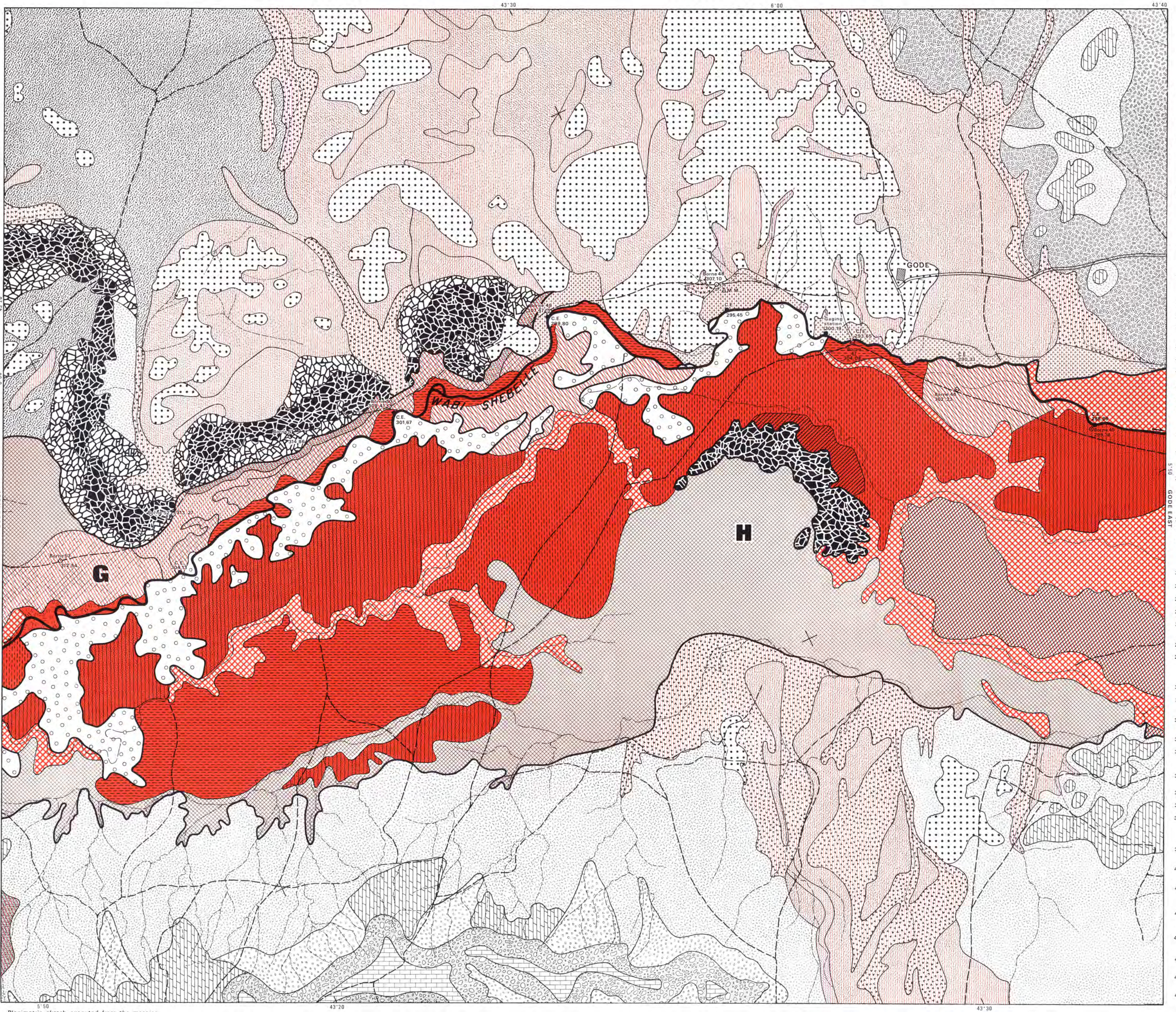
EXPLANATION OF THE SYMBOLS
SIGNIFICATION DES SYMBOLES

Factors changing the quality of the soils suitable for irrigation.
Facteurs altérant les qualités des sols irrigables.

- d — Slight drainage necessary / *Drainage léger nécessaire*
- D — Drainage necessary on a larger scale / *Drainage important nécessaire*
- s — Weak salinity in the depth / *Salure faible en profondeur*
- S — High salinity affecting the whole soil. / *Salure forte affectant l'ensemble du sol*
- G — Fine non-clayey texture unsuitable for irrigation / *Granulométrie fine non argileuse défavorable à l'irrigation*
- m — Slighty broken micro-relief requiring very slight leveling / *Microrelief peu uniforme nécessitant des planages très légers*
- M — Broken micro-relief requiring a great deal of leveling / *Microrelief peu uniforme nécessitant des planages importants*
- P — Depth of the soil less than 1 m / *Profondeur du sol inférieure à 1 m*

Symbols concerning non irrigable soils.
Symboles concernant les sols non irrigables.

- R — Abundant coarse elements / *Eléments grossiers abondants*
- T — Steep slopes / *Pentes fortes*
- U — Superficial limestone or gypsum flags / *Dalles calcaire ou gypseuse superficielles*
- W — Depth of soil less than 50 cm / *Profondeur du sol inférieure à 50 cm*
- Y — Dunes / *Dunes*



Planimetric sketch executed from the mosaics of 1964.67 aerial photos.
Esquisse planimétrique exécutée d'après les mosaïques photographiques de 1964-67.

INDEX SHEET

11 IMI WEST	10 IMI	9 IMI EAST	8 MADISO	7 GODE WEST	6 GODE	5 GODE EAST	4 KELAFO	3 MUSTAHIL WEST	2 MUSTAHIL	1 BURKUR

Limits of irrigable soils - 1st Class
Limite des sols irrigables - Classe I

A Indication of large irrigable zones
Indication des grandes zones irrigables

Scale 1: 50 000 approximate

Mile 1 ¾ ½ ¼ 0 1 2 3 Miles

M 1000 500 0 1 2 3 4 5 Km.

Fa Flooded area (highly)
Zone fortement inondable

C.E. Water level
Cote d'eau

⊙ Bench-mark
Boulon, borne

ABREVIATIONS

- m.S. Medium sand
- *sm* *sableux à sables moyens*
- m.f.S. Medium and fine sand with predominance of medium sand
- *smsf* *sableux à sables moyens et sables fins*
- f.S. Fine sand
- *sf* *sableux à sables fins*
- c.m.S. Coarse and medium sand with predominance of coarse sand
- *sgsf* *sableux à sables grossiers et sables fins*
- f.c.S. Fine and coarse sand
- *sfsg* *sableux à sables fins et sables grossiers*
- f.m.S. Fine and medium sand
- *sfsm* *sableux à sables fins et sables moyens*
- S.L.L. Sandy loam to loam
- *sfstf* *sableux à sables fins et sables très fins*
- S.C.L. Sandy clay loam
- *sfa* *sablo-argileux à sables fins*
- L. Loam
- *stf* *sableux à sables très fins*
- S.i.L. Silty loam
- *stfl* *sablo-limoneux à sables très fins*
- C.L. Clay loam
- *stfa* *sablo-argileux à sables très fins*
- S.i.C.L. Silty clay loam
- *la* *limono-argileux*
- C.S.i.C. Clay - Silty clay
- *astfl* *argilo sablo-limoneux à sables très fins*
- S.i.C. Silty clay
- *al* *argilo-limoneux*
- C. Clay
- *a* *argileux*

LEGEND OF THE SOILS MAP
LEGENDE DE LA CARTE PEDOLOGIQUE

WEAKLY DEVELOPED SOILS *SOLS PEU EVOLUES*

XEROSOLS *XERIQUES*

GYPSEOUS SOILS Derived from marl and gypsum
GYPSEUX Issus des marnes gypseuses

1 Yellowish-grey soils L with superficial gypsum flag : LARGE FLATS (IMI, KELAFO, MUSTAHIL, BURKUR).
Sols gris-jaune stf en place à dalle de gypse superficielle GRANDS FLATS : IMI, KELAFO, MUSTAHIL, BURKUR.

2 Yellowish-gray soils SiL with a gypsum flag at 50 cm depth on COLLUVIA : LARGE FLATS (IMI, KELAFO, MUSTAHIL, BURKUR).
Sols gris-jaune stfl à dalle de gypse enterrée à 50 cm sur COLLUVIONS : GRANDS FLATS (IMI, KELAFO, MUSTAHIL, BURKUR).

NON CLIMATIC SOILS *NON CLIMATIQUES*

LITHIC ERODED SOILS WITH POWDERY LIME Derived from marl and gypsum
SOLS D'EROSION LITHIQUES A CALCAIRE DIFFUS Issus des marnes gypseuses

3 Yellowish-grey soils SiL with superficial gypsum flag : LOWER HILLS
Sol gris-jaune stfl en place à dalle de gypse superficielle : COLLINES BASSES

4 Whitish-yellow soils L shallow with gypsum flag on COLLUVIA : DEBRIS-SLOPE of the LOWER HILLS.
Sols jaune-blanc stf à dalle de gypse peu profonde sur COLLUVIONS : DEBRIS-SLOPES sous les COLLINES BASSES

Derived from limestone *Issus des calcaires*

5 Yellowish-red soils L to CL with limestone fragments and calcareous nodules on COLLUVIA : TALUS below the BLUFF of the LIMESTONE PLATEAUS.
Sols rouge-jaune stf à stfa à débris et nodules calcaires sur COLLUVIONS : TALUS sous les CORNICHES des PLATEAUX CALCAIRES.

6 Red soils SiL with gypsum flag at 20 cm depth on COLLUVIA : GODE area (DEBRIS SLOPE) and FERFER area (PLATEAUS).
Sols rouges stfl à dalle de gypse à 20 cm de profondeur sur COLLUVIONS environs de GODE (DEBRIS SLOPE) et de FERFER (PLATEAUX).

Derived from basalts *Issus des basaltes*

7 Pale-brown soils SL to L very stony on WEATHERED Basalt BOULDERS : HILLS.
Sols brun-clair sf à stf très caillouteux sur ALTERATION en BOULE des basaltes : COLLINES.

SOILS DEVELOPED ON WIND BLOWN MATERIAL WITH POWDERY LIMESTONE.
SOLS D'APPORTS EOLIENS A CALCAIRE DIFFUS

8 Yellow soils SL to L on DUNES : GODE area.
Sols jaune sf à stf sur DUNES : environs de GODE

VERTISOLS AND VERTIC SOILS *VERTISOLS ET SOLS VERTIQUES*

WITH CURVED STRUCTURE *A STRUCTURE ARRONDIE*

BROWN OR REDDISH BROWN VERTISOLS WITH POWDERY LIME AND POWDERY GYPSUM IN THE DEPTH.
VERTISOLS BRUNS A BRUN-ROUGE A CALCAIRE DIFFUS ET CRISTAUX DE GYPSE EN PROFONDEUR

On RED-BROWN oued ALLUVIA derived from limestone
Sur ALLUVIONS BRUN-ROUGE d'oued issues des calcaires

9 Reddish-brown vertisols, grumosolic on 40 cm C. to SiC with powdery gypsum at 100 cm depth, easily flooded : oued Bu-Y ALLUVIA.
Vertisols brun-rouge grumosoliques sur 40 cm a. à al à cristaux de gypse vers 100 cm inondables : ALLUVIONS de l'oued Bu-Y.

On BROWN oued ALLUVIA derived from basalts
Sur ALLUVIONS BRUNES d'oued issus des basaltes

10 Brown to red vertisols, grumosolic on 40 cm C. to SiC. with powdery gypsum at 40 cm depth, easily flooded : oued ALLUVIA : North West GODE area.
Vertisols bruns à rouges grumosoliques sur 40 cm a. à al à cristaux de gypse à plus de 40 cm, inondables ALLUVIONS d'oued : Nord Ouest GODE.

On BROWN ALLUVIA of the Wabi Shebelle *Sur ALLUVIONS BRUNES du Wabi Shebelle*
GODE - I M I series. *Séries IMI-GODE*

11 Brown vertisols grumosolic on 30 cm C. with little powdery gypsum below 60 cm, easily flooded.
Vertisols bruns grumosoliques sur 30 cm a. quelques cristaux de gypse à partir de 60 cm, inondables.

12 Brown vertic soils grumosolic on 30 cm C. little powdery gypsum below 30 cm.
Sols bruns vertiques grumosoliques sur 30 cm a. quelques cristaux de gypse à partir de 30 cm.

13 Brown vertic soils grumosolic on 20 cm SiC. to C. with powdery gypsum in depth.
Sols bruns vertiques grumosoliques sur 20 cm stfl à a. à cristaux de gypse en profondeur.

KELAFO - MUSTAHIL - BURKUR series. *Séries KELAFO-MUSTAHIL-BURKUR*

14 Brown vertisols, grumosolic on 30 cm SiC to C. with powdery gypsum below 90 cm, seldom flooded.
Vertisols bruns grumosoliques sur 30 cm astfl à a. avec cristaux de gypse à plus de 90 cm, faiblement inondables.

15 Reddish-brown vertisols, grumosolic on 20 cm C. with powdery gypsum below 100 cm (KELAFO only).
Vertisols brun-rouge grumosoliques sur 20 cm a. avec cristaux de gypse à plus de 100 cm (KELAFO seulement).

16 Brown vertisols, grumosolic on 30 cm C. with powdery gypsum below 80 cm, very easily flooded (MUSTAHIL plain).
Vertisols bruns grumosoliques sur 30 cm a. avec nombreux cristaux de gypse à plus de 80 cm, fortement inondables : (plaine de MUSTAHIL).

17 Brown vertic soils, grumosolic on 20 cm C. with powdery gypsum below 80 cm, seldom flooded (SHEBELLE plain).
Sols bruns vertiques grumosoliques sur 20 cm a. avec cristaux de gypse à plus de 80 cm, faiblement inondables. (plaine de SHEBELLE).

SOILS WITH CALCAREOUS DIFFERENCIATION
SOLS A DIFFERENCIATION CALCAIRE

WITHOUT MELANIC HORIZON *SANS HORIZON MELANIQUE*

WITH POWDERY LIME : MODAL *A CALCAIRE DIFFUS : MODAUX*

COLLUVIA derived from limestone *COLLUVIONS issues des calcaires*

18 Yellowish-red soils fS with many limestone debris and pebbles : DEBRIS SLOPE below the LIMESTONE PLATEAUS (GODE to BURKUR).
Sols rouge-jaune sf riches en débris calcaires peu émoussés : DEBRIS-SLOPE sous les PLATEAUX CALCAIRES (GODE à BURKUR).

19 Yellowish-red soils mfs with limestone and basaltic pebbles : HILLOCKS of the LARGE ALLUVIAL FANS (IMI).
Sols rouge-jaune smsf à galets calcaires et basaltiques PETITS MAMELONS des GRANDS CONES de DEJECTION (IMI).

WITH NODULES *A AMAS ET NODULES*

Derived from limestone *Issus des calcaires*

20 Yellowish-red soils SiL to L with calcareous nodules : LIMESTONE PLATEAUX (GODE to BURKUR).
Sols rouge-jaune stfl à stf à nodules calcaires en place : PLATEAUX CALCAIRES (GODE à BURKUR).

Derived from sandstone *Issus des grès*

21 Red soils SL-L with calcareous nodules : LOWER PLATEAUS (IMI).
Sols rouges sfstf à amas et nodules calcaires en place : BAS PLATEAUX (IMI).

On ancient oued ALLUVIA *Sur anciennes ALLUVIONS d'oued*

22 Yellowish-red soils CmS, with calcareous pebbles often cemented in conglomerate near the surface : HILLOCKS in the LARGE ALLUVIAL FANS (GODE).
Sols rouge-jaune sgsf à galets calcaires souvent soudés en conglomérat à faible profondeur : MAMELONS des GRANDS CONES de DEJECTION (GODE).

SOILS WITH GYPSEOUS DIFFERENCIATION
SOLS A DIFFERENCIATION GYPSEUSE

WITH POWDERY GYPSUM : MODAL *A GYPSE DIFFUS : MODAUX*

On BROWN ALLUVIA of the Wabi Shebelle
Sur ALLUVIONS BRUNES du Wabi Shebelle
I M I - GODE series *Séries IMI-GODE*

23 Brown soils SiC weakly organic/fs (ANCIENT MEANDERS of the Wabi Shebelle.
Sols bruns al faiblement humifères/st : (MEANDRES MORTS du WABI SHEBELLE).

24 Brown to yellowish-brown soils SiL to SiC in depth.
Sols bruns à brun-jaune stfl à al. en profondeur.

25 Brown soils C/fs (GODE).
Sols bruns a./sf (GODE).

26 Brown soils SiL to C. in depth (GODE).
Sols bruns stfl à a. en profondeur : (GODE).

27 Brown soils CL (GODE).
Sols bruns stfa (Gode).

South KELAFO - MUSTAHIL - BURKUR series *Séries Sud KELAFO-MUSTAHIL-BURKUR*

28 Brown soils C/brownish-yellow L, seldom flooded to easily flooded (KELAFO).
Sols bruns a./jaune-brunâtre stf, peu inondables à inondables (KELAFO).

29 Brown soils SiL to C. in depth.
Sols bruns stfl à a. en profondeur.

On BROWNISH - YELLOW ALLUVIA of the Wabi Shebelle
Sur ALLUVIONS JAUNE-BRUN du Wabi Shebelle
I M I - North GODE series *Séries IMI-Nord GODE*

30 Brownish-yellow soils fcS : BANKS of the Wabi Shebelle.
Sols jaune-brun à sfsg : BOURRELETS de BERGE du Wabi Shebelle.

31 Brownish-yellow fS/C.
Sols jaune brun sf/a.

I M I - North GODE - KELAFO series *Série IMI-Nord GODE-KELAFO*

32 Brownish-yellow soils SiL to fS : RECENT or ANCIENT BANKS of the Wabi Shebelle.
Sols jaune-brun stfl sf : BOURRELETS de BERGE du Wabi Shebelle ACTUELS ou ANCIENS.

South KELAFO - MUSTAHIL - BURKUR series *Séries Sud KELAFO-MUSTAHIL-BURKUR*

33 Brownish-yellow soils SiL to fmS in depth : BANKS of the Wabi Shebelle.
Sols jaune-brun stfl à sfsm en profondeur : BOURRELETS de BERGE du Wabi Shebelle.

34 Brownish-yellow soils SiL to SiL C in depth.
Sols jaune-brun stfl à stfla en profondeur.

On REDDISH - YELLOW oued ALLUVIA *Sur ALLUVIONS JAUNE-ROUGE des oueds*

35 Reddish-yellow soils fS to L with pebbles in the depth often salty : ALLUVIAL FANS : HIGHER position (GODE to BURKUR).
Sols jaune-rouge sf à stf à galets en profondeur, souvent salés : ALLUVIONS des CONES de DEJECTION : position HAUTE (GODE à BURKUR).

36 Reddish-yellow soils L and mS ALLUVIAL FANS (IMI).
Sols jaune-rouge stf et sm : ALLUVIONS des CONES de DEJECTION (IMI).

37 Reddish-yellow soils SiL : RECENT ALLUVIA of the larger oueds.
Sols jaune-rouge stfl : ALLUVIONS RECENTES des grands oueds.

38 Reddish-yellow soils fS-SiL : RECENT ALLUVIA of the larger oueds (MADISO).
Sols jaune-rouge sf-stfl : ALLUVIONS RECENTES des grands oueds (MADISO).

WITH POWDERY GYPSUM : VERTIC *A GYPSE DIFFUS : VERTIQUES*

On BROWN ALLUVIA of the Wabi Shebelle *Sur ALLUVIONS BRUNES du Wabi Shebelle*
North GODE serie *Série Nord GODE*

39 Brown soils with SiC predominance
Sols bruns à dominance al

GODE - KELAFO serie *Série GODE-KELAFO*

40 Brown soils C.
Sols bruns a

On YELLOWISH - RED oued ALLUVIA *Sur ALLUVIONS ROUGE-JAUNE des Oueds*

41 Yellowish-red soils SiL to C. : RECENT ALLUVIA of the smaller oueds.
Sols rouge-jaune stfl à a. : ALLUVIONS RECENTES des petits oueds.

On Wabi Shebelle YELLOWISH - BROWN ALLUVIA over RED basaltic ALLUVIA
Sur ALLUVIONS BRUN-JAUNE du Wabi Shebelle recouvrant les ALLUVIONS ROUGES basaltiques.

42 Yellowish-brown soils SiL/red C. (GODE)
Sols brun-jaune stfl/rouge a. (GODE)

WITH GYPSEOUS CRUST : MODAL *ENCROUTES : MODAUX*

From RED COLLUVIA derived from basalts *Sur COLLUVIONS ROUGES issues des basaltes*

43 Red soils SCL to C with gypseous crust at 60 cm depth : DEBRIS SLOPE below the basaltic HILLS (GODE North GODE).
Sols rouges sfa à a. à croûte de gypse vers 60 cm : DEBRIS-SLOPE des COLLINES de basalte (GODE Nord GODE).

From YELLOWISH - RED oued ALLUVIA *Sur ALLUVIONS ROUGE-JAUNE des oueds*

44 Yellowish-red soils L to SiL with gypsum crust at 70 cm depth, salty in depth : ALLUVIAL FANS LOWER position (GODE).
Sols rouge-jaune stf à stfl à croûte de gypse vers 70 cm, salés en profondeur : ALLUVIONS des CONES de DEJECTION position BASSE (GODE).

45 Yellowish-red soils SiL to SiCL with gypsum crust at 70 cm depth, salty near the surface : ALLUVIAL FANS LOWER position (GODE to BURKUR).
Sols rouge-jaune stfl à la, à croûte de gypse à 70 cm, salés à faible profondeur : ALLUVIONS des CONES de DEJECTION position BASSE (GODE à BURKUR).

46 Yellowish-red soils L to SiC with gypsum accumulation "SAND ROSE" type : ALLUVIAL FANS LOWER position (IMI-GODE).
Sols rouge-jaune stf à al à accumulation de gypse sous forme de ROSE des SABLES : ALLUVIONS des CONES de DEJECTION position BASSE (IMI-GODE).

On Wabi Shebelle YELLOWISH - BROWN ALLUVIA over YELLOWISH - RED oued ALLUVIA
Sur ALLUVIONS BRUN-JAUNE du Wabi Shebelle recouvrant les ALLUVIONS ROUGE-JAUNE des oueds

47 Yellowish-brown soils SCL/yellowish red C. (GODE)
Sols brun-jaune sfa/rouge-jaune a. (GODE)

HYDROMORPHIC SOILS *SOLS HYDROMORPHES*

MEDIUM ORGANIC *MOYENNEMENT ORGANIQUES*

HUMIC GLEY WITH POWDERY LIME *HUMIQUES A GLEY A CALCAIRE DIFFUS*

On BROWN ALLUVIA of the Wabi Shebelle *Sur ALLUVIONS BRUNES du Wabi Shebelle*
SHEBELLE plain serie *Série de la plaine de SHEBELLE*

48 Brown soils C. very easily flooded (PAPYRUS area).
Sols bruns a. fortement inondables (zone à PAPYRUS).

MUSTAHIL plain serie *Série de la plaine de MUSTAHIL*

49 Brown soils C. very easily flooded (GRAMINEA area).
Sols bruns a. fortement inondables (zone à GRAMINEES).

SODIC SOILS *SOLS SODIQUES*

WITH NON DEGRADED STRUCTURE *A STRUCTURE NON DEGRADEE*

SALINE SOILS WITH SALT EFFLORESCENCES *SOLS SALINS A EFFLORESCENCES SALINES*

On RED oued ALLUVIA *Sur ALLUVIONS ROUGES d'oued*

50 Red soils SiL to C. with gypsum flag at medium depth (BURKUR-FERFER).
Sols rouges stfl à a. à dalle de gypse à moyenne profondeur (BURKUR-FERFER).

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IMPERIAL ETHIOPIAN GOVERNMENT

NATIONAL WATER RESOURCES COMMISSION

ETHIOPIA - FRANCE COOPERATIVE PROGRAM

WABI SHEBELLE SURVEY

IN COLLABORATION WITH

FRENCH MINISTRY OF FOREIGN AFFAIRS — NATIONAL WATER RESOURCES COMMISSION — BCEOM, ORSTOM, EDF IGN_BDPA

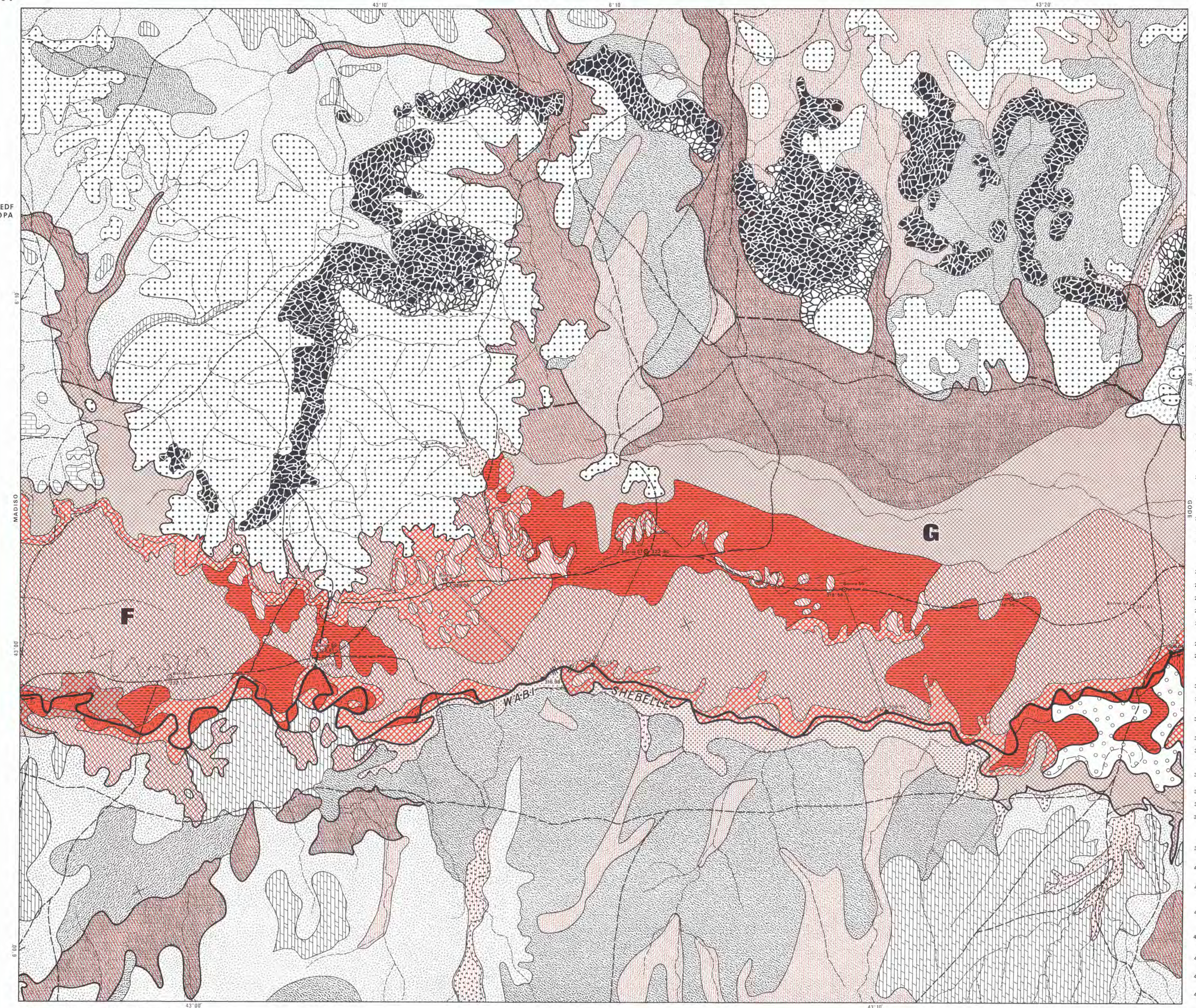
V

SOILS MAP - CARTE DES SOLS

Lower Valley - Basse Vallée

GODE WEST

JANUARY 1973
MAP N° 7



Planimetric sketch executed from the mosaics of 1964.67 aerial photos.
Esquisse planimetrique executée d'apres les mosaïques photographiques de 1964.67.

INDEX SHEET

IMI WEST 11	IMI 10	IMI EAST 9	MADISO 8	GODE WEST 7	GODE 6	GODE EAST 5	KELAFO 4	MUSTAHIL WEST 3	MUSTAHIL 2	BURKUR 1

Limits of irrigable soils. 1st Class
Limite des sols irrigables. Classe 1

A — Indication of large irrigable zones
Indication des grandes zones irrigables

Scale 1:50000 approximate

Mile 1 ¾ ½ ¼ 0 1 2 3 Miles

M 1000 500 0 1 2 3 4 5 Km

Fa — Flooded area (highly)
Zone fortement inondable

C.E. — Water level
Cote d'eau

⊙ — Bench-mark
Boulon, borne

ABREVIATIONS

m.S.	Medium sand	L.	Loam
sm	*sableux à sables moyens*	stf	*sableux à sables très fins*
m.f.S.	Medium and fine sand with predominance of medium sand	Si.L.	Silty loam
smf	*sableux à sables moyens et sables fins*	stfl	*sablo-limoneux à sables très fins*
f.S.	Fine sand	C.L.	Clay loam
sf	*sableux à sables fins*	stfa	*sablo-argileux à sables très fins*
c.m.S.	Coarse and medium sand with predominance of coarse sand	Si.C.L.	Silty clay loam
sgsf	*sableux à sables grossiers et sables fins*	la	*limono-argileux*
f.c.S.	Fine and coarse sand	C.Si.C.	Clay - Silty clay
sfsg	*sableux à sables fins et sables grossiers*	astfl	*argilo-sablo-limoneux à sables très fins*
f.m.S.	Fine and medium sand	Si.C.	Silty clay
sfsm	*sableux à sables fins et sables moyens*	al	*argilo-limoneux*
S.L.L.	Sandy loam to loam	C.	Clay
sfstf	*sableux à sables fins et sables très fins*	a	*argileux*
S.C.L.	Sandy clay loam		
sfa	*sablo-argileux à sables fins*		

SOILS FEATURES FAVOURING IRRIGATION
APTITUDES DES SOLS A L'IRRIGATION

1ST CLASS - VERY SUITABLE SOILS FOR IRRIGATION
CLASSE I - SOLS TRES FAVORABLES A L'IRRIGATION

I A - for all tropical crops in arid zone.
pour toutes cultures tropicales de zone aride.

I A d s — 24, 25, 26
I A D S — 23, 27, 28, 29

I B - for tropical fruit-trees, citrus, pine-apples, tomatoes (juice) vegetables, maize, sorghum, wheat, groundnuts, other oilseeds, forages (graminea).
pour arbres fruitiers tropicaux, agrumes, ananas, tomates (jus), cultures légumières, maïs, sorgho, blé, arachide, autres oléagineux, graminées fourragères.

I B d s — 30, 32, 33, 34
I B D S — 31

I C - for sugar-cane, cotton, artificial pastures, maize, sorghum, wheat, textile fiber plants, oilseeds.
pour canne à sucre, coton, pâturages artificiels, maïs, sorgho, blé, plantes à fibres, plantes à huile.

I C D s m — 9, 10, 12, 13, 14, 15, 17, 39, 40, 42

$I\ D_A$ - for sugar-cane, coton, hill rice.
pour canne à sucre, coton, riz pluvial.

$I\ D_A\ D\ S\ m$ — 11, 16, 48, 49

2ND CLASS - LOW SUITABILITY FOR IRRIGATION
CLASSE II - SOLS PEU FAVORABLES A L'IRRIGATION

II B - possible crops : tropical fruit-trees, citrus, pine-apples, tomatoes (juice) vegetables, maize, sorghum, wheat, groundnuts, other oilseeds.
cultures possibles : arbres fruitiers tropicaux, agrumes, ananas, tomates (jus), cultures légumières, maïs, sorgho, blé, arachide, autres oléagineux.

II B d m — 36, 37, 38

II C - possible crops : sugar-cane, cotton, artificial pastures, maize, sorghum, wheat, textile fiber plants.
cultures possibles : canne à sucre, coton, pâturages artificiels, maïs, sorgho, blé, plantes à fibres textiles.

II C D S m — 41, 47
II C D S G M — 44, 45, 46
II C D S P — 50

3RD CLASS - UNSUITABLE FOR IRRIGATION
CLASSE III - SOLS NON IRRIGABLES

III Y — 8
III R U — 1, 2, 4
III R T — 3, 5, 7, 18, 19, 22, 35, 43
III U — 6
III W — 20, 21

EXPLANATION OF THE SYMBOLS
SIGNIFICATION DES SYMBOLES

Factors changing the quality of the soils suitable for irrigation.
Facteurs altérant les qualités des sols irrigables.

- d — Slight drainage necessary / *Drainage léger nécessaire*
- D — Drainage necessary on a larger scale / *Drainage important nécessaire*
- s — Weak salinity in the depth / *Salure faible en profondeur*
- S — High salinity affecting the whole soil / *Salure forte affectant l'ensemble du sol*
- G — Fine non clayey texture unsuitable for irrigation / *Granulométrie fine non argileuse défavorable à l'irrigation*
- m — Slighty broken micro-relief requiring very slight leveling / *Microrelief peu uniforme nécessitant des planages très légers*
- M — Broken micro-relief requiring a great deal of leveling / *Microrelief peu uniforme nécessitant des planages importants*
- P — Depth of the soil less than 1 m / *Profondeur du sol inférieure à 1 m*

Symbols concerning non irrigable soils.
Symboles concernant les sols non irrigables.

- R — Abundant coarse elements / *Eléments grossiers abondants*
- T — Steep slopes / *Pentes fortes*
- U — Superficial limestone or gypsum flags / *Dalles calcaire ou gypseuse superficielles*
- W — Depth of soil less than 50 cm / *Profondeur du sol inférieure à 50 cm*
- Y — Dunes / *Dunes*

N

LEGEND OF THE SOILS MAP
LEGENDE DE LA CARTE PEDOLOGIQUE

WEAKLY DEVELOPED SOILS *SOLS PEU EVOLUES*

XEROSOLS *XERIQUES*

GYPSEOUS SOILS Derived from marl and gypsum
GYPSEUX Issus des marnes gypseuses

1 — Yellowish-gray soils L with superficial gypsum flag . LARGE FLATS (IMI, KELAFO, MUSTAHIL, BURKUR). *Sols gris-jaune slf en place à dalle de gypse superficielle GRANDS FLATS (IMI, KELAFO, MUSTAHIL, BURKUR)*

2 — Yellowish-gray soils SiL with a gypsum flag at 50 cm depth on COLLUVIA . LARGE FLATS (IMI, KELAFO, MUSTAHIL, BURKUR). *Sols gris-jaune stfl à dalle de gypse enterrée à 50 cm sur COLLUVIONS . GRANDS FLATS (IMI, KELAFO, MUSTAHIL, BURKUR)*

NON CLIMATIC SOILS *NON CLIMATIQUES*

LITHIC ERODED SOILS WITH POWDERY LIME Derived from marl and gypsum
SOLS D'EROSION LITHIQUES A CALCAIRE DIFFUS Issus des marnes gypseuses

3 — Yellowish-gray soils SiL with superficial gypsum flag . LOWER HILLS. *Sol gris-jaune stfl en place à dalle de gypse superficielle . COLLINES BASSES*

4 — Whitish-yellow soils L shallow with gypsum flag on COLLUVIA . DEBRIS-SLOPE of the LOWER HILLS. *Sols jaune-blanc slf à dalle de gypse peu profonde sur COLLUVIONS . DEBRIS SLOPES sous les COLLINES BASSES*

Derived from limestone *Issus des calcaires*

5 — Yellowish-red soils L to CL with limestone fragments and calcareous nodules on COLLUVIA. TALUS below the BLUFF of the LIMESTONE PLATEAUS. *Sols rouge-jaune slf à stfa à débris et nodules calcaires sur COLLUVIONS. TALUS sous les CORNICHES des PLATEAUX CALCAIRES.*

6 — Red soils SiL with gypsum flag at 20 cm depth on COLLUVIA. GODE area (DEBRIS SLOPE) and FERFER area (PLATEAUS). *Sols rouges stfl à dalle de gypse à 20 cm de profondeur sur COLLUVIONS environs de GODE (DEBRIS-SLOPE) et de FERFER (PLATEAUX)*

Derived from basalts *Issus des basaltes*

7 — Pale-brown soils SL to L very stony on WEATHERED Basalt BOULDERS . HILLS. *Sols brun clair sf à stf très caillouteux sur ALTERATION en BOULE des basaltes . COLLINES*

SOILS DEVELOPED ON WIND BLOWN MATERIAL WITH POWDERY LIMESTONE.
SOLS D'APPORTS EOLIENS A CALCAIRE DIFFUS

8 — Yellow soils SL to L on DUNES . GODE area. *Sols jaune sf à stf sur DUNES . environs de GODE*

VERTISOLS AND VERTIC SOILS *VERTISOLS ET SOLS VERTIQUES*

WITH CURVED STRUCTURE *A STRUCTURE ARRONDIE*

BROWN OR REDDISH BROWN VERTISOLS WITH POWDERY LIME AND POWDERY GYPSUM IN THE DEPTH.
VERTISOLS BRUNS A BRUN-ROUGE A CALCAIRE DIFFUS ET CRISTAUX DE GYPSE EN PROFONDEUR

On RED-BROWN oued ALLUVIA derived from limestone
Sur ALLUVIONS BRUN-ROUGE d'oued issues des calcaires

9 — Reddish brown vertisols, grumosolic on 40 cm C to SiC with powdery gypsum at 100 cm depth, easily flooded . oued Bu-Y ALLUVIA. *Vertisols brun-rouge grumosoliques sur 40 cm a. à al à cristaux de gypse vers 100 cm, inondables . ALLUVIONS de l'oued Bu-Y*

On BROWN oued ALLUVIA derived from basalts
Sur ALLUVIONS BRUNES d'oued issus des basaltes

10 — Brown to red vertisols, grumosolic on 40 cm C to SiC with powdery gypsum at 40 cm depth, easily flooded oued ALLUVIA . North West GODE area. *Vertisols bruns à rouges grumosoliques sur 40 cm a. à al à cristaux de gypse à plus de 40 cm, inondables ALLUVIONS d'oued . Nord Ouest GODE*

On BROWN ALLUVIA of the Wabi Shebelle *Sur ALLUVIONS BRUNES du Wabi Shebelle*
GODE - IMI series. *Séries IMI-GODE*

11 — Brown vertisols grumosolic on 30 cm C with little powdery gypsum below 60 cm easily flooded. *Vertisols bruns grumosoliques sur 30 cm a. quelques cristaux de gypse à partir de 60 cm, inondables*

12 — Brown vertic soils grumosolic on 30 cm C, little powdery gypsum below 30 cm. *Sols bruns vertiques grumosoliques sur 30 cm a. quelques cristaux de gypse à partir de 30 cm*

13 — Brown vertic soils grumosolic on 20 cm SiC to C with powdery gypsum in depth. *Sols bruns vertiques grumosoliques sur 20 cm stfl à a. à cristaux de gypse en profondeur*

KELAFO - MUSTAHIL - BURKUR series. *Séries KELAFO-MUSTAHIL-BURKUR*

14 — Brown vertisols grumosolic on 30 cm SiC to C with powdery gypsum below 90 cm, seldom flooded. *Vertisols bruns grumosoliques sur 30 cm astfl à a. avec cristaux de gypse à plus de 90 cm, faiblement inondables*

15 — Reddish-brown vertisols, grumosolic on 20 cm C with powdery gypsum below 100 cm (KELAFO only). *Vertisols brun-rouge grumosoliques sur 20 cm a. avec cristaux de gypse à plus de 100 cm (KELAFO seulement)*

16 — Brown vertisols grumosolic on 30 cm C with powdery gypsum below 80 cm, very easily flooded (MUSTAHIL plain). *Vertisols bruns grumosoliques sur 30 cm a. avec nombreux cristaux de gypse à plus de 80 cm fortement inondables (plaine de MUSTAHIL)*

17 — Brown vertic soils, grumosolic on 20 cm C with powdery gypsum below 80 cm, seldom flooded (SHEBELLE plain). *Sols bruns vertiques grumosoliques sur 20 cm a. avec cristaux de gypse à plus de 80 cm, faiblement inondables (plaine de SHEBELLE)*

SOILS WITH CALCAREOUS DIFFERENCIATION
SOLS A DIFFERENCIATION CALCAIRE

WITHOUT MELANIC HORIZON *SANS HORIZON MELANIQUE*

WITH POWDERY LIME . MODAL *A CALCAIRE DIFFUS : MODAUX*

COLLUVIA derived from limestone *COLLUVIONS issues des calcaires*

18 — Yellowish-red soils fS with many limestone debris and pebbles. DEBRIS SLOPE below the LIMESTONE PLATEAUS (GODE to BURKUR). *Sols rouge-jaune sf riches en débris calcaires peu émoussés. DEBRIS-SLOPE sous les PLATEAUX CALCAIRES (GODE à BURKUR)*

19 — Yellowish-red soils mfs, with limestone and basaltic pebbles . HILLOCKS of the LARGE ALLUVIAL FANS (IMI). *Sols rouge-jaune smsf à galets calcaires et basaltiques. PETITS MAMELONS des GRANDS CONES de DEJECTION (IMI)*

WITH NODULES *A AMAS ET NODULES*

Derived from limestone *Issus des calcaires*

20 — Yellowish-red soils SiL to L with calcareous nodules . LIMESTONE PLATEAUX (GODE to BURKUR). *Sols rouge-jaune stfl à stf à nodules calcaires en place . PLATEAUX CALCAIRES (GODE à BURKUR)*

Derived from sandstone *Issus des grès*

21 — Red soils SL-L with calcareous nodules . LOWER PLATEAUS (IMI). *Sols rouges sfstf à amas et nodules calcaires en place . BAS PLATEAUX (IMI)*

On ancient oued ALLUVIA *Sur anciennes ALLUVIONS d'oued*

22 — Yellowish red soils CmS with calcareous pebbles often cemented in conglomerate near the surface. HILLOCKS in the LARGE ALLUVIAL FANS (GODE). *Sols rouge-jaune sgsf à galets calcaires souvent soudés en conglomérat à faible profondeur. MAMELONS des GRANDS CONES de DEJECTION (GODE)*

SOILS WITH GYPSEOUS DIFFERENCIATION
SOLS A DIFFERENCIATION GYPSEUSE

WITH POWDERY GYPSUM : MODAL *A GYPSE DIFFUS : MODAUX*

On BROWN ALLUVIA of the Wabi Shebelle
Sur ALLUVIONS BRUNES du Wabi Shebelle
I M I - GODE series *Séries IMI-GODE*

23 — Brown soils SiC weakly organic/fs (ANCIENT MEANDERS of the Wabi Shebelle). *Sols bruns al faiblement humifères/sf (MEANDRES MORTS du WABI SHEBELLE)*

24 — Brown to yellowish-brown soils SiL to SiC in depth. *Sols bruns à brun-jaune stfl à al, en profondeur*

25 — Brown soils C/fs (GODE). *Sols bruns a/sf (GODE)*

26 — Brown soils SiL to C in depth (GODE). *Sols bruns stfl à a. en profondeur (GODE)*

27 — Brown soils CL (GODE). *Sols bruns stfa (Gode)*

South KELAFO - MUSTAHIL - BURKUR series *Séries Sud KELAFO-MUSTAHIL-BURKUR*

28 — Brown soils C/brownish-yellow L seldom flooded to easily flooded (KELAFO). *Sols bruns a/jaune-brunâtre slf peu inondables à inondables (KELAFO)*

29 — Brown soils SiL to C in depth. *Sols bruns stfl à a en profondeur*

On BROWNISH - YELLOW ALLUVIA of the Wabi Shebelle
Sur ALLUVIONS JAUNE-BRUN du Wabi Shebelle
I M I - North GODE series *Séries IMI-Nord GODE*

30 — Brownish-yellow soils fcS . BANKS of the Wabi Shebelle. *Sols jaune-brun à sfsg . BOURRELETS de BERGE du Wabi Shebelle*

31 — Brownish-yellow fS/C. *Sols jaune-brun sf/a*

I M I - North GODE - KELAFO series *Série IMI-Nord GODE-KELAFO*

32 — Brownish-yellow soils SiL to fS . RECENT or ANCIENT BANKS of the Wabi Shebelle. *Sols jaune-brun stfl sf . BOURRELETS de BERGE du Wabi Shebelle ACTUELS ou ANCIENS*

South KELAFO - MUSTAHIL - BURKUR series *Séries Sud KELAFO-MUSTAHIL-BURKUR*

33 — Brownish-yellow soils SiL to fmS in depth . BANKS of the Wabi Shebelle. *Sols jaune-brun stfl à sfsm en profondeur . BOURRELETS de BERGE du Wabi Shebelle*

34 — Brownish-yellow soils SiL to SiL-C in depth. *Sols jaune-brun stfl à stfla en profondeur*

On REDDISH - YELLOW oued ALLUVIA *Sur ALLUVIONS JAUNE-ROUGE des oueds*

35 — Reddish-yellow soils fS to L with pebbles in the depth often salty. ALLUVIAL FANS . HIGHER position (GODE to BURKUR). *Sols jaune-rouge sf à slf à galets en profondeur, souvent salés. ALLUVIONS des CONES de DEJECTION . position HAUTE (GODE à BURKUR)*

36 — Reddish-yellow soils L and mS ALLUVIAL FANS (IMI). *Sols jaune-rouge slf et sm . ALLUVIONS des CONES de DEJECTION (IMI)*

37 — Reddish-yellow soils SiL . RECENT ALLUVIA of the larger oueds. *Sols jaune-rouge stfl . ALLUVIONS RECENTES des grands oueds*

38 — Reddish-yellow soils fS-SiL . RECENT ALLUVIA of the larger oueds (MADISO). *Sols jaune-rouge sf-stfl . ALLUVIONS RECENTES des grands oueds (MADISO)*

WITH POWDERY GYPSUM . VERTIC *A GYPSE DIFFUS . VERTIQUES*

On BROWN ALLUVIA of the Wabi Shebelle *Sur ALLUVIONS BRUNES du Wabi Shebelle*
North GODE serie *Série Nord GODE*

39 — Brown soils with SiC predominance. *Sols bruns à dominance al*

GODE - KELAFO serie *Série GODE-KELAFO*

40 — Brown soils C. *Sols bruns a*

On YELLOWISH - RED oued ALLUVIA *Sur ALLUVIONS ROUGE-JAUNE des Oueds*

41 — Yellowish-red soils SiL to C . RECENT ALLUVIA of the smaller oueds. *Sols rouge-jaune stfl à a . ALLUVIONS RECENTES des petits oueds*

On Wabi Shebelle YELLOWISH - BROWN ALLUVIA over RED basaltic ALLUVIA
Sur ALLUVIONS BRUN-JAUNE du Wabi Shebelle recouvrant les ALLUVIONS ROUGES basaltiques

42 — Yellowish-brown soils SiL/red C (GODE). *Sols brun-jaune stfl/rouge a . (GODE)*

WITH GYPSEOUS CRUST : MODAL *ENCROUTES : MODAUX*

From RED COLLUVIA derived from basalts *Sur COLLUVIONS ROUGES issues des basaltes*

43 — Red soils SCL to C with gypseous crust at 60 cm depth . DEBRIS SLOPE below the basaltic HILLS (GODE North GODE). *Sols rouges sfa à a . à croûte de gypse vers 60 cm . DEBRIS-SLOPE des COLLINES de basalte (GODE-Nord GODE)*

From YELLOWISH - RED oued ALLUVIA *Sur ALLUVIONS ROUGE-JAUNE des oueds*

44 — Yellowish-red soils L to SiL with gypsum crust at 70 cm depth, salty in depth . ALLUVIAL FANS LOWER position (GODE). *Sols rouge-jaune slf à stfl à croûte de gypse vers 70 cm, salés en profondeur . ALLUVIONS des CONES de DEJECTION position BASSE (GODE)*

45 — Yellowish-red soils SiL to SiCL with gypsum crust at 70 cm depth, salty near the surface . ALLUVIAL FANS LOWER position (GODE to BURKUR). *Sols rouge-jaune stfl à la à croûte de gypse à 70 cm, salés à faible profondeur. ALLUVIONS des CONES de DEJECTION position BASSE (GODE à BURKUR)*

46 — Yellowish-red soils L to SiC, with gypsum accumulation " SAND ROSE " type . ALLUVIAL FANS LOWER position (IMI-GODE). *Sols rouge-jaune slf à al à accumulation de gypse sous forme de ROSE des SABLES. ALLUVIONS des CONES de DEJECTION position BASSE (IMI-GODE)*

On Wabi Shebelle YELLOWISH - BROWN ALLUVIA over YELLOWISH - RED oued ALLUVIA
Sur ALLUVIONS BRUN-JAUNE du Wabi Shebelle recouvrant les ALLUVIONS ROUGE-JAUNE des oueds

47 — Yellowish-brown soils SCL/yellowish-red C (GODE). *Sols brun-jaune sfa/rouge-jaune a (GODE)*

HYDROMORPHIC SOILS *SOLS HYDROMORPHES*

MEDIUM ORGANIC *MOYENNEMENT ORGANIQUES*

HUMIC GLEY WITH POWDERY LIME *HUMIQUES A GLEY A CALCAIRE DIFFUS*

On BROWN ALLUVIA of the Wabi Shebelle *Sur ALLUVIONS BRUNES du Wabi Shebelle*
SHEBELLE plain serie *Série de la plaine de SHEBELLE*

48 — Brown soils C very easily flooded (PAPYRUS area). *Sols bruns a. fortement inondables (zone à PAPYRUS)*

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WITH NON DEGRADED STRUCTURE *A STRUCTURE NON DEGRADEE*

SALINE SOILS WITH SALT EFFLORESCENCES *SOLS SALINS A EFFLORESCENCES SALINES*

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V

SOILS MAP - CARTE DES SOLS

Lower Valley - Basse Vallée

MADISO

JANUARY 1973
MAP N°8

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CLASSE II - SOLS PEU FAVORABLES A L'IRRIGATION

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- II C D S m: 41, 47
- II C D S G M: 44, 45, 46
- II C D S P: 50

3RD CLASS - UNSUITABLE FOR IRRIGATION
CLASSE III - SOLS NON IRRIGABLES

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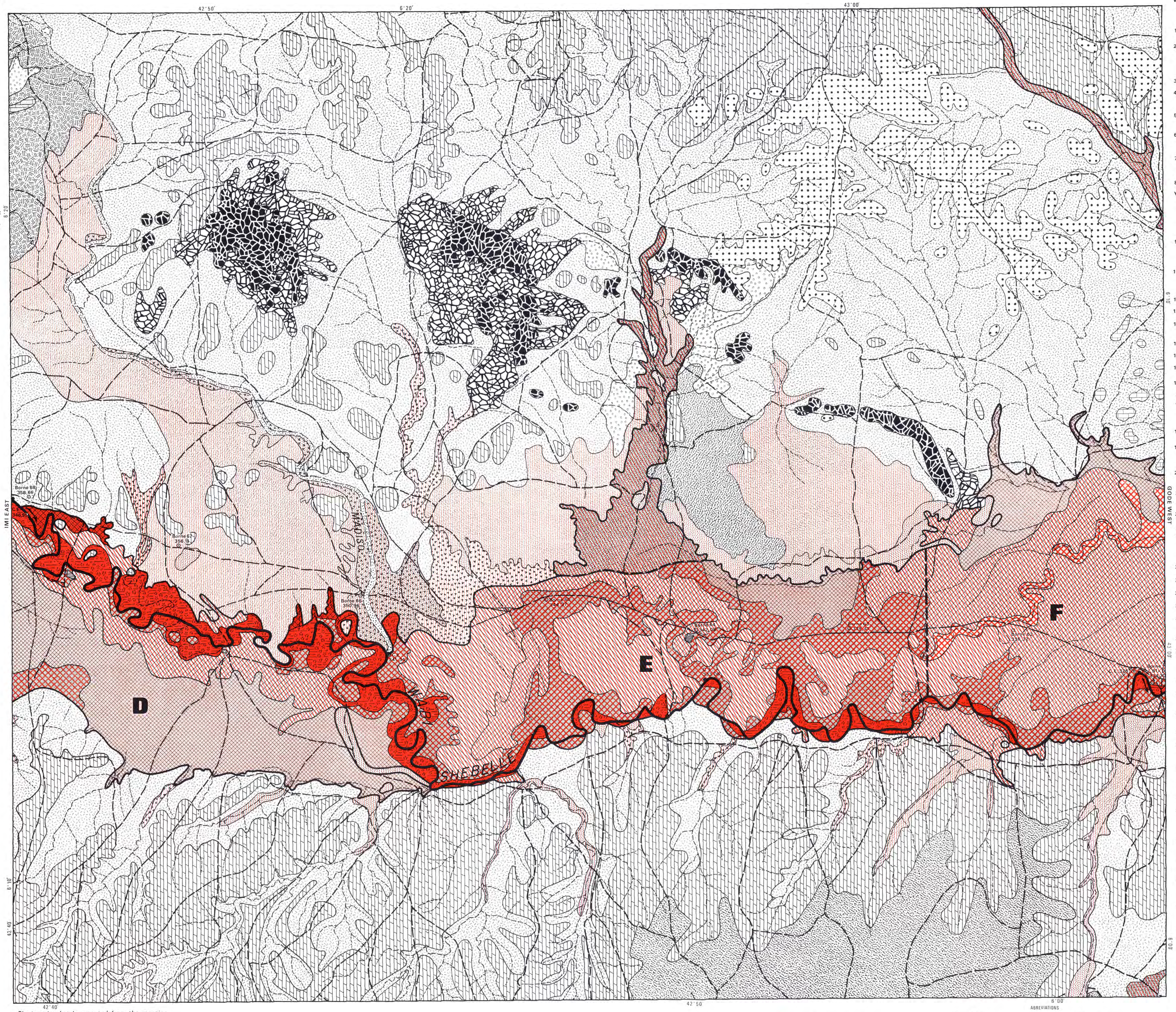
- s — Weak salinity in the depth / *Salure faible en profondeur*
- S — High salinity affecting the whole soil. / *Salure forte affectant l'ensemble du sol*
- G — Fine non-clayey texture unsuitable for irrigation / *Granulométrie fine non argileuse, défavorable à l'irrigation*
- m — Slighty broken micro relief requiring very slight leveling / *Microrelief peu uniforme nécessitant des planages très légers*
- M — Broken micro-relief requiring a great deal of leveling / *Microrelief peu uniforme necessitant des planages importants*
- P — Depth of the soil less than 1 m / *Profondeur du sol inférieure à 1 m*

Symbols concerning non irrigable soils.
Symboles concernant les sols non irrigables.

- R — Abundant coarse elements / *Eléments grossiers abondants*
- T — Steep slopes / *Pentes fortes*
- U — Superficial limestone or gypsum flags / *Dalles calcaire ou gypseuse superficielles*
- W — Depth of soil less than 50 cm / *Profondeur du sol inférieure à 50 cm*
- Y — Dunes / *Dunes*



Planimetric sketch executed from the mosaics of 1964.67 aerial photos.
Esquisse planimétrique éxecutée d'après les mosaïques photographiques de 1964.67

INDEX SHEET

11 IMI WEST	10 IMI	9 IMI EAST	8 MADISO	7 GODE WEST	6 GODE	5 GODE EAST	4 KELAFO	3 MUSTAHIL WEST	2 MUSTAHIL	1 BURKUR

Limits of irrigable soils. 1st Class
Limite des sols irrigables. Classe 1

A — Indication of large irrigable zones
Indication des grandes zones irrigables

Scale 1: 50000 approximate

Mile 1 ¾ ½ ¼ 0 1 2 3 Miles

M 1000 500 0 1 2 3 4 5 Km.

Fa — Flooded area (highly)
Zone fortement inondable

C.E. — Water level
Cote d'eau

⊙ — Bench-mark
Boulon, borne

ABREVIATIONS

m.S.	Medium sand
sm	*sableux à sables moyens*
m.f.S.	Medium and fine sand with predominance of medium sand
msf	*sableux à sables moyens et sables fins*
f.S.	Fine sand
sf	*sableux à sables fins*
c.m.S.	Coarse and medium sand with predominance of coarse sand
sgsf	*sableux à sables grossiers et sables fins*
f.c.S.	Fine and coarse sand
sfsg	*sableux à sables fins et sables grossiers*
f.m.S.	Fine and medium sand
sfsm	*sableux à sables fins et sables moyens*
S.L.L.	Sandy loam to loam
sfstf	*sableux à sables fins et sables très fins*
S.C.L.	Sandy clay loam
sfa	*sablo-argileux à sables fins*
L.	Loam
stf	*sableux à sables très fins*
S.i.L.	Silty loam
stfl	*sablo-limoneux à sables très fins*
C.L.	Clay loam
stfa	*sablo-argileux à sables très fins*
S.i.C.L.	Silty clay loam
la	*limono-argileux*
C.S.i.C.	Clay - Silty clay
astfl	*argilo-sablo-limoneux à sables très fins*
S.i.C.	Silty clay
al	*argilo-limoneux*
C.	Clay
a	*argileux*

LEGEND OF THE SOILS MAP
LEGENDE DE LA CARTE PEDOLOGIQUE

WEAKLY DEVELOPED SOILS *SOLS PEU EVOLUES*

XEROSOLS *XERIQUES*

GYPSEOUS SOILS Derived from marl and gypsum
GYPSEUX Issus des marnes gypseuses

1 Yellowish-gray soils L. with superficial gypsum flag : LARGE FLATS (IMI, KELAFO, MUSTAHIL, BURKUR).
Sols gris-jaune stf en place à dalle de gypse superficielle GRANDS FLATS IMI, KELAFO, MUSTAHIL, BURKUR.

2 Yellowish-gray soils SiL. with a gypsum flag at 50 cm depth on COLLUVIA LARGE FLATS (IMI, KELAFO, MUSTAHIL, BURKUR).
Sols gris-jaune stfl à dalle de gypse enterrée à 50 cm sur COLLUVIONS GRANDS FLATS (IMI, KELAFO, MUSTAHIL, BURKUR).

NON CLIMATIC SOILS *NON CLIMATIQUES*

LITHIC ERODED SOILS WITH POWDERY LIME Derived from marl and gypsum
SOLS D'EROSION LITHIQUES A CALCAIRE DIFFUS Issus des marnes gypseuses

3 Yellowish-gray soils SiL. with superficial gypsum flag : LOWER HILLS.
Sol gris-jaune stfl en place à dalle de gypse superficielle COLLINES BASSES.

4 Whitish-yellow soils L. shallow with gypsum flag on COLLUVIA : DEBRIS-SLOPE of the LOWER HILLS
Sols jaune-blanc stf à dalle de gypse peu profonde sur COLLUVIONS : DEBRIS-SLOPES sous les COLLINES BASSES.

Derived from limestone *Issus des calcaires*

5 Yellowish-red soils L. to CL. with limestone fragments and calcareous nodules on COLLUVIA : TALUS below the BLUFF of the LIMESTONE PLATEAUS.
Sols rouge-jaune stf à stfa à debris et nodules calcaires sur COLLUVIONS. TALUS sous les CORNICHES des PLATEAUX CALCAIRES.

6 Red soils SiL with gypsum flag at 20 cm depth on COLLUVIA GODE area (DEBRIS SLOPE) and FERFER area (PLATEAUS).
Sols rouges stfl à dalle de gypse à 20 cm de profondeur sur COLLUVIONS environs de GODE (DEBRIS SLOPE) et de FERFER (PLATEAUX).

Derived from basalts *Issus des basaltes*

7 Pale-brown soils SL to L. very stony on WEATHERED Basalt BOULDERS HILLS.
Sols brun-clair sf à stf très caillouteux sur ALTERATION en BOULE des basaltes COLLINES.

SOILS DEVELOPED ON WIND BLOWN MATERIAL WITH POWDERY LIMESTONE.
SOLS D'APPORTS EOLIENS A CALCAIRE DIFFUS

8 Yellow soils SL to L. on DUNES GODE area.
Sols jaune sf à stf sur DUNES : environs de GODE.

VERTISOLS AND VERTIC SOILS *VERTISOLS ET SOLS VERTIQUES*

WITH CURVED STRUCTURE *A STRUCTURE ARRONDIE*

BROWN OR REDDISH BROWN VERTISOLS WITH POWDERY LIME AND POWDERY GYPSUM IN THE DEPTH.
VERTISOLS BRUNS A BRUN-ROUGE A CALCAIRE DIFFUS ET CRISTAUX DE GYPSE EN PROFONDEUR

On RED-BROWN oued ALLUVIA derived from limestone
Sur ALLUVIONS BRUN-ROUGE d'oued issues des calcaires

9 Reddish-brown vertisols, grumosolic on 40 cm C. to SiC with powdery gypsum at 100 cm depth, easily flooded : oued Bu-Y ALLUVIA.
Vertisols brun-rouge grumosoliques sur 40 cm a. à al à cristaux de gypse vers 100 cm, inondables : ALLUVIONS de l'oued Bu-Y.

On BROWN oued ALLUVIA derived from basalts
Sur ALLUVIONS BRUNES d'oued issus des basaltes

10 Brown to red vertisols, grumosolic on 40 cm C. to SiC, with powdery gypsum at 40 cm depth, easily flooded oued ALLUVIA North West GODE area.
Vertisols bruns à rouges grumosoliques sur 40 cm a. à al. à cristaux de gypse à plus de 40 cm. inondables ALLUVIONS d'oued : Nord Ouest GODE.

On BROWN ALLUVIA of the Wabi Shebelle *Sur ALLUVIONS BRUNES du Wabi Shebelle*

GODE - IMI series. *Séries IMI-GODE*

11 Brown vertisols grumosolic on 30 cm C. with little powdery gypsum below 60 cm, easily flooded.
Vertisols bruns grumosoliques sur 30 cm a. quelques cristaux de gypse à partir de 60 cm. inondables.

12 Brown vertic soils grumosolic on 30 cm C. little powdery gypsum below 30 cm.
Sols bruns vertiques grumosoliques sur 30 cm, a. quelques cristaux de gypse à partir de 30 cm.

13 Brown vertic soils grumosolic on 20 cm SiC. to C. with powdery gypsum in depth.
Sols bruns vertiques grumosoliques sur 20 cm stfl à a. à cristaux de gypse en profondeur

KELAFO - MUSTAHIL - BURKUR series. *Séries KELAFO-MUSTAHIL-BURKUR*

14 Brown vertisols, grumosolic on 30 cm SiC to C. with powdery gypsum below 90 cm, seldom flooded
Vertisols bruns grumosoliques sur 30 cm astfl à a. avec cristaux de gypse à plus de 90 cm faiblement inondables.

15 Reddish-brown vertisols, grumosolic on 20 cm C. with powdery gypsum below 100 cm (KELAFO only).
Vertisols brun-rouge grumosoliques sur 20 cm a. avec cristaux de gypse à plus de 100 cm (KELAFO seulement)

16 Brown vertisols, grumosolic on 30 cm C. with powdery gypsum below 80 cm, very easily flooded (MUSTAHIL plain)
Vertisols bruns grumosoliques sur 30 cm a. avec nombreux cristaux de gypse à plus de 80 cm, fortement inondables : (plaine de MUSTAHIL)

17 Brown vertic soils, grumosolic on 20 cm C. with powdery gypsum below 80 cm, seldom flooded (SHEBELLE plain).
Sols bruns vertiques grumosoliques sur 20 cm a. avec cristaux de gypse à plus de 80 cm, faiblement inondables : (plaine de SHEBELLE)

SOILS WITH CALCAREOUS DIFFERENCIATION
SOLS A DIFFERENCIATION CALCAIRE

WITHOUT MELANIC HORIZON *SANS HORIZON MELANIQUE*

WITH POWDERY LIME : MODAL *A CALCAIRE DIFFUS : MODAUX*

COLLUVIA derived from limestone *COLLUVIONS issues des calcaires*

18 Yellowish-red soils fS with many limestone debris and pebbles : DEBRIS SLOPE below the LIMESTONE PLATEAUS (GODE to BURKUR).
Sols rouge-jaune sf riches en débris calcaires peu émoussés DEBRIS-SLOPE sous les PLATEAUX CALCAIRES (GODE à BURKUR).

19 Yellowish-red soils mfs, with limestone and basaltic pebbles : HILLOCKS of the LARGE ALLUVIAL FANS (IMI).
Sols rouge jaune smsf à galets calcaires et basaltiques : PETITS MAMELONS des GRANDS CONES de DEJECTION (IMI)

WITH NODULES *A AMAS ET NODULES*

Derived from limestone *Issus des calcaires*

20 Yellowish-red soils SiL to L, with calcareous nodules LIMESTONE PLATEAUX (GODE to BURKUR).
Sols rouge-jaune stfl à stf, à nodules calcaires en place PLATEAUX CALCAIRES (GODE à BURKUR)

Derived from sandstone *Issus des grès*

21 Red soils SL-L with calcareous nodules LOWER PLATEAUS (IMI).
Sols rouges sfstf à amas et nodules calcaires, en place BAS PLATEAUX (IMI)

On ancient oued ALLUVIA *Sur anciennes ALLUVIONS d'oued*

22 Yellowish-red soils CmS, with calcareous pebbles often cemented in conglomerate near the surface HILLOCKS in the LARGE ALLUVIAL FANS (GODE).
Sols rouge-jaune sgsf à galets calcaires souvent soudés en conglomérat à faible profondeur MAMELONS des GRANDS CONES de DEJECTION (GODE).

SOILS WITH GYPSEOUS DIFFERENCIATION
SOLS A DIFFERENCIATION GYPSEUSE

WITH POWDERY GYPSUM : MODAL *A GYPSE DIFFUS : MODAUX*

On BROWN ALLUVIA of the Wabi Shebelle
Sur ALLUVIONS BRUNES du Wabi Shebelle

IMI - GODE series *Séries IMI-GODE*

23 Brown soils SiC weakly organic/fs (ANCIENT MEANDERS of the Wabi Shebelle.
Sols bruns al. faiblement humifères/sf : (MEANDRES MORTS du WABI SHEBELLE).

24 Brown to yellowish-brown soils SiL to SiC in depth.
Sols bruns à brun-jaune stfl à al. en profondeur.

25 Brown soils C/fs (GODE).
Sols bruns a./sf (GODE).

26 Brown soils SiL to C. in depth (GODE).
Sols bruns stfl à a. en profondeur (GODE).

27 Brown soils CL (GODE).
Sols bruns stfa (Gode)

South KELAFO - MUSTAHIL - BURKUR series *Séries Sud KELAFO-MUSTAHIL-BURKUR*

28 Brown soils C/brownish-yellow L. seldom flooded to easily flooded (KELAFO)
Sols bruns a./jaune brunâtre stf. peu inondables à inondables (KELAFO)

29 Brown soils SiL to C. in depth
Sols bruns stfl à a en profondeur

On BROWNISH - YELLOW ALLUVIA of the Wabi Shebelle
Sur ALLUVIONS JAUNE-BRUN du Wabi Shebelle

IMI - North GODE series *Séries IMI-Nord GODE*

30 Brownish-yellow soils fcS BANKS of the Wabi Shebelle.
Sols jaune-brun à sfsg BOURRELETS de BERGE du Wabi Shebelle

31 Brownish-yellow fS/C
Sols jaune-brun sf/a.

IMI - North GODE - KELAFO series *Série IMI-Nord GODE-KELAFO*

32 Brownish-yellow soils SiL to fS RECENT or ANCIENT BANKS of the Wabi Shebelle.
Sols jaune-brun stfl-sf BOURRELETS de BERGE du Wabi Shebelle ACTUELS ou ANCIENS

South KELAFO - MUSTAHIL - BURKUR series *Séries Sud KELAFO-MUSTAHIL-BURKUR*

33 Brownish-yellow soils SiL to fmS in depth BANKS of the Wabi Shebelle.
Sols jaune-brun stfl à sfsm en profondeur BOURRELETS de BERGE du Wabi Shebelle

34 Brownish-yellow soils SiL to SiL-C in depth
Sols jaune-brun stfl à stfla en profondeur.

On REDDISH - YELLOW oued ALLUVIA *Sur ALLUVIONS JAUNE-ROUGE des oueds*

35 Reddish-yellow soils fS to L. with pebbles in the depth often salty : ALLUVIAL FANS : HIGHER position (GODE to BURKUR).
Sols jaune-rouge sf à stf à galets en profondeur, souvent salés ALLUVIONS des CONES de DEJECTION position HAUTE (GODE à BURKUR).

36 Reddish-yellow soils L. and mS ALLUVIAL FANS (IMI).
Sols jaune-rouge stf et sm ALLUVIONS des CONES de DEJECTION (IMI).

37 Reddish-yellow soils SiL RECENT ALLUVIA of the larger oueds
Sols jaune-rouge stfl ALLUVIONS RECENTES des grands oueds.

38 Reddish-yellow soils fS-SiL RECENT ALLUVIA of the larger oueds (MADISO)
Sols jaune-rouge sf-stfl ALLUVIONS RECENTES des grands oueds (MADISO)

WITH POWDERY GYPSUM : VERTIC *A GYPSE DIFFUS : VERTIQUES*

On BROWN ALLUVIA of the Wabi Shebelle *Sur ALLUVIONS BRUNES du Wabi Shebelle*

North GODE serie *Série Nord GODE*

39 Brown soils with SiC predominance
Sols bruns à dominance al.

GODE - KELAFO serie *Série GODE KELAFO*

40 Brown soils C.
Sols bruns a.

On YELLOWISH - RED oued ALLUVIA *Sur ALLUVIONS ROUGE-JAUNE des Oueds*

41 Yellowish-red soils SiL to C. RECENT ALLUVIA of the smaller oueds.
Sols rouge-jaune stfl à a. ALLUVIONS RECENTES des petits oueds

On Wabi Shebelle YELLOWISH - BROWN ALLUVIA over RED basaltic ALLUVIA
Sur ALLUVIONS BRUN-JAUNE du Wabi Shebelle recouvrant les ALLUVIONS ROUGES basaltiques.

42 Yellowish-brown soils SiL/red C. (GODE).
Sols brun-jaune stfl/rouge a. (GODE).

WITH GYPSEOUS CRUST : MODAL *ENCROUTES : MODAUX*

From RED COLLUVIA derived from basalts *Sur COLLUVIONS ROUGES issues des basaltes*

43 Red soils SCL to C. with gypseous crust at 60 cm depth : DEBRIS SLOPE below the basaltic HILLS (GODE North GODE)
Sols rouges sfa à a. à croûte de gypse vers 60 cm : DEBRIS-SLOPE des COLLINES de basalte (GODE-Nord GODE)

From YELLOWISH - RED oued ALLUVIA *Sur ALLUVIONS ROUGE-JAUNE des oueds*

44 Yellowish-red soils L. to SiL. with gypsum crust at 70 cm depth, salty in depth : ALLUVIAL FANS LOWER position (GODE).
Sols rouge-jaune stf à stfl, à croûte de gypse vers 70 cm, salés en profondeur : ALLUVIONS des CONES de DEJECTION position BASSE (GODE).

45 Yellowish-red soils SiL to SiCL. with gypsum crust at 70 cm depth, salty near the surface ALLUVIAL FANS LOWER position (GODE to BURKUR).
Sols rouge-jaune stfl à la. à croûte de gypse à 70 cm, salés à faible profondeur ALLUVIONS des CONES de DEJECTION position BASSE (GODE à BURKUR)

46 Yellowish-red soils L. to SiC, with gypsum accumulation " SAND ROSE " type : ALLUVIAL FANS LOWER position (IMI-GODE).
Sols rouge-jaune stf à al. à accumulation de gypse sous forme de ROSE des SABLES ALLUVIONS des CONES de DEJECTION position BASSE (IMI-GODE)

On Wabi Shebelle YELLOWISH - BROWN ALLUVIA over YELLOWISH - RED oued ALLUVIA
Sur ALLUVIONS BRUN-JAUNE du Wabi Shebelle recouvrant les ALLUVIONS ROUGE-JAUNE des oueds

47 Yellowish-brown soils SCL/yellowish-red C. (GODE).
Sols brun-jaune sfa/rouge-jaune a. (GODE).

HYDROMORPHIC SOILS *SOLS HYDROMORPHES*

MEDIUM ORGANIC *MOYENNEMENT ORGANIQUES*

HUMIC GLEY WITH POWDERY LIME *HUMIQUES A GLEY A CALCAIRE DIFFUS*

On BROWN ALLUVIA of the Wabi Shebelle *Sur ALLUVIONS BRUNES du Wabi Shebelle*

SHEBELLE plain serie *Série de la plaine de SHEBELLE*

48 Brown soils C. very easily flooded (PAPYRUS area).
Sols bruns a. fortement inondables (zone à PAPYRUS)

MUSTAHIL plain serie *Série de la plaine de MUSTAHIL*

49 Brown soils C. very easily flooded (GRAMINEA area).
Sols bruns a. fortement inondables (zone à GRAMINEES).

SODIC SOILS *SOLS SODIQUES*

WITH NON DEGRADED STRUCTURE *A STRUCTURE NON DEGRADEE*

SALINE SOILS WITH SALT EFFLORESCENCES *SOLS SALINS A EFFLORESCENCES SALINES*

On RED oued ALLUVIA *Sur ALLUVIONS ROUGES d'oued*

50 Red soils SiL to C. with gypsum flag at medium depth (BURKUR-FERFER).
Sols rouges stfl à a. à dalle de gypse à moyenne profondeur (BURKUR-FERFER)

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ብሔራዊ የውሃ ሀብት ልማት ኮሚሽን መሥሪያ ቤት

IMPERIAL ETHIOPIAN GOVERNMENT

NATIONAL WATER RESOURCES COMMISSION

ETHIOPIA - FRANCE COOPERATIVE PROGRAM

WABI SHEBELLE SURVEY

IN COLLABORATION WITH

FRENCH MINISTRY OF FOREIGN AFFAIRS — NATIONAL WATER RESOURCES COMMISSION — BCEOM_ORSTOM.EDF IGN_BDPA

V

SOILS MAP - CARTE DES SOLS

Lower Valley - Basse Vallée

IMI EAST

JANUARY 1973
MAP N° 9

SOILS FEATURES FAVOURING IRRIGATION
APTITUDES DES SOLS A L'IRRIGATION

1ST CLASS - VERY SUITABLE SOILS FOR IRRIGATION
CLASSE I - SOLS TRES FAVORABLES A L'IRRIGATION

I A - for all tropical crops in arid zone.
pour toutes cultures tropicales de zone aride.

I A d s — 24, 25, 26
I A D S — 23, 27, 28, 29

I B - for tropical fruit-trees, citrus, pine-apples, tomatoes (juice) vegetables, maize, sorghum, wheat, groundnuts, other oilseeds, forages (graminea).
pour arbres fruitiers tropicaux, agrumes, ananas, tomates (jus), cultures légumières, maïs, sorgho, blé, arachide, autres oléagineux, graminées fourragères.

I B d s — 30, 32, 33, 34
I B D S — 31

I C - for sugar-cane, cotton, artificial pastures, maize, sorghum, wheat, textile fiber plants, oilseeds.
pour canne à sucre, coton, pâturages artificiels, maïs, sorgho, blé, plantes à fibres, plantes à huile.

I C D s m — 9, 10, 12, 13, 14, 15, 17, 39, 40, 42

I D_A - for sugar-cane, coton, hill rice.
pour canne à sucre, coton, riz pluvial.

I D_A D S m — 11, 16, 48, 49

2ND CLASS - LOW SUITABILITY FOR IRRIGATION
CLASSE II - SOLS PEU FAVORABLES A L'IRRIGATION

II B - possible crops : tropical fruit-trees, citrus, pine-apples, tomatoes (juice) vegetables, maize, sorghum, wheat, groundnuts, other oilseeds.
cultures possibles : arbres fruitiers tropicaux, agrumes, ananas, tomates (jus), cultures légumières, maïs, sorgho, blé, arachide, autres oléagineux.

II B d m — 36, 37, 38

II C - possible crops : sugar-cane, cotton, artificial pastures, maize, sorghum, wheat, textile fiber plants, oilseeds.
cultures possibles : canne à sucre, coton, pâturages artificiels, maïs, sorgho, blé, plantes à fibres textiles.

II C D S m — 41, 47
II C D S G M — 44, 45, 46
II C D S P — 50

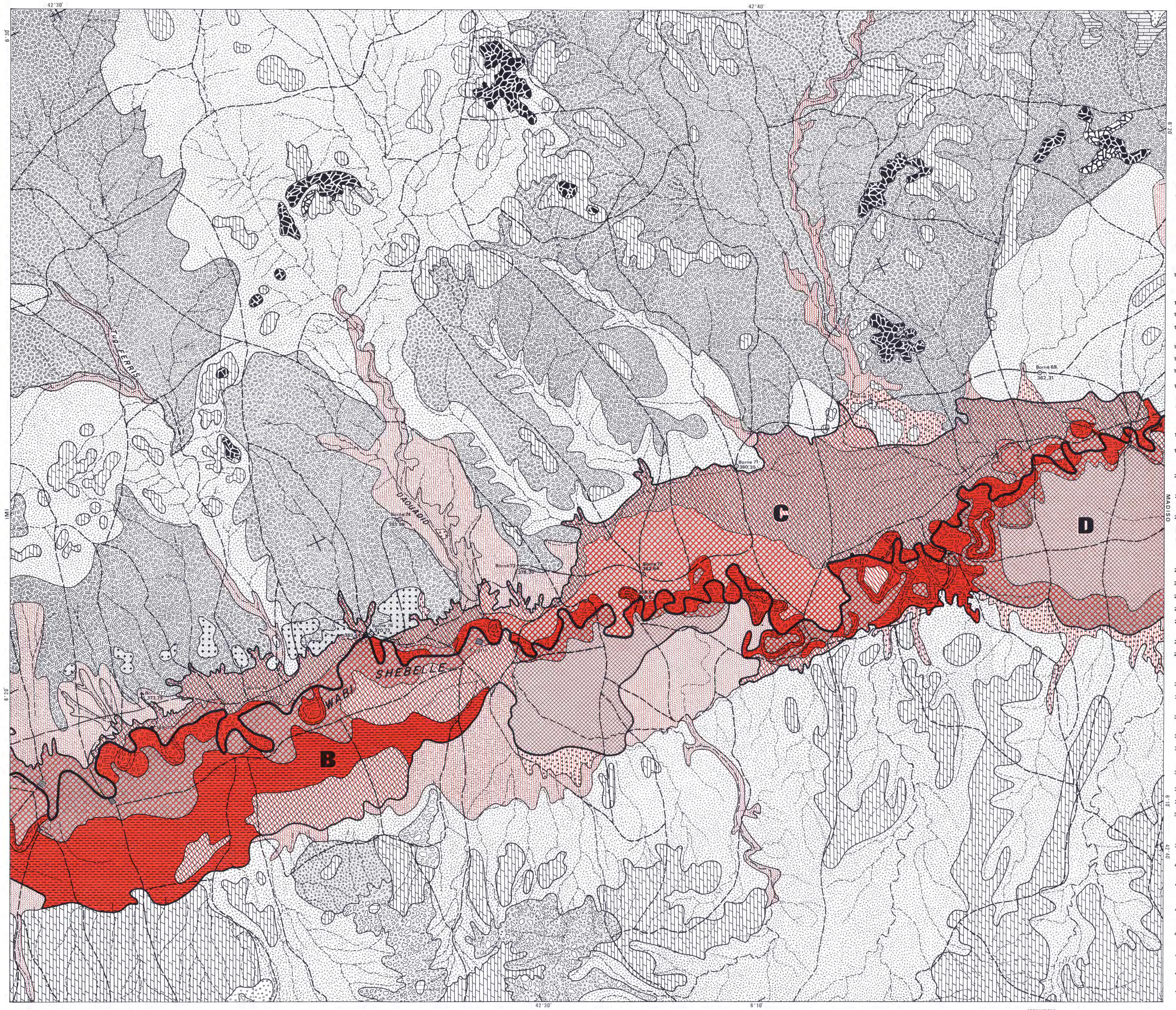
3RD CLASS - UNSUITABLE FOR IRRIGATION
CLASSE III - SOLS NON IRRIGABLES

III Y — 8
III R U — 1, 2, 3, 4, 5, 6
III R T — 19, 22, 35, 7, 18, 43
III U — 6
III W — 20, 21

EXPLANATION OF THE SYMBOLS
SIGNIFICATION DES SYMBOLES

Factors changing the quality of the soils suitable for irrigation.
Facteurs altérant les qualités des sols irrigables.

Symbols concerning non irrigable soils.
Symboles concernant les sols non irrigables.



Planimetric sketch executed from the mosaics of 1964.67 aerial photos.
Esquisse planimétrique exécutée d'après les mosaiques photographiques de 1964.67

INDEX SHEET

Limits of irrigable soils, 1st Class
Limite des sols irrigables, Classe I

Indication of large irrigable zones
Indication des grandes zones irrigables

Scale 1: 50 000 approximate

Flooded area (highly)
Zone fortement inondable

Water level
Cote d'eau

Bench-mark
Boulon borne

ABREVIATIONS

m.S.	Medium sand	L.	Loam
sm	*sableux à sables moyens*	*stf*	*sableux à sables très fins*
m.f.S.	Medium and fine sand with predominance of medium sand	S.i.L.	Silty loam
smsf	*sableux à sables moyens et sables fins*	*stfl*	*sablo-limoneux à sables très fins*
f.S.	Fine sand	C.L.	Clay loam
sf	*sableux à sables fins*	*stfa*	*sablo-argileux à sables très fins*
c.m.S.	Coarse and medium sand with predominance of coarse sand	S.i.C.L.	Silty clay loam
sgsf	*sableux à sables grossiers et sables fins*	*la*	*limono-argileux*
f.c.S.	Fine and coarse sand	C.S.i.C.	Clay - Silty clay
sfsg	*sableux à sables fins et sables grossiers*	*astfl*	*argilo-sablo-limoneux à sables très fins*
f.m.S.	Fine and medium sand	S.i.C.	Silty clay
sfsm	*sableux à sables fins et sables moyens*	*al*	*argilo-limoneux*
S.L.L.	Sandy loam to loam	C.	Clay
sfstf	*sableux à sables fins et sables très fins*	*a*	*argileux*
S.C.L.	Sandy clay loam		
sfa	*sablo-argileux à sables fins*		

LEGEND OF THE SOILS MAP
LEGENDE DE LA CARTE PEDOLOGIQUE

WEAKLY DEVELOPED SOILS *SOLS PEU EVOLUES*

XEROSOLS *XERIQUES*

GYPSEOUS SOILS Derived from marl and gypsum
GYPSEUX Issus des marnes gypseuses

1 Yellowish-gray soils L. with superficial gypsum flag : LARGE FLATS (IMI, KELAFO, MUSTAHIL, BURKUR).
Sols gris-jaune stf en place à dalle de gypse superficielle GRANDS FLATS : IMI, KELAFO, MUSTAHIL, BURKUR

2 Yellowish-gray soils SiL. with a gypsum flag at 50 cm depth on COLLUVIA LARGE FLATS (IMI, KELAFO, MUSTAHIL, BURKUR).
Sols gris-jaune stfl à dalle de gypse enterrée à 50 cm sur COLLUVIONS GRANDS FLATS (IMI, KELAFO, MUSTAHIL, BURKUR).

NON CLIMATIC SOILS *NON CLIMATIQUES*

LITHIC ERODED SOILS WITH POWDERY LIME Derived from marl and gypsum
SOLS D'EROSION LITHIQUES A CALCAIRE DIFFUS Issus des marnes gypseuses

3 Yellowish-gray soils SiL. with superficial gypsum flag : LOWER HILLS.
Sol gris-jaune stfl en place à dalle de gypse superficielle : COLLINES BASSES.

4 Whitish-yellow soils L. shallow with gypsum flag on COLLUVIA : DEBRIS-SLOPE of the LOWER HILLS.
Sols jaune-blanc stf à dalle de gypse peu profonde sur COLLUVIONS : DEBRIS-SLOPES sous les COLLINES BASSES.

Derived from limestone *Issus des calcaires*

5 Yellowish-red soils L. to CL. with limestone fragments and calcareous nodules on COLLUVIA ; TALUS below the BLUFF of the LIMESTONE PLATEAUS.
Sols rouge-jaune stf à stfa à debris et nodules calcaires sur COLLUVIONS. TALUS sous les CORNICHES des PLATEAUX CALCAIRES.

6 Red soils SiL with gypsum flag at 20 cm depth on COLLUVIA : GODE area (DEBRIS SLOPE) and FERFER area (PLATEAUS).
Sols rouges stfl à dalle de gypse à 20 cm de profondeur sur COLLUVIONS environs de GODE (DEBRIS-SLOPE) et de FERFER (PLATEAUX).

Derived from basalts *Issus des basaltes*

7 Pale-brown soils SL to L. very stony on WEATHERED Basalt BOULDERS : HILLS.
Sols brun-clair sf à stf très caillouteux sur ALTERATION en BOULE des basaltes : COLLINES.

SOILS DEVELOPED ON WIND BLOWN MATERIAL WITH POWDERY LIMESTONE.
SOLS D'APPORTS EOLIENS A CALCAIRE DIFFUS

8 Yellow soils SL to L. on DUNES : GODE area.
Sols jaune sf à stf sur DUNES : environs de GODE.

VERTISOLS AND VERTIC SOILS *VERTISOLS ET SOLS VERTIQUES*

WITH CURVED STRUCTURE *A STRUCTURE ARRONDIE*

BROWN OR REDDISH BROWN VERTISOLS WITH POWDERY LIME AND POWDERY GYPSUM IN THE DEPTH.
VERTISOLS BRUNS A BRUN-ROUGE A CALCAIRE DIFFUS ET CRISTAUX DE GYPSE EN PROFONDEUR

On RED-BROWN oued ALLUVIA derived from limestone
Sur ALLUVIONS BRUN-ROUGE d'oued issues des calcaires

9 Reddish-brown vertisols, grumosolic on 40 cm C. to SiC with powdery gypsum at 100 cm depth, easily flooded : oued Bu-Y ALLUVIA.
Vertisols brun-rouge grumosoliques sur 40 cm a. à al à cristaux de gypse vers 100 cm, inondables : ALLUVIONS de l'oued Bu-Y.

On BROWN oued ALLUVIA derived from basalts
Sur ALLUVIONS BRUNES d'oued issus des basaltes

10 Brown to red vertisols, grumosolic on 40 cm C. to Si C. with powdery gypsum at 40 cm depth, easily flooded : oued ALLUVIA : North West GODE area.
Vertisols bruns à rouges grumosoliques sur 40 cm a. à al. à cristaux de gypse à plus de 40 cm, inondables : ALLUVIONS d'oued : Nord Ouest GODE.

On BROWN ALLUVIA of the Wabi Shebelle *Sur ALLUVIONS BRUNES du Wabi Shebelle*
GODE - IMI series. *Séries IMI-GODE*

11 Brown vertisols grumosolic on 30 cm C. with little powdery gypsum below 60 cm, easily flooded.
Vertisols bruns grumosoliques sur 30 cm a. quelques cristaux de gypse à partir de 60 cm, inondables.

12 Brown vertic soils grumosolic on 30 cm C. little powdery gypsum below 30 cm.
Sols bruns vertiques grumosoliques sur 30 cm, a. quelques cristaux de gypse à partir de 30 cm.

13 Brown vertic soils grumosolic on 20 cm SiC. to C. with powdery gypsum in depth.
Sols bruns vertiques grumosoliques sur 20 cm stfl à a. à cristaux de gypse en profondeur.

KELAFO - MUSTAHIL - BURKUR series. *Séries KELAFO-MUSTAHIL-BURKUR*

14 Brown vertisols, grumosolic on 30 cm SiC to C. with powdery gypsum below 90 cm, seldom flooded.
Vertisols bruns grumosoliques sur 30 cm astfl à a. avec cristaux de gypse à plus de 90 cm, faiblement inondables.

15 Reddish-brown vertisols, grumosolic on 20 cm C. with powdery gypsum below 100 cm (KELAFO only).
Vertisols brun-rouge grumosoliques sur 20 cm a. avec cristaux de gypse à plus de 100 cm (KELAFO seulement).

16 Brown vertisols, grumosolic on 30 cm C. with powdery gypsum below 80 cm, very easily flooded (MUSTAHIL plain).
Vertisols bruns grumosoliques sur 30 cm a. avec nombreux cristaux de gypse à plus de 80 cm. fortement inondables (plaine de MUSTAHIL).

17 Brown vertic soils, grumosolic on 20 cm C. with powdery gypsum below 80 cm, seldom flooded (SHEBELLE plain).
Sols bruns vertiques grumosoliques sur 20 cm a. avec cristaux de gypse à plus de 80 cm, faiblement inondables; (plaine de SHEBELLE).

SOILS WITH CALCAREOUS DIFFERENCIATION
SOLS A DIFFERENCIATION CALCAIRE

WITHOUT MELANIC HORIZON *SANS HORIZON MELANIQUE*
WITH POWDERY LIME : MODAL *A CALCAIRE DIFFUS : MODAUX*
COLLUVIA derived from limestone *COLLUVIONS issues des calcaires*

18 Yellowish-red soils fS with many limestone debris and pebbles : DEBRIS SLOPE below the LIMESTONE PLATEAUS (GODE to BURKUR).
Sols rouge-jaune sf riches en débris calcaires peu émoussés : DEBRIS-SLOPE sous les PLATEAUX CALCAIRES (GODE à BURKUR).

19 Yellowish-red soils mfs, with limestone and basaltic pebbles : HILLOCKS of the LARGE ALLUVIAL FANS (IMI).

SOILS WITH GYPSEOUS DIFFERENCIATION
SOLS A DIFFERENCIATION GYPSEUSE

HYDROMORPHIC SOILS *SOLS HYDROMORPHES*

MEDIUM ORGANIC *MOYENNEMENT ORGANIQUES*

SODIC SOILS *SOLS SODIQUES*

WITH NON DEGRADED STRUCTURE *A STRUCTURE NON DEGRADEE*

የኢትዮጵያ ንጉሠ ነገሥት መንግሥት
ብሔራዊ የውሃ ሀብት ልማት ኮሚሽን መሥሪያ ቤት

IMPERIAL ETHIOPIAN GOVERNMENT

NATIONAL WATER RESOURCES COMMISSION

ETHIOPIA - FRANCE COOPERATIVE PROGRAM

WABI SHEBELLE SURVEY

IN COLLABORATION WITH

FRENCH MINISTRY OF FOREIGN AFFAIRS — NATIONAL WATER RESOURCES COMMISSION — BCEOM_ORSTOM.EDF IGN_BDPA

V

SOILS MAP - CARTE DES SOLS

Lower Valley - Basse Vallée

IMI

JANUARY 1973
MAP N°10

ORSTOM
ign

SOILS FEATURES FAVOURING IRRIGATION
APTITUDES DES SOLS A L'IRRIGATION

1ST CLASS - VERY SUITABLE SOILS FOR IRRIGATION
CLASSE I - SOLS TRES FAVORABLES A L'IRRIGATION

I A - for all tropical crops in arid zone.
pour toutes cultures tropicales de zone aride.

- I A d s: 24, 25, 26
- I A D S: 23, 27, 28, 29

I B - for tropical fruit-trees, citrus, pine-apples, tomatoes (juice) vegetables, maize, sorghum, wheat, groundnuts, other oilseeds, forages (graminea).
pour arbres fruitiers tropicaux, agrumes, ananas, tomates (jus), cultures légumières, maïs, sorgho, blé, arachide, autres oléagineux, graminées fourragères.

- I B d s: 30, 32, 33, 34
- I B D S: 31

I C - for sugar-cane, cotton, artificial pastures, maize, sorghum, wheat, textile fiber plants, oilseeds.
pour canne à sucre, coton, pâturages artificiels, maïs, sorgho, blé, plantes à fibres, plantes à huile.

- I C D s m: 9, 10, 12, 13, 14, 15, 17, 39, 40, 42

I D_A - for sugar-cane, coton, hill rice.
pour canne à sucre, coton, riz pluvial.

- I D_A D S m: 11, 16, 48, 49

2ND CLASS - LOW SUITABILITY FOR IRRIGATION
CLASSE II - SOLS PEU FAVORABLES A L'IRRIGATION

II B - possible crops : tropical fruit-trees, citrus, pine-apples, tomatoes (juice) vegetables, maize, sorghum, wheat, groundnuts, other oilseeds.
cultures possibles : arbres fruitiers tropicaux, agrumes, ananas, tomates (jus), cultures légumières, maïs, sorgho, blé, arachide, autres oléagineux.

- II B d m: 36, 37, 38

II C - possible crops : sugar-cane, cotton, artificial pastures, maize, sorghum, wheat, textile fiber plants.
cultures possibles : canne à sucre, coton, pâturages artificiels, maïs, sorgho, blé, plantes à fibres textiles.

- II C D S m: 41, 47
- II C D S G M: 44, 45, 46
- II C D S P: 50

3RD CLASS - UNSUITABLE FOR IRRIGATION
CLASSE III - SOLS NON IRRIGABLES

- III Y: 8
- III R U: 1, 2, 4
- III R T: 3, 5, 7, 18, 19, 22, 35, 43
- III U: 6
- III W: 20, 21

EXPLANATION OF THE SYMBOLS
SIGNIFICATION DES SYMBOLES

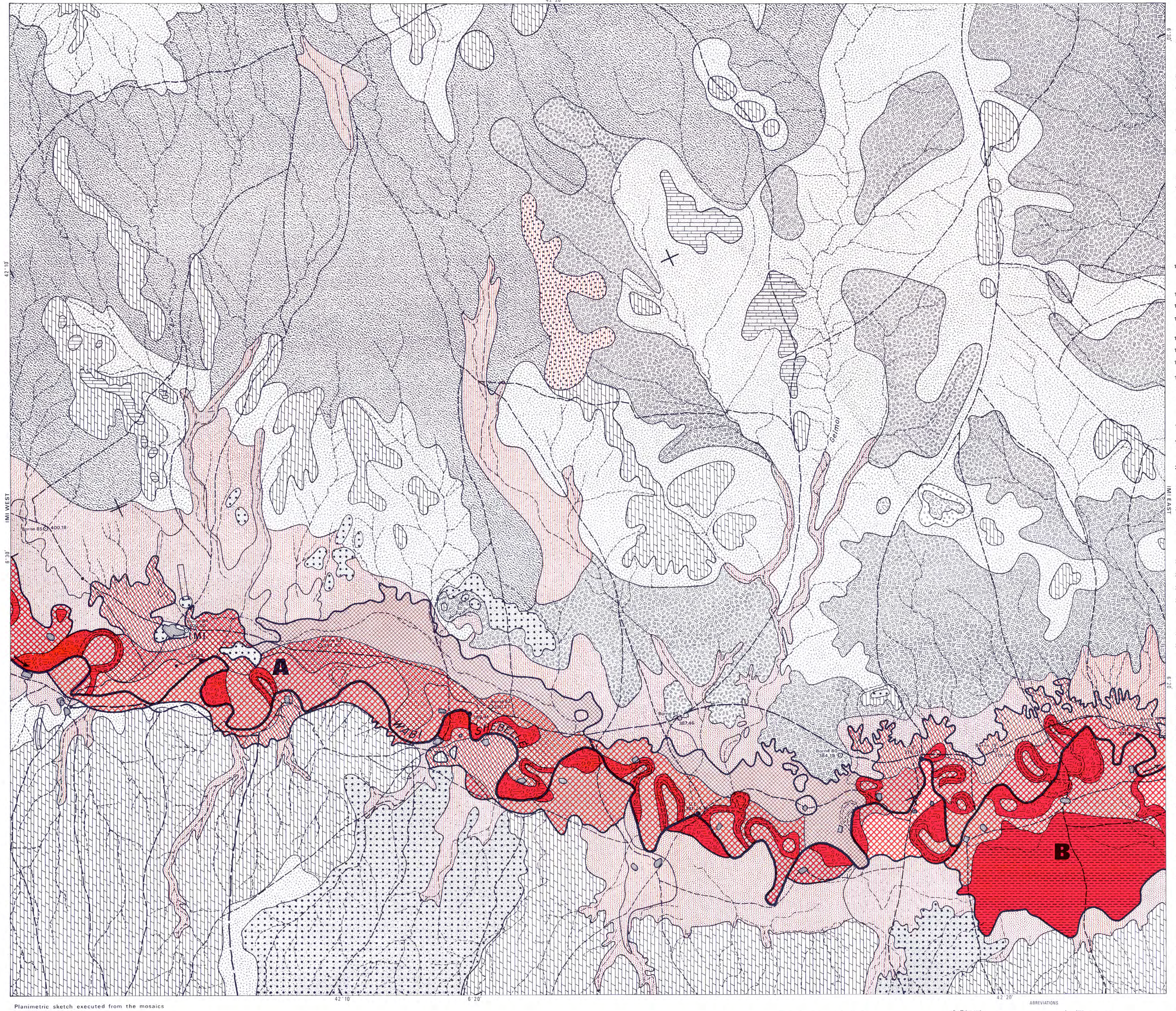
Factors changing the quality of the soils suitable for irrigation.
Facteurs altérant les qualités des sols irrigables.

- d — Slight drainage necessary / *Drainage léger nécessaire*
- D — Drainage necessary on a larger scale / *Drainage important nécessaire*
- s — Weak salinity in the depth / *Salure faible en profondeur*
- S — High salinity affecting the whole soil. / *Salure forte affectant l'ensemble du sol*
- G — Fine non-clayey texture unsuitable for irrigation / *Granulométrie fine non argileuse, défavorable a l'irrigation*
- m — Slighty broken micro relief requiring very slight leveling / *Microrelief peu uniforme nécessitant des planages très légers*
- M — Broken micro-relief requiring a great deal of leveling / *Microrelief peu uniforme necessitant des planages importants*
- P — Depth of the soil less than 1 m / *Profondeur du sol inférieure à 1 m*

Symbols concerning non irrigable soils.
Symboles concernant les sols non irrigables.

- R — Abundant coarse elements / *Eléments grossiers abondants*
- T — Steep slopes / *Pentes fortes*
- U — Superficial limestone or gypsum flags / *Dalles calcaire ou gypseuse superficielles*
- W — Depth of soil less than 50 cm / *Profondeur du sol inférieure à 50 cm*
- Y — Dunes / *Dunes*

N



Planimetric sketch executed from the mosaics of 1964.67 aerial photos.
Esquisse planimétrique exécutée d'apres les mosaïques photographiques de 1964.67.

INDEX SHEET

11 IMI WEST	10 IMI	9 IMI EAST	8 MADISO	7 GODE WEST	6 GODE	5 GODE EAST	4 KELAFO	3 MUSTAHIL WEST	2 MUSTAHIL	1 BURKUR

Limits of irrigable soils _ 1st Class
Limite des sols irrigables _ Classe 1

A — Indication of large irrigable zones
Indication des grandes zones irrigables

Scale 1: 50 000° approximate

Mile 1 ¾ ½ ¼ 0 1 2 3 Miles
M 1000 500 0 1 2 3 4 5 Km.

Fa — Flooded area (highly)
Zone fortement inondable

C.E. — Water level
Cote d'eau

⊙ — Bench-mark
Boulon, borne

ABREVIATIONS

m.S.	Medium sand
sm	*sableux à sables moyens*
m.f.S.	Medium and fine sand with predominance of medium sand
smsf	*sableux à sables moyens et sables fins*
f.S.	Fine sand
sf	*sableux à sables fins*
c.m.S.	Coarse and medium sand with predominance of coarse sand
sgsf	*sableux à sables grossiers et sables fins*
f.c.S.	Fine and coarse sand
sfsg	*sableux à sables fins et sables grossiers*
f.m.S.	Fine and medium sand
sfsm	*sableux à sables fins et sables moyens*
S.L.L.	Sandy loam to loam
sfstf	*sableux à sables fins et sables très fins*
S.C.L.	Sandy clay loam
sfa	*sablo-argileux à sables fins*
L.	Loam
stf	*sableux à sables très fins*
S.i.L.	Silty loam
stfl	*sablo-limoneux à sables très fins*
C.L.	Clay loam
stfa	*sablo-argileux à sables très fins*
S.i.C.L.	Silty clay loam
la	*limono-argileux*
C.S.i.C.	Clay - Silty clay
astfl	*argilo-sablo-limoneux à sables très fins*
S.i.C.	Silty clay
al	*argilo-limoneux*
C.	Clay
a	*argileux*

LEGEND OF THE SOILS MAP
LEGENDE DE LA CARTE PEDOLOGIQUE

WEAKLY DEVELOPED SOILS *SOLS PEU EVOLUES*

XEROSOLS *XERIQUES*

GYPSEOUS SOILS Derived from marl and gypsum
GYPSEUX Issus des marnes gypseuses

1. Yellowish-gray soils L with superficial gypsum flag : LARGE FLATS (IMI, KELAFO, MUSTAHIL, BURKUR). *Sols gris-jaune stf en place à dalle de gypse superficielle GRANDS FLATS (IMI, KELAFO, MUSTAHIL, BURKUR)*
2. Yellowish-gray soils SiL, with a gypsum flag at 50 cm depth on COLLUVIA : LARGE FLATS (IMI, KELAFO, MUSTAHIL, BURKUR). *Sols gris-jaune stfl à dalle de gypse enterrée à 50 cm sur COLLUVIONS : GRANDS FLATS (IMI, KELAFO, MUSTAHIL, BURKUR).*

NON CLIMATIC SOILS *NON CLIMATIQUES*

LITHIC ERODED SOILS WITH POWDERY LIME Derived from marl and gypsum
SOLS D'EROSION LITHIQUES A CALCAIRE DIFFUS Issus des marnes gypseuses

3. Yellowish-gray soils SiL, with superficial gypsum flag : LOWER HILLS. *Sol gris-jaune stfl en place à dalle de gypse superficielle : COLLINES BASSES*
4. Whitish-yellow soils L shallow with gypsum flag on COLLUVIA : DEBRIS-SLOPE of the LOWER HILLS. *Sols jaune-blanc stf à dalle de gypse peu profonde sur COLLUVIONS : DEBRIS-SLOPES sous les COLLINES BASSES*

Derived from limestone *Issus des calcaires*

5. Yellowish-red soils L. to CL, with limestone fragments and calcareous nodules on COLLUVIA : TALUS below the BLUFF of the LIMESTONE PLATEAUS. *Sols rouge-jaune stf à stfa à debris et nodules calcaires sur COLLUVIONS. TALUS sous les CORNICHES des PLATEAUX CALCAIRES.*
6. Red soils SiL with gypsum flag at 20 cm depth on COLLUVIA : GODE area (DEBRIS SLOPE) and FERFER area (PLATEAUS). *Sols rouges stfl à dalle de gypse à 20 cm de profondeur sur COLLUVIONS environs de GODE (DEBRIS-SLOPE) et de FERFER (PLATEAUX)*

Derived from basalts *Issus des basaltes*

7. Pale-brown soils SL to L. very stony on WEATHERED Basalt BOULDERS : HILLS. *Sols brun-clair sf à stf très caillouteux sur ALTERATION en BOULE des basaltes : COLLINES*

SOILS DEVELOPED ON WIND BLOWN MATERIAL WITH POWDERY LIMESTONE.
SOLS D'APPORTS EOLIENS A CALCAIRE DIFFUS

8. Yellow soils SL to L. on DUNES : GODE area. *Sols jaune sf à stf sur DUNES : environs de GODE*

VERTISOLS AND VERTIC SOILS *VERTISOLS ET SOLS VERTIQUES*

WITH CURVED STRUCTURE *A STRUCTURE ARRONDIE*
BROWN OR REDDISH BROWN VERTISOLS WITH POWDERY LIME AND POWDERY GYPSUM IN THE DEPTH.
VERTISOLS BRUNS A BRUN-ROUGE A CALCAIRE DIFFUS ET CRISTAUX DE GYPSE EN PROFONDEUR

On RED-BROWN oued ALLUVIA derived from limestone
Sur ALLUVIONS BRUN-ROUGE d'oued issues des calcaires

9. Reddish-brown vertisols, grumosolic on 40 cm C. to SiC with powdery gypsum at 100 cm depth, easily flooded : oued Bu-Y ALLUVIA. *Vertisols brun-rouge grumosoliques sur 40 cm a. à al à cristaux de gypse vers 100 cm inondables : ALLUVIONS de l'oued Bu-Y.*

On BROWN oued ALLUVIA derived from basalts
Sur ALLUVIONS BRUNES d'oued issus des basaltes

10. Brown to red vertisols, grumosolic on 40 cm C. to SiC, with powdery gypsum at 40 cm depth, easily flooded : oued ALLUVIA : North West GODE area. *Vertisols bruns à rouges grumosoliques sur 40 cm a. à al. à cristaux de gypse à plus de 40 cm, inondables : ALLUVIONS d'oued : Nord Ouest GODE*

On BROWN ALLUVIA of the Wabi Shebelle *Sur ALLUVIONS BRUNES du Wabi Shebelle*
GODE - IMI series. *Séries IMI-GODE*

11. Brown vertisols grumosolic on 30 cm C. with little powdery gypsum below 60 cm, easily flooded. *Vertisols bruns grumosoliques sur 30 cm a. quelques cristaux de gypse à partir de 60 cm, inondables.*
12. Brown vertic soils grumosolic on 30 cm C. little powdery gypsum below 30 cm. *Sols bruns vertiques grumosoliques sur 30 cm, a. quelques cristaux de gypse à partir de 30 cm.*
13. Brown vertic soils grumosolic on 20 cm SiC. to C. with powdery gypsum in depth. *Sols bruns vertiques grumosoliques sur 20 cm stfl à a. à cristaux de gypse en profondeur.*

KELAFO - MUSTAHIL - BURKUR series. *Séries KELAFO-MUSTAHIL-BURKUR*

14. Brown vertisols, grumosolic on 30 cm SiC to C. with powdery gypsum below 90 cm, seldom flooded. *Vertisols bruns grumosoliques sur 30 cm astfl à a. avec cristaux de gypse à plus de 90 cm faiblement inondables*
15. Reddish-brown vertisols, grumosolic on 20 cm C. with powdery gypsum below 100 cm (KELAFO only). *Vertisols brun-rouge grumosoliques sur 20 cm a. avec cristaux de gypse à plus de 100 cm (KELAFO seulement)*
16. Brown vertisols, grumosolic on 30 cm C. with powdery gypsum below 80 cm, very easily flooded (MUSTAHIL plain). *Vertisols bruns grumosoliques sur 30 cm a. avec nombreux cristaux de gypse à plus de 80 cm fortement inondables : (plaine de MUSTAHIL).*
17. Brown vertic soils, grumosolic on 20 cm C. with powdery gypsum below 80 cm, seldom flooded (SHEBELLE plain). *Sols bruns vertiques grumosoliques sur 20 cm a avec cristaux de gypse à plus de 80 cm, faiblement inondables (plaine de SHEBELLE)*

SOILS WITH CALCAREOUS DIFFERENCIATION
SOLS A DIFFERENCIATION CALCAIRE

WITHOUT MELANIC HORIZON *SANS HORIZON MELANIQUE*
WITH POWDERY LIME : MODAL *A CALCAIRE DIFFUS : MODAUX*
COLLUVIA derived from limestone *COLLUVIONS issues des calcaires*

18. Yellowish-red soils fS with many limestone debris and pebbles : DEBRIS SLOPE below the LIMESTONE PLATEAUS (GODE to BURKUR). *Sols rouge-jaune sf riches en débris calcaires peu émoussés : DEBRIS-SLOPE sous les PLATEAUX CALCAIRES (GODE à BURKUR)*
19. Yellowish-red soils mfs, with limestone and basaltic pebbles : HILLOCKS of the LARGE ALLUVIAL FANS (IMI). *Sols rouge-jaune smsf à galets calcaires et basaltiques : PETITS MAMELONS des GRANDS CONES de DEJECTION (IMI)*

WITH NODULES *A AMAS ET NODULES*
Derived from limestone *Issus des calcaires*

20. Yellowish-red soils SiL to L. with calcareous nodules : LIMESTONE PLATEAUX (GODE to BURKUR). *Sols rouge-jaune stfl à stf, à nodules calcaires en place : PLATEAUX CALCAIRES (GODE à BURKUR)*

Derived from sandstone *Issus des grès*

21. Red soils SL-L with calcareous nodules : LOWER PLATEAUS (IMI). *Sols rouges sfstf à amas et nodules calcaires, en place : BAS PLATEAUX (IMI)*

On ancient oued ALLUVIA *Sur anciennes ALLUVIONS d'oued*

22. Yellowish-red soils CmS, with calcareous pebbles often cemented in conglomerate near the surface : HILLOCKS in the LARGE ALLUVIAL FANS (GODE). *Sols rouge-jaune sgsf à galets calcaires souvent soudés en conglomerat à faible profondeur MAMELONS des GRANDS CONES de DEJECTION (GODE)*

SOILS WITH GYPSEOUS DIFFERENCIATION
SOLS A DIFFERENCIATION GYPSEUSE

WITH POWDERY GYPSUM : MODAL *A GYPSE DIFFUS : MODAUX*
On BROWN ALLUVIA of the Wabi Shebelle
Sur ALLUVIONS BRUNES du Wabi Shebelle
IMI - GODE series *Séries IMI-GODE*

23. Brown soils SiC weakly organic/fs (ANCIENT MEANDERS of the Wabi Shebelle). *Sols bruns al faiblement humifères/sf : (MEANDRES MORTS du WABI SHEBELLE)*
24. Brown to yellowish-brown soils SiL to SiC in depth. *Sols bruns à brun-jaune stfl à al en profondeur*
25. Brown soils C/fs (GODE). *Sols bruns a./sf (GODE)*
26. Brown soils SiL to C. in depth (GODE). *Sols bruns stfl à a. en profondeur (GODE)*
27. Brown soils CL (GODE). *Sols bruns stfa (Gode)*

South KELAFO - MUSTAHIL - BURKUR series *Séries Sud KELAFO-MUSTAHIL-BURKUR*

28. Brown soils C/brownish-yellow L. seldom flooded to easily flooded (KELAFO). *Sols bruns a./jaune-brunâtre stf peu inondables à inondables (KELAFO)*
29. Brown soils SiL to C. in depth. *Sols bruns stfl à a en profondeur*

On BROWNISH - YELLOW ALLUVIA of the Wabi Shebelle
Sur ALLUVIONS JAUNE-BRUN du Wabi Shebelle
IMI - North GODE series *Séries IMI-Nord GODE*

30. Brownish-yellow soils fcS : BANKS of the Wabi Shebelle. *Sols jaune-brun à sfsg : BOURRELETS de BERGE du Wabi Shebelle*
31. Brownish-yellow fS/C. *Sols jaune-brun sf/a*

IMI - North GODE - KELAFO series *Série IMI-Nord GODE-KELAFO*

32. Brownish-yellow soils SiL to fS : RECENT or ANCIENT BANKS of the Wabi Shebelle. *Sols jaune-brun stfl-sf : BOURRELETS de BERGE du Wabi Shebelle ACTUELS ou ANCIENS*

South KELAFO - MUSTAHIL - BURKUR series *Séries Sud KELAFO-MUSTAHIL-BURKUR*

33. Brownish-yellow soils SiL to fmS in depth : BANKS of the Wabi Shebelle. *Sols jaune-brun stfl à sfsm en profondeur : BOURRELETS de BERGE du Wabi Shebelle*
34. Brownish yellow soils SiL to SiL-C in depth. *Sols jaune-brun stfl à stfla en profondeur.*

On REDDISH - YELLOW oued ALLUVIA *Sur ALLUVIONS JAUNE-ROUGE des oueds*

35. Reddish-yellow soils fS to L with pebbles in the depth often salty : ALLUVIAL FANS : HIGHER position (GODE to BURKUR). *Sols jaune-rouge sf à stf à galets en profondeur souvent salés : ALLUVIONS des CONES de DEJECTION : position HAUTE (GODE à BURKUR)*
36. Reddish-yellow soils L. and mS ALLUVIAL FANS (IMI). *Sols jaune-rouge stf et sm : ALLUVIONS des CONES de DEJECTION (IMI)*
37. Reddish-yellow soils SiL : RECENT ALLUVIA of the larger oueds. *Sols jaune-rouge stfl : ALLUVIONS RECENTES des grands oueds.*
38. Reddish-yellow soils fS-SiL : RECENT ALLUVIA of the larger oueds (MADISO). *Sols jaune-rouge sf-stfl : ALLUVIONS RECENTES des grands oueds (MADISO)*

WITH POWDERY GYPSUM : VERTIC *A GYPSE DIFFUS : VERTIQUES*
On BROWN ALLUVIA of the Wabi Shebelle *Sur ALLUVIONS BRUNES du Wabi Shebelle*
North GODE serie *Série Nord GODE*

39. Brown soils with SiC predominance. *Sols bruns à dominance al.*

GODE - KELAFO serie *Série GODE-KELAFO*

40. Brown soils C. *Sols bruns a.*

On YELLOWISH - RED oued ALLUVIA *Sur ALLUVIONS ROUGE-JAUNE des Oueds*

41. Yellowish-red soils SiL to C. : RECENT ALLUVIA of the smaller oueds. *Sols rouge-jaune stfl à a. : ALLUVIONS RECENTES des petits oueds*

On Wabi Shebelle YELLOWISH - BROWN ALLUVIA over RED basaltic ALLUVIA
Sur ALLUVIONS BRUN-JAUNE du Wabi Shebelle recouvrant les ALLUVIONS ROUGES basaltiques

42. Yellowish-brown soils SiL/red C. (GODE). *Sols brun-jaune stfl/rouge a. (GODE)*

WITH GYPSEOUS CRUST : MODAL *ENCROUTES : MODAUX*
From RED COLLUVIA derived from basalts *Sur COLLUVIONS ROUGES issues des basaltes*

43. Red soils SCL to C. with gypseous crust at 60 cm depth : DEBRIS SLOPE below the basaltic HILLS (GODE North GODE). *Sols rouges sfa à a. à croûte de gypse vers 60 cm : DEBRIS SLOPE des COLLINES de basalte (GODE-Nord GODE).*

From YELLOWISH - RED oued ALLUVIA *Sur ALLUVIONS ROUGE-JAUNE des oueds*

44. Yellowish-red soils L. to SiL with gypsum crust at 70 cm depth, salty in depth : ALLUVIAL FANS LOWER position (GODE). *Sols rouge-jaune stf à stfl à croûte de gypse vers 70 cm salés en profondeur : ALLUVIONS des CONES de DEJECTION position BASSE (GODE)*
45. Yellowish-red soils SiL to SiCL with gypsum crust at 70 cm depth, salty near the surface : ALLUVIAL FANS LOWER position (GODE to BURKUR). *Sols rouge-jaune stfl à la. à croûte de gypse à 70 cm, salés à faible profondeur ALLUVIONS des CONES de DEJECTION position BASSE (GODE à BURKUR)*
46. Yellowish-red soils L. to SiC, with gypsum accumulation " SAND ROSE " type : ALLUVIAL FANS LOWER position (IMI-GODE). *Sols rouge-jaune stf à al. à accumulation de gypse sous forme de ROSE des SABLES ALLUVIONS des CONES de DEJECTION position BASSE (IMI GODE)*

On Wabi Shebelle YELLOWISH - BROWN ALLUVIA over YELLOWISH - RED oued ALLUVIA
Sur ALLUVIONS BRUN-JAUNE du Wabi Shebelle recouvrant les ALLUVIONS ROUGE-JAUNE des oueds

47. Yellowish brown soils SCL/yellowish-red C. (GODE). *Sols brun-jaune sfa/rouge-jaune a. (GODE)*

HYDROMORPHIC SOILS *SOLS HYDROMORPHES*

MEDIUM ORGANIC *MOYENNEMENT ORGANIQUES*
HUMIC GLEY WITH POWDERY LIME *HUMIQUES A GLEY A CALCAIRE DIFFUS*
On BROWN ALLUVIA of the Wabi Shebelle *Sur ALLUVIONS BRUNES du Wabi Shebelle*
SHEBELLE plain serie *Série de la plaine de SHEBELLE*

48. Brown soils C. very easily flooded (PAPYRUS area). *Sols bruns a. fortement inondables (zone à PAPYRUS)*

MUSTAHIL plain serie *Série de la plaine de MUSTAHIL*

49. Brown soils C. very easily flooded (GRAMINEA area). *Sols bruns a fortement inondables (zone à GRAMINEES)*

SODIC SOILS *SOLS SODIQUES*

WITH NON DEGRADED STRUCTURE *A STRUCTURE NON DEGRADEE*
SALINE SOILS WITH SALT EFFLORESCENCES *SOLS SALINS A EFFLORESCENCES SALINES*
On RED oued ALLUVIA *Sur ALLUVIONS ROUGES d'oued*

50. Red soils SiL to C. with gypsum flag at medium depth (BURKUR-FERFER). *Sols rouges stfl à a. à dalle de gypse à moyenne profondeur (BURKUR-FERFER)*

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IMPERIAL ETHIOPIAN GOVERNMENT

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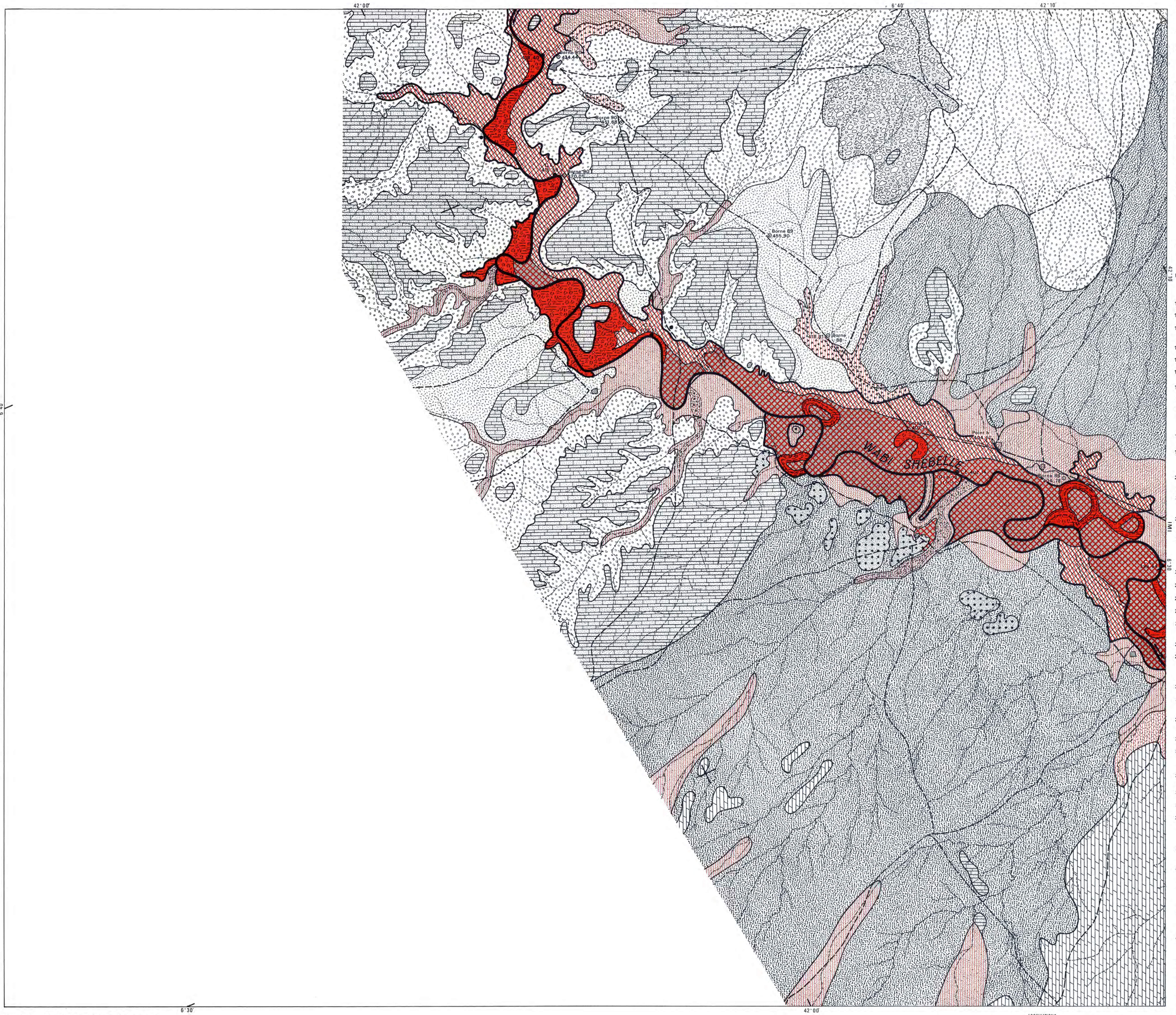
V

SOILS MAP - CARTE DES SOLS

Lower Valley - Basse Vallée

IMI WEST

JANUARY 1973
MAP N° 11



Planimetric sketch executed from the mosaics of 1964.67 aerial photos.
Esquisse planimétrique executée d'après les mosaïques photographiques de 1964.67.

INDEX SHEET

IMI WEST 11	IMI 10	IMI EAST 9	MADISO 8	GODE WEST 7	GODE 6	GODE EAST 5	KELAFO 4	MUSTAHIL WEST 3	MUSTAHIL 2	BURKUR 1

Limits of irrigable soils - 1st Class
Limite des sols irrigables - Classe 1

A — Indication of large irrigable zones
Indication des grandes zones irrigables

Scale 1:50 000 approximate

Mile 1 ¾ ½ ¼ 0 1 2 3 Miles
M 1000 500 0 1 2 3 4 5 Km.

Fa — Flooded area (highly) / *Zone fortement inondable*
C.E. — Water level / *Cote d'eau*
⊙ — Bench-mark / *Boulon, borne*

ABREVIATIONS

m.S.	Medium sand	L.	Loam
sm	*sableux à sables moyens*	*stf*	*sableux à sables très fins*
m.f.S.	Medium and fine sand with predominance of medium sand	S.i.L.	Silty loam
smsf	*sableux à sables moyens et sables fins*	*stfl*	*sablo-limoneux à sables très fins*
f.S.	Fine sand	C.L.	Clay loam
sf	*sableux à sables fins*	*stfa*	*sablo-argileux à sables très fins*
c.m.S.	Coarse and medium sand with predominance of coarse sand	S.i.C.L.	Silty clay loam
sgsf	*sableux à sables grossiers et sables fins*	*la*	*limono-argileux*
f.c.S.	Fine and coarse sand	C.S.i.C.	Clay - Silty clay
sfsg	*sableux à sables fins et sables grossiers*	*astfl*	*argilo-sablo-limoneux à sables très fins*
f.m.S.	Fine and medium sand	S.i.C.	Silty clay
sfsm	*sableux à sables fins et sables moyens*	*al*	*argilo-limoneux*
S.L.L.	Sandy loam to loam	C.	Clay
sfstf	*sableux à sables fins et sables très fins*	*a*	*argileux*
S.C.L.	Sandy clay loam		
sfa	*sablo-argileux à sables fins*		

SOILS FEATURES FAVOURING IRRIGATION
APTITUDES DES SOLS A L'IRRIGATION

1st CLASS - VERY SUITABLE SOILS FOR IRRIGATION
CLASSE I - SOLS TRES FAVORABLES A L'IRRIGATION

I A - for all tropical crops in arid zone.
pour toutes cultures tropicales de zone aride.

- I A d s: 24, 25, 26
- I A D S: 23, 27, 28, 29

I B - for tropical fruit-trees, citrus, pine-apples, tomatoes (juice) vegetables, maize, sorghum, wheat, groundnuts, other oilseeds, forages (graminea).
pour arbres fruitiers tropicaux, agrumes, ananas, tomates (jus), cultures légumières, maïs, sorgho, blé, arachide, autres oléagineux, graminées fourragères.

- I B d s: 30, 32, 33, 34
- I B D S: 31

I C - for sugar-cane, cotton, artificial pastures, maize, sorghum, wheat, textile fiber plants, oilseeds.
pour canne à sucre, coton, pâturages artificiels, maïs, sorgho, blé, plantes à fibres, plantes à huile.

- I C D s m: 9, 10, 12, 13, 14, 15, 17, 39, 40, 42

I D_A - for sugar-cane, coton, hill rice.
pour canne à sucre, coton, riz pluvial.

- I D_A D S m: 11, 16, 48, 49

2nd CLASS - LOW SUITABILITY FOR IRRIGATION
CLASSE II - SOLS PEU FAVORABLES A L'IRRIGATION

II B - possible crops : tropical fruit-trees, citrus, pine-apples, tomatoes (juice) vegetables, maize, sorghum, wheat, groundnuts, other oilseeds.
cultures possibles : arbres fruitiers tropicaux, agrumes, ananas, tomates (jus), cultures légumières, maïs, sorgho, blé, arachide, autres oléagineux.

- II B d m: 36, 37, 38

II C - possible crops : sugar-cane, cotton, artificial pastures, maize, sorghum, wheat, textile fiber plants.
cultures possibles : canne à sucre, coton, pâturages artificiels, maïs, sorgho, blé, plantes à fibres textiles.

- II C D S m: 41, 47
- II C D S G M: 44, 45, 46
- II C D S P: 50

3rd CLASS - UNSUITABLE FOR IRRIGATION
CLASSE III - SOLS NON IRRIGABLES

- III Y: 8
- III R U: 1, 2, 4
- III R T: 3, 5, 7, 18, 19, 22, 35, 43
- III U: 6
- III W: 20, 21

EXPLANATION OF THE SYMBOLS
SIGNIFICATION DES SYMBOLES

Factors changing the quality of the soils suitable for irrigation.
Facteurs altérant les qualités des sols irrigables.

- **d** Slight drainage necessary / *Drainage léger nécessaire*
- **D** Drainage necessary on a larger scale / *Drainage important nécessaire*
- **s** Weak salinity in the depth / *Salure faible en profondeur*
- **S** High salinity affecting the whole soil. / *Salure forte affectant l'ensemble du sol*
- **G** Fine non-clayey texture unsuitable for irrigation / *Granulométrie fine non argileuse défavorable à l'irrigation*
- **m** Slighty broken micro-relief requiring very slight leveling / *Microrelief peu uniforme nécessitant des planages très légers*
- **M** Broken micro-relief requiring a great deal of leveling / *Microrelief peu uniforme necessitant des planages importants*
- **P** Depth of the soil less than 1 m / *Profondeur du sol inférieure à 1 m*

Symbols concerning non irrigable soils.
Symboles concernant les sols non irrigables.

- **R** Abundant coarse elements / *Eléments grossiers abondants*
- **T** Steep slopes / *Pentes fortes*
- **U** Superficial limestone or gypsum flags / *Dalles calcaire ou gypseuse superficielles*
- **W** Depth of soil less than 50 cm / *Profondeur du sol inférieure à 50 cm*
- **Y** Dunes / *Dunes*

N

LEGEND OF THE SOILS MAP
LEGENDE DE LA CARTE PEDOLOGIQUE

WEAKLY DEVELOPED SOILS *SOLS PEU EVOLUES*
XEROSOLS *XERIQUES*
GYPSEOUS SOILS Derived from marl and gypsum
GYPSEUX Issus des marnes gypseuses

1 Yellowish-gray soils L. with superficial gypsum flag : LARGE FLATS (IMI, KELAFO, MUSTAHIL, BURKUR).
Sols gris-jaune stf en place à dalle de gypse superficielle GRANDS FLATS : IMI, KELAFO, MUSTAHIL, BURKUR.

2 Yellowish-gray soils SiL. with a gypsum flag at 50 cm depth on COLLUVIA : LARGE FLATS (IMI, KELAFO, MUSTAHIL, BURKUR).
Sols gris-jaune stfl à dalle de gypse enterrée à 50 cm sur COLLUVIONS : GRANDS FLATS (IMI, KELAFO, MUSTAHIL, BURKUR)

NON CLIMATIC SOILS *NON CLIMATIQUES*
LITHIC ERODED SOILS WITH POWDERY LIME Derived from marl and gypsum
SOLS D'EROSION LITHIQUES A CALCAIRE DIFFUS Issus des marnes gypseuses

3 Yellowish-gray soils SiL. with superficial gypsum flag : LOWER HILLS.
Sol gris-jaune stfl en place à dalle de gypse superficielle : COLLINES BASSES.

4 Whitish-yellow soils L. shallow with gypsum flag on COLLUVIA : DEBRIS-SLOPE of the LOWER HILLS.
Sols jaune-blanc stf à dalle de gypse peu profonde sur COLLUVIONS : DEBRIS-SLOPES sous les COLLINES BASSES.

Derived from limestone *Issus des calcaires*

5 Yellowish-red soils L to CL, with limestone fragments and calcareous nodules on COLLUVIA : TALUS below the BLUFF of the LIMESTONE PLATEAUS.
Sols rouge-jaune stf à stfa à debris et nodules calcaires sur COLLUVIONS. TALUS sous les CORNICHES des PLATEAUX CALCAIRES.

6 Red soils SiL with gypsum flag at 20 cm depth on COLLUVIA : GODE area (DEBRIS SLOPE) and FERFER area (PLATEAUS).
Sols rouges stfl à dalle de gypse à 20 cm de profondeur sur COLLUVIONS environs de GODE (DEBRIS-SLOPE) et de FERFER (PLATEAUX).

Derived from basalts *Issus des basaltes*

7 Pale-brown soils SL to L. very stony on WEATHERED Basalt BOULDERS : HILLS.
Sols brun-clair sf à stf très caillouteux sur ALTERATION en BOULE des basaltes : COLLINES.

SOILS DEVELOPED ON WIND BLOWN MATERIAL WITH POWDERY LIMESTONE.
SOLS D'APPORTS EOLIENS A CALCAIRE DIFFUS

8 Yellow soils SL to L. on DUNES : GODE area.
Sols jaune sf à stf sur DUNES : environs de GODE.

VERTISOLS AND VERTIC SOILS *VERTISOLS ET SOLS VERTIQUES*
WITH CURVED STRUCTURE *A STRUCTURE ARRONDIE*
BROWN OR REDDISH BROWN VERTISOLS WITH POWDERY LIME AND POWDERY GYPSUM IN THE DEPTH.
VERTISOLS BRUNS A BRUN-ROUGE A CALCAIRE DIFFUS ET CRISTAUX DE GYPSE EN PROFONDEUR
On RED-BROWN oued ALLUVIA derived from limestone
Sur ALLUVIONS BRUN-ROUGE d'oued issues des calcaires

9 Reddish-brown vertisols, grumosolic on 40 cm C. to SiC with powdery gypsum at 100 cm depth, easily flooded : oued Bu-Y ALLUVIA.
Vertisols brun-rouge grumosoliques sur 40 cm a. à al à cristaux de gypse vers 100 cm, inondables : ALLUVIONS de l'oued Bu-Y.

On BROWN oued ALLUVIA derived from basalts
Sur ALLUVIONS BRUNES d'oued issus des basaltes

10 Brown to red vertisols, grumosolic on 40 cm C. to SiC, with powdery gypsum at 40 cm depth, easily flooded : oued ALLUVIA : North West GODE area.
Vertisols bruns à rouges grumosoliques sur 40 cm a. à al. à cristaux de gypse à plus de 40 cm, inondables : ALLUVIONS d'oued : Nord Ouest GODE.

On BROWN ALLUVIA of the Wabi Shebelle *Sur ALLUVIONS BRUNES du Wabi Shebelle*
GODE - IMI series. *Séries IMI-GODE*

11 Brown vertisols grumosolic on 30 cm C. with little powdery gypsum below 60 cm, easily flooded.
Vertisols bruns grumosoliques sur 30 cm a. quelques cristaux de gypse à partir de 60 cm, inondables.

12 Brown vertic soils grumosolic on 30 cm C. little powdery gypsum below 30 cm.
Sols bruns vertiques grumosoliques sur 30 cm, a. quelques cristaux de gypse à partir de 30 cm.

13 Brown vertic soils grumosolic on 20 cm SiC. to C. with powdery gypsum in depth.
Sols bruns vertiques grumosoliques sur 20 cm stfl à a. à cristaux de gypse en profondeur.

KELAFO - MUSTAHIL - BURKUR series. *Séries KELAFO-MUSTAHIL-BURKUR*

14 Brown vertisols, grumosolic on 30 cm SiC to C. with powdery gypsum below 90 cm, seldom flooded.
Vertisols bruns grumosoliques sur 30 cm astfl à a. avec cristaux de gypse à plus de 90 cm. faiblement inondables.

15 Reddish-brown vertisols, grumosolic on 20 cm C. with powdery gypsum below 100 cm (KELAFO only).
Vertisols brun-rouge grumosoliques sur 20 cm a. avec cristaux de gypse à plus de 100 cm (KELAFO seulement).

16 Brown vertisols, grumosolic on 30 cm C. with powdery gypsum below 80 cm, very easily flooded (MUSTAHIL plain).
Vertisols bruns grumosoliques sur 30 cm a. avec nombreux cristaux de gypse à plus de 80 cm, fortement inondables : (plaine de MUSTAHIL).

17 Brown vertic soils, grumosolic on 20 cm C. with powdery gypsum below 80 cm, seldom flooded (SHEBELLE plain).
Sols bruns vertiques grumosoliques sur 20 cm a. avec cristaux de gypse à plus de 80 cm, faiblement inondables : (plaine de SHEBELLE).

SOILS WITH CALCAREOUS DIFFERENCIATION
SOLS A DIFFERENCIATION CALCAIRE
WITHOUT MELANIC HORIZON *SANS HORIZON MELANIQUE*
WITH POWDERY LIME : MODAL *A CALCAIRE DIFFUS : MODAUX*
COLLUVIA derived from limestone *COLLUVIONS issues des calcaires*

18 Yellowish-red soils fS with many limestone debris and pebbles : DEBRIS SLOPE below the LIMESTONE PLATEAUS (GODE to BURKUR).
Sols rouge-jaune sf riches en débris calcaires peu émoussés : DEBRIS-SLOPE sous les PLATEAUX CALCAIRES (GODE à BURKUR).

19 Yellowish-red soils mfs, with limestone and basaltic pebbles : HILLOCKS of the LARGE ALLUVIAL FANS (IMI).
Sols rouge-jaune smsf à galets calcaires et basaltiques : PETITS MAMELONS des GRANDS CONES de DEJECTION (IMI).

WITH NODULES *A AMAS ET NODULES*
Derived from limestone *Issus des calcaires*

20 Yellowish-red soils SiL to L. with calcareous nodules : LIMESTONE PLATEAUX (GODE to BURKUR).
Sols rouge-jaune stfl à stf. à nodules calcaires en place : PLATEAUX CALCAIRES (GODE à BURKUR).

Derived from sandstone *Issus des grès*

21 Red soils SL-L with calcareous nodules : LOWER PLATEAUS (IMI).
Sols rouges sfstf à amas et nodules calcaires, en place : BAS PLATEAUX (IMI).

On ancient oued ALLUVIA *Sur anciennes ALLUVIONS d'oued*

22 Yellowish-red soils CmS, with calcareous pebbles often cemented in conglomerate near the surface : HILLOCKS in the LARGE ALLUVIAL FANS (GODE).
Sols rouge-jaune sgsf à galets calcaires souvent soudés en conglomérat à faible profondeur : MAMELONS des GRANDS CONES de DEJECTION (GODE).

SOILS WITH GYPSEOUS DIFFERENCIATION
SOLS A DIFFERENCIATION GYPSEUSE
WITH POWDERY GYPSUM : MODAL *A GYPSE DIFFUS : MODAUX*
On BROWN ALLUVIA of the Wabi Shebelle
Sur ALLUVIONS BRUNES du Wabi Shebelle
IMI - GODE series *Séries IMI-GODE*

23 Brown soils SiC weakly organic/ls (ANCIENT MEANDERS of the Wabi Shebelle.
Sols bruns al. faiblement humifères/st : (MEANDRES MORTS du WABI SHEBELLE).

24 Brown to yellowish-brown soils SiL to SiC in depth.
Sols bruns à brun-jaune stfl à al. en profondeur.

25 Brown soils C/fs (GODE).
Sols bruns a./sf (GODE).

26 Brown soils SiL to C. in depth (GODE).
Sols bruns stfl à a. en profondeur : (GODE).

27 Brown soils CL (GODE).
Sols bruns stfa (Gode).

South KELAFO - MUSTAHIL - BURKUR series *Séries Sud KELAFO-MUSTAHIL-BURKUR*

28 Brown soils C/brownish-yellow L. seldom flooded to easily flooded (KELAFO).
Sols bruns a./jaune-brunâtre stf. peu inondables à inondables (KELAFO).

29 Brown soils SiL to C. in depth.
Sols bruns stfl à a. en profondeur.

On BROWNISH - YELLOW ALLUVIA of the Wabi Shebelle
Sur ALLUVIONS JAUNE-BRUN du Wabi Shebelle
IMI - North GODE series *Séries IMI-Nord GODE*

30 Brownish-yellow soils fcS : BANKS of the Wabi Shebelle.
Sols jaune-brun à sfsg : BOURRELETS de BERGE du Wabi Shebelle.

31 Brownish-yellow fS/C.
Sols jaune-brun sf/a.

IMI - North GODE - KELAFO series *Série IMI-Nord GODE-KELAFO*

32 Brownish-yellow soils SiL to fS : RECENT or ANCIENT BANKS of the Wabi Shebelle.
Sols jaune-brun stfl-sf : BOURRELETS de BERGE du Wabi Shebelle ACTUELS ou ANCIENS.

South KELAFO - MUSTAHIL - BURKUR series *Séries Sud KELAFO-MUSTAHIL-BURKUR*

33 Brownish-yellow soils SiL to fmS in depth : BANKS of the Wabi Shebelle.
Sols jaune-brun stfl à sfsm en profondeur : BOURRELETS de BERGE du Wabi Shebelle.

34 Brownish-yellow soils SiL to SiL-C in depth.
Sols jaune-brun stfl à stfla en profondeur.

On REDDISH - YELLOW oued ALLUVIA *Sur ALLUVIONS JAUNE-ROUGE des oueds*

35 Reddish-yellow soils fS to L. with pebbles in the depth often salty : ALLUVIAL FANS : HIGHER position (GODE to BURKUR).
Sols jaune-rouge sf à stf à galets en profondeur, souvent salés : ALLUVIONS des CONES de DEJECTION : position HAUTE (GODE à BURKUR).

36 Reddish-yellow soils L. and mS ALLUVIAL FANS (IMI).
Sols jaune-rouge stf et sm ALLUVIONS des CONES de DEJECTION (IMI).

37 Reddish-yellow soils SiL : RECENT ALLUVIA of the larger oueds.
Sols jaune-rouge stfl : ALLUVIONS RECENTES des grands oueds.

38 Reddish-yellow soils fS-SiL : RECENT ALLUVIA of the larger oueds (MADISO).
Sols jaune-rouge sf-stfl : ALLUVIONS RECENTES des grands oueds (MADISO).

WITH POWDERY GYPSUM : VERTIC *A GYPSE DIFFUS : VERTIQUES*
On BROWN ALLUVIA of the Wabi Shebelle *Sur ALLUVIONS BRUNES du Wabi Shebelle*
North GODE serie *Série Nord GODE*

39 Brown soils with SiC predominance.
Sols bruns à dominance al.

GODE - KELAFO serie *Série GODE-KELAFO*

40 Brown soils C.
Sols bruns a.

On YELLOWISH - RED oued ALLUVIA *Sur ALLUVIONS ROUGE-JAUNE des Oueds*

41 Yellowish-red soils SiL to C. : RECENT ALLUVIA of the smaller oueds.
Sols rouge-jaune stfl à a. : ALLUVIONS RECENTES des petits oueds.

On Wabi Shebelle YELLOWISH - BROWN ALLUVIA over RED basaltic ALLUVIA
Sur ALLUVIONS BRUN-JAUNE du Wabi Shebelle recouvrant les ALLUVIONS ROUGES basaltiques.

42 Yellowish-brown soils SiL/red C. (GODE).
Sols brun-jaune stfl/rouge a. : (GODE).

WITH GYPSEOUS CRUST : MODAL *ENCROUTES : MODAUX*
From RED COLLUVIA derived from basalts *Sur COLLUVIONS ROUGES issues des basaltes*

43 Red soils SCL to C. with gypseous crust at 60 cm depth : DEBRIS SLOPE below the basaltic HILLS (GODE North GODE).
Sols rouges sfa à a. à croûte de gypse vers 60 cm : DEBRIS-SLOPE des COLLINES de basalte (GODE-Nord GODE).

From YELLOWISH - RED oued ALLUVIA *Sur ALLUVIONS ROUGE-JAUNE des oueds*

44 Yellowish-red soils L. to SiL. with gypsum crust at 70 cm depth, salty in depth : ALLUVIAL FANS LOWER position (GODE).
Sols rouge-jaune stf à stfl, à croûte de gypse vers 70 cm, salés en profondeur : ALLUVIONS des CONES de DEJECTION position BASSE. (GODE).

45 Yellowish-red soils SiL to SiCL, with gypsum crust at 70 cm depth, salty near the surface : ALLUVIAL FANS LOWER position (GODE to BURKUR).
Sols rouge-jaune stfl à la. à croûte de gypse à 70 cm, salés à faible profondeur : ALLUVIONS des CONES de DEJECTION position BASSE (GODE à BURKUR).

46 Yellowish-red soils L. to SiC, with gypsum accumulation " SAND ROSE " type : ALLUVIAL FANS LOWER position (IMI-GODE).
Sols rouge-jaune stf à al. à accumulation de gypse sous forme de ROSE des SABLES : ALLUVIONS des CONES de DEJECTION position BASSE (IMI-GODE).

On Wabi Shebelle YELLOWISH - BROWN ALLUVIA over YELLOWISH - RED oued ALLUVIA
Sur ALLUVIONS BRUN-JAUNE du Wabi Shebelle recouvrant les ALLUVIONS ROUGE-JAUNE des oueds

47 Yellowish-brown soils SCL/yellowish-red C. (GODE).
Sols brun-jaune sfa/rouge-jaune a. (GODE).

HYDROMORPHIC SOILS *SOLS HYDROMORPHES*
MEDIUM ORGANIC *MOYENNEMENT ORGANIQUES*
HUMIC GLEY WITH POWDERY LIME *HUMIQUES A GLEY A CALCAIRE DIFFUS*
On BROWN ALLUVIA of the Wabi Shebelle *Sur ALLUVIONS BRUNES du Wabi Shebelle*
SHEBELLE plain serie *Série de la plaine de SHEBELLE*

48 Brown soils C. very easily flooded (PAPYRUS area).
Sols bruns a. fortement inondables (zone à PAPYRUS).

MUSTAHIL plain serie *Série de la plaine de MUSTAHIL*

49 Brown soils C. very easily flooded (GRAMINEA area).
Sols bruns a. fortement inondables (zone à GRAMINEES).

SODIC SOILS *SOLS SODIQUES*
WITH NON DEGRADED STRUCTURE *A STRUCTURE NON DEGRADEE*
SALINE SOILS WITH SALT EFFLORESCENCES *SOLS SALINS A EFFLORESCENCES SALINES*
On RED oued ALLUVIA *Sur ALLUVIONS ROUGES d'oued*

50 Red soils SiL to C. with gypsum flag at medium depth (BURKUR-FERFER).
Sols rouges stfl à a. à dalle de gypse à moyenne profondeur (BURKUR-FERFER).

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NATIONAL WATER RESOURCES COMMISSION

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V

Note on the Soil Map of the Lower Valley of the Fafen

Scale : 1/60.000

Delineation of flood zones

JUNE 1973

SIX MAPS ANNEXED

THE SOILS OF THE FAFEN VALLEY

MAP N° 1	NORTH SHEKOSH
MAP N° 2	SOUTH SHEKOSH
MAP N° 3	NORTH KEBRI-DEHAR
MAP N° 4	KORAHE PLAIN AND SOUTH KORAHE
MAP N° 5	DOBAWEIN PLAIN
MAP N° 6	YOGLE PLAIN - Last depression of Fafen

TABLE OF CONTENTS

Pages

This pedologic note is a summary of the studies carried out by the Soil Science Division of the WABI SHEBELLE Project in the Lower Valley of the Fafen.

The Scientific Management of Studies was assumed by M. Pierre SEGALEN, "Inspecteur des Recherches" from O.R.S.T.O.M. (France) and Consultant in Ethiopia.

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- Jean Olivier JOB, "Ingénieur Chimiste" from O.R.S.T.O.M. (France) and chief of the Laboratory for Soil Analyses.

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A soil map at 1/60.000 of the Lower Valley of the Fafen delineates the flood zones located between the Jerer-Fafen junction and Iglole, thus enabling to determine the agro-pastoral potential.

I. NATURAL ENVIRONMENT

A. CLIMATOLOGY

This zone is characterized by a sub-arid climate of Ogadenian type.

1. Rainfall

Annual rainfall is approximately 300 mm or less, distributed in two rainy seasons (characteristic of equatorial latitudes), the most important being in march-april-may and the other in october-november. The rainfall data of Kebri-Dahar station, for 8 observation-years, gives a mean annual rainfall of 277 mm distributed as follows :

Month	J	F	M	A	M	J	Jt	A	S	O	N	D	Total in mm
monthly %	0.7	0.1	10.9	26.5	19.5	0	0.4	0.1	2.5	27.9	9.6	0.9	277
			1st rainy season							2nd rainy season			

Though the percentage of rainfall for each month seems correct whatever the importance of total rainfall may be in the region, on the other hand, inter-annual variations are sometimes considerable. The highest and lowest rainfall data respectively correspond to more than 400 mm and less than 100 mm. But the recurrence of such unusual years is not known.

2. Temperatures

Another characteristic of equatorial latitudes is the very small inter-monthly temperature variation, the difference being only 1°9 between the "coolest" month (July) and the hottest month (February). The mean annual temperature is 26°,4.

Month	J	F	M	A	M	J	J	A	S	O	N	D	Mean annual Temperature
Temp.	26.1	26.9	27.8	26.7	26.5	26.8	25.0	26.1	26.9	26.6	26.0	25.9	26.4

3. Winds and whirlwinds

Strong winds blow regularly in this zone as in all Lower-Ogaden and a still atmosphere is seldom observed. The highest winds blow from the South West in July and August.

During the warm hours of the day ascending currents give rise to huge dust whirlwinds (sometimes several hundred meters high) which cover the plain.

B. VEGETATION

The vegetation on the outskirts of the Fafen Valley is very distinct from that of the valley.

1. Vegetation on the outskirsts of the valley :

On limestone plateaux and on foothills grows a more or less dense thicket of *Acacia spp*. and *Commiphora* and a discontinuous gramineae carpet.

2. Vegetation in the Fafen valley

It is mainly herbaceous with a predominance of gramineae forming a loose carpet in non-flooded zones and growing denser as the flood intensity increases.

In strongly-flooded zones or in areas where a ground water table exists near the surface, a usually dense shrubby vegetation grows with predominant *Acacia mellifera*.

C. GEOLOGY

The Lower Valley ot the Fafen is framed by limestone hills to the North and gypsum hills to the South, the altitude of which does not exceed 50 m compared to the general level of the plain.

Though the marine sedimentary series seem to be horizontal, they slightly dip from the North-West to the South-East, the stratigraphic succession being as follows, i.e. :

- Kebri Dahar limestone : Jurassic
- Main gypsum formation : Upper Jurassic and Lower Cretaceous
- Mustahil limestone : Berriasian - Lower Cenomanian
- Belet Uen limestone : Cenomanian
- Gesoma sandstone : Cretaceous

The limits between these various series are distinct except in the case of Kebri Dahar limestone and of the main gypsum formation.

A very distinct discontinuity in the Kebri Dahar latitude may be observed : the Kebri Dahar limestone seems to sink suddenly and the main gypsum formation appears instead. This is probably due to the existence of a fault at this level.

From the geologic point of view, the alluvial deposits of the Fafen or of temporary rivers may be classed as quaternary sediments.

The stratigraphic succession above mentioned is not wholly identical from the North to the South of the Valley :

North of Kebri Dahar, the hills consist only of Kebri Dahar limestone forming white to grey beds. In the Shekosh-Bircot region, very hard, brownish to black limestone intercalations may be observed. These hills present very steep slopes and are broken up by the hydrographic system of temporary rivers.

South of Kebri Dahar, the hills are constituted by the main gypsum formation which includes thick marl layers intercalated with gypsum beds. The relief is not so pronounced as in the North but, in the Iglole region, the higher parts of hills are crowned with the thin Mustahil limestone formation to which is due their tabular aspect.

East of the Dobowein plain, the vast and very low limestone plateaux consist of Belet Uen limestone.

In this zone, Gesoma sandstone only appears in the form ot reddish weathered material either of alluvial or colluvial origin or wind-transported. They distinctly outcrop to the East near Shilavo.

D. GEOMORPHOLOGY

1. Formation of the Lower Valley of the Fafen

The Lower Valley of the Fafen is apparently due to the slight subsidence of a sedimentary block along a N.W. S.E., fault line which is probably contemporary with the fault which caused the formation of the Lower Valley of the Wabi Shebelle. This assumption rests on the following features, i.e. :

- The valley is rectilineal from Shekosh to Fanhad and from Fanhad to the Dobowein plain.

- The presence to the South of the Kebri Dahar "unconformity" with the three large plains or "depressions" of Korahe, Dobowein and Iglole.

- The presence of intrusive basalt, East of Korahe and West of Dobowein (which does not appear on the map as it is located just outside the limits of the mapped area).

2. Sedimentation in the Lower Valley of the Fafen

Consecutive to this land subsidence, a considerable recurrence of erosion occurred in the upstream part as well as an accelerated filling-in in the downstream part. But the drainage system of the Lower Valley of the Fafen is divided into two :

- the Fafen
- the Fafen "tributaries" (temporary rivers) which are not real tributaries as they seldom reach the river but end in the outskirts forming detrital fans.

Consequently, two distinct types of sedimentation are observed :

- the brown Fafen alluvial deposits derived from the weathered basalt, limestone and granite of the High Plateaus mainly spreading in the Korahe and Dobowein plains owing to the meandering of the river in these zones.

- the reddish alluvial deposits of temporary rivers derived from reddish weathered local limestone and which occupy all the valley between Fanhad and Shekosh. In this zone, the flow of temporary rivers is strong and may transport a greater quantity of material than the deeply embanked Fafen. Conversely, to the South, the temporary rivers being shorter have a weaker flow and their alluvial deposits are less extended and often limited to detrital fans in the outskirts of the Valley.

E. HYDROLOGICAL REGIME OF FLOODS

The independent characteristics of the drainage systems should result into different hydrological conditions of floods.

However, the problem is more complex, the Fafen runoff being slowed down since it supplies water to the deficient alluvial water tables which largely extend from Fanhad to Kebri Dahar. This accretion occurs during rainfall in the upstream part of the basin which precedes rainfall in the downstream part.

Runoff in the Fafen is therefore observed at the same period as in temporary rivers, during the rainy months in Ogaden : April-May and October-November.

Both drainage systems communicate, though indirectly, through the alluvial water-table.

Flood intensity and duration

It is difficult to get an accurate idea of the intensity and duration of floods since observations bearing on long periods are lacking. Nonetheless, taking into account the aspect of vegetation, floods may be classed according to their "value" without any important mistake being made.

The classification used on the map is as follows, i.e. :

- Fafen floods :

  . very highly flooded zones
  . highly flooded zones
  . easily flooded zones
  . scarcely flooded zones

- Floods of Fafen "tributaries"

  . flooded zones (large temporary rivers)
  . flooded zones (small temporary rivers)

The quantitative knowledge of the depth of runoff and of the flood duration could be acquired later if needed.

As an indication, the hydrological data concerning the annual volume of water for Kebri Dahar are given below, i.e. :

Year	1969	1970	1971
Annual Volume : m3	18.921.600	36.266.400	22.075.200

II. SOIL-FORMING PROCESS

The sub-arid climate of this region with a mean rainfall under 300 mm distributed in two rainy seasons and with intense evaporation linked to the latitude and permanent wind, conditions :

- a vegetation characterized by its reduced growth and short vegetative cycle, and consequently, a very small accumulation of organic matter which is soon mineralized.

- a frequent accumulation of soluble salts, especially gypsum, in the soil.

However, as soon as the pedo-climate becomes more humid, as in flooded zones, the following features may be observed, i.e. :

- vertic characters appear in clayey soils and a thick grumosolic horizon always exists.

- the content of organic matter increases but is never greater than 3 percent, even in highly flooded zones.

A. SALT MIGRATION ACCUMULATION

1. Limestone

The entire plain and its surroundings consist of limestone. Two types of calcareous differenciation may be observed : powdery lime and calcareous heaps and nodules.

1.1. Powdery lime :

Limestone remains powdery and invisible in the alluvial deposits although calcium carbonate attains more than 20 percent.

1.2. Calcareous accumulations and nodules :

On the hills surrounding the valley, limestone is well individualized in the form of numerous and hard calcareous accumulations and nodules resting on the bed-rock.

These facts bring about the following observations :

- the climate is not at present suitable for the migration and accumulation of calcium carbonate, despite the large quantity of total limestone existent in the soil.

- the calcareous nodules of plateaux are probably remnants left by a previous more humid climate.

2. Gypsum

Gypsum being far more soluble than limestone, it migrates and accumulates in a climate of this type.

However, gypsum sources are not so abundant as in the Lower Valley of the Wabi Shebelle where the environment wholly consists of gypsum. Consequently, the gypsum accumulation is low in most soils.

2.1. Powdery gypsum

This form of accumulation of crystals, mainly of saccharoid type, not linked to one another or cemented in very small friable heaps, may be observed in the Fafen alluvia as well as in those of temporary rivers.

2.2. Gypsum crusts

Real gypsum crusts are only observed in the last spreading zone of the Fafen where all the surrounding hills consist of gypsum. This crust is composed of gypsum crystals or heaps cemented together. It is often cavernous with infiltrations of fine and always friable soil.

In some places, on the banks of the Fafen (for instance at the Kebri Dahar bridge), gypsum crusts may also be observed, but in this case, they are only superficial formations and do not extend laterally.

3. Sodium chloride

This is the most soluble salt and it consequently moves easily under a subarid climate. Yet, no saline efflorescences or horizons are ever seen in the soils.

As in the case of gypsum, this is due to the lack of considerable sources of sodium chloride. Besides, soil is not alkalinized because of the large quantity of calcium on the absorbing complex.

B. VERTIC CHARACTERS

Vertic characters appear in clayey soils of montmorillonitic type liable to be flooded but which also present pronounced drying up periods. They are characterized by :

- the presence, when dry, of vertical shrinkage cracks delimiting a prismatic structure with distinct (vertisols) or not very distinct (vertic soils) slickensides.

- a surface horizon, with a very divided-up granular or crumb structure, about 25 cm deep (grumosolic horizon).

C. ACCUMULATION OF ORGANIC MATTER

1. In non-flooded zones,

that is to say in soils where the pedo-climate is only affected by regional climatic conditions, a humic surface horizon is not easily distinguished. The content of organic matter is approximately 1 percent in the first 20 centimeters.

2. In flooded zones,

The content of organic matter increases together with the duration of flooding.

Vertisols present 2 to 2,5 percent of organic matter for 60 cm about, and hydromorphic soils, scarcely more than 2,7 percent for 60 cm.

The C/N of organic matter is approximately 10 and characterizes a calcic humus which is easily mineralized and which consequently soon disappears if it is not reconstituted, for instance, for cultivation needs.

III. DESCRIPTION OF SOILS

Soils are described in the same order as in the soil map at 1/60.000. Besides, soil series presenting an agricultural or pastoral interest are studied in detail.

A. CLASS OF SOILS IN EARLY STAGE OF DEVELOPMENT

This class is only represented here by the sub-class of non-climatic soils in early stage of development with two groups which are differenciated by their forming processes.

- erosion soil-group
- wind-transported soil group

Erosion soil-group

Not very thick erosion soils with numerous coarse elements (especially on limestone) develop in steeply sloping zones or on glacis where sheet erosion is considerable.

The vegetation consists of small *Acacia* and *Commiphora*, the size and density of which vary according to the type of soils. The graminea carpet is discontinuous.

The soil mass is calcareous and powdery lime may be observed in fine earth.

1. <u>Yellowish-red soils, very fine silt to very fine sandy clay</u>

These soils develop at the foot of the plateaus surrounding the valley and also on narrow-topped hills which are affected by very strong erosion.

The vegetation consists of small and usually dense *Acacia* and *Commiphora* with a discontinuous graminea carpet.

These soils are very stony with limestone fragments of various sizes as well as calcareous nodules due to the weathering of calcareous accumulation layers of plateaus.

The pastoral aptitudes of these soils are not considerable even during the rainy season, owing the steepness of slopes.

2. <u>Yellowish-white superficial loam soils</u>

They exist on the tops and slopes of round gypsum hills located between the valley and the limestone plateaus, West of the Korahe plain.

The vegetation consists of a very loose thicket of small *Acacia* and *Commiphora* with a very discontinuous graminea carpet.

These are superficial soils. When fine earth exists, it consists of a thin yellowish-white gypsum powder resting directly on the gypsum slab which outcrops almost everywhere.

The pastoral fitness of these soils is relatively good during the rainy season.

3. <u>Yellowish-white not very deep loam soils</u>

They exist on colluvial deposits at the foot of gypsum hills West of Korahe and on the large gypsum flat of Iglole.

The vegetation consists of a relatively dense thicket of small *Acacia* and *Commiphora* with a discontinuous graminea carpet.

These soils are moderately deep : from 10 to 20 cm. The fine earth consists of colluvial powdery weathered gypsum resting directly on the gypsum slab in situ. The latter outcrops in places owing to the varying thickness of colluvial deposits, and may present sodium chloride efflorescences.

The pastoral fitness of these soils is moderate during the rainy season. Owing to their usually high salt content, and consequently, to the presence of grazing plants, they constitute pasture grounds which are sought for by livestock and wild animals.

Group of wind-transported soils

4. Yellow sandy soils

These soils develop on small areas all along the Valley, between Bircot and the Dobowein plain. The original material from the previously existing natural levees of the Fafen has often been transported by the wind and form small isolated round dunes never more than 2 to 3 meters high. Conversely, to the North of the Dobowein plain, a range of higher dunes (3 to 6 meters) may be observed.

Pastoral fitness :

A relatively dense bushy vegetation grows on these soils (except on the dunes of Dobowein plain) and the herbaceous carpet is usually dense and varied. These soils constitute good grazing-grounds during and after the rainy season.

B. VERTISOL CLASS

SUB-CLASS OF VERTISOLS WITH A DIVIDED STRUCTURE (GRUMOSOLS)

Vertisols are clayey soils the evolution of which is characterized by a predominance of montmorillonitic clay. The latter develops in a base-satured milieu which is liable to be weakly or moderately flooded but also presents very dry periods. These soils only exist in the lower zones of the Fafen Valley and in the most depressed areas of the detrital fans of temporary rivers.

The vertic features of vertisols are very pronounced in this region, for instance : broad vertical cracks delimiting a very weakly developed prismatic structure, slickensides on the prisms and a surface gilgaï micro-relief.

They are also characterized by the presence of a very thick crumb or granular surface horizon and consequently belong to the sub-class of vertisols with a divided structure or grumosols.

All these soils are carbonated but lime is not visible and only exists in a powdery form : this is the carbonated vertisol groups at the base.

of profiles, a gypsum individualization in the form of crystals may often be observed.

Carbonated group

5. Brown grumosolic vertisols ; silty loam to clay loam in the depth : easily flooded

These soils exist on the brown alluvial deposits of the Valley and spread on large areas South of Kebri Dahar. They are regularly flooded by the Fafen floods but the flood intensity which is considerable in the Kebri Dahar region and in the Korahe plain, decreases in the Dobowein plain though it is still important there.

Trees and shrubs grow in the Kebri Dahar and Maharato regions with a very dense herbaceous carpet.

In Dobowein plain, the vegetation is only herbaceous and not so dense.

Morphology

Profile N° 7-24, 3 km to the East of Maharoto.

A very dense vegetation of gramineae and tall Acacia in some places. Very pronounced gilgaï microrelief with large holes.

0-4 cm : Brown (10 YR R/3) ; clay ; well-developed medium to fine granular ; dry and loose ; numerous bits of straw ; distinct and rolling transition to :

4-35 cm : Brown (10 YR 5/3) ; clay and fine sand ; numerous small shrinkage cracks in all directions delimiting friable fragments and giving a fine granular pseudostructure ; generally dry and friable ; numerous rootlets ; gradual and uniform transition to :

35-150 cm and deeper: Brown (10 YR 5/3) ; clay ; 1 to 30 cm broad, big vertical shrinkage cracks delimiting very coarse prisms with distinct slickensides; generally relatively humid and compact ; few rootlets.

Physico-chemical characteristics

Soil Series	Depth cm	tex- ture	CO_3Ca %	Org.m. %	N ‰	C/N	pH	Conductivity of satur. extract mmhos/cm	Total P2 05 ‰
	0.5	SiL	28.8	1.2	0.70	10	8.4	2.8	2.17
	5.35	C	27.3	0.9	0.55	10	8.3	3.3	1.97
	35 +	C	28.8	0.8	0.43	11	8.3	2.9	1.97

These soils are brown with a clayey to heavy clayey texture and a small, silty loam superficial horizon.

They present a very divided-up structure in the first horizon and a less divided structure of granular type in the second. Both these horizons are grumosolic, which means that they remain friable when drying-up ("self-mulching" horizon). In the depth, the structure is gradually larger and coarsely prismatic with distinct slickensides and very wide shrinkage cracks. At this level, the soil turns very compact when dry. A noticeable difference between surface and deep horizons may therefore be observed and this is due to the variations of the structure and of the soil consistency only, and not of the texture. This characterizes grumosolic vertisols which are friable at the surface and compact in the depth.

The calcium carbonate content is medium and does not vary in the profile.

The content of organic matter is low but only decreases very slowly with the depth.

The nitrogen content is also low and C/N, approximately 10, reveals that humus is soon mineralized.

pH is alkaline but the conductivity of the saturation extract remains low. Soil is not alkalinized.

Total phosphorus is abundant.

The $\frac{\text{Total N}}{\text{Total phosphorus}}$ ratio is distinctly lower than 2 which shows an unbalance detrimental to nitrogen.

Cultural and pastoral fitness of soils

Vertisols have a very high water retention. The agricultural and pastoral potential depends for these types of soils on the intensity and duration of the Fafen floods.

In the Korahe plain, to the West, North and South of Maharato, strong floods are favourable to the growth of a very dense herbaceous carpet much grazed by livestock. However, small installations such as a partial diversion of the Fafen waters through pennate gullies would enable developing in a considerable way the cultivation of sorghum and especially of maize which is not damaged by birds. In this case, nitrogen carriers (ammonium nitrate and ammonium sulphate) should allow a large increase of the yield.

In the Dobowein plain, floods are not so considerable but the herbaceous carpet nevertheless remains quite dense. Grazing-grounds could be used during a longer period if floods were controlled for a better distribution of water in this large plain (see chap. IV A-1. 1-2).

6. Brown scarcely flooded clay grumosolic vertisols

These vertisols are located in slightly higher areas than for the previously described soils to which they are linked. They may be observed South of the Korahe plain and in the central part of the Dobowein plain.

They present the same morphological and physico-chemical characteristics as the vertisols of series 5, but they are scarcely flooded.

Their pastoral fitness is therefore much less considerable than for the preceding soils. The vegetation is herbaceous and continuous but very loose, with a mean height of 15 cm, and a very short vegetative cycle.

7. Reddish fine sandy clay grumosolic vertisols on alluvia of temporary rivers

These vertisols spread on all the Fafen Valley from Bircot in the North to the Fanhad hill in the South. All this zone is covered with the reddish alluvia of strong temporary rivers flowing from the East and West. Conversely, the Fafen is deeply embanked,hence flooding is only due to temporary rivers when rainfalls occur in this region.

Morphology

Profile 7-100, 3 km to the South of Shekosh.

Very dense vegetation with dry gramineae and tall Acacia mellifera in some places. Very pronounced gilgaï microrelief with large holes.

At the surface : 2 to 3 mm thick reddish-brown platy deposits ; silty-clay due to floods of temporary rivers.

0-20 cm : Brown (7,5 YR 5/4) ; clay ; well-developed, medium to fine granular ; dry and friable ; very dense graminea rootlets ; gradual and uniform transition to :

20-60 cm : Reddish-brown (5 YR 4/4) clay ; vertical, 0.5 to 2 cm broad shrinkage cracks, delimiting a mean prismatic structure with distinct slickensides ; friable prisms giving a well-developed mean subangular blocky sub-structure ; dry and scarcely compact ; dense graminea rootlets ; gradual and uniform transition to :

60-200 cm and deeper : Reddish-brown to red (2,5 YR 4/4 to 4/6) clay ; some vertical shrinkage cracks ; compact medium prismatic fragments with distinct slickensides ; generally relatively humid and compact ; many graminea rootlets.

Physico-chemical characteristics

Soil Series	Depth cm	Texture	CO_3Ca %	org. m. %	N ‰	C/N	pH	Conductivity of saturation extract in mmhos/cm 25°C	Total P2 05 %
6	0-20	C	47.0	2.7	0.9	17	7.8	1.8	1.6
	20-60	C	45.5	2.0	0.7	17	7.9	2.0	1.8
	60 +	C	42.5	1.0	0.4	15	8.5	4.0	1.7

These yellowish to reddish soils in the depth have a clayey to heavy clayey texture.

They present a very well-developed crumb structure in the surface horizon but it is still very divided-up down to about a 60 cm depth, conferring to these horizons a very friable character. Conversely, in the depth, the structure broadens and becomes prismatic and soil is very compact.

The calcium carbonate content is high and practically always the same throughout the profile.

The content of organic matter is medium and decreases very slowly with the depth.

The nitrogen content is low and C/N = 17 shows that humus is soon mineralized.

pH is scarcely alkaline in the surface but increases with the depth. However the conductivity of the saturation extract remains low and soil is not alkalinized.

The percentage of total phosphorous is high.

The $\frac{\text{Total N}}{\text{Total phosphorous}}$ ratio is approximately 2 and less than 2 at a small depth which reveals a slight unbalance detrimental to nitrogen and which will increase when soils are cultivated.

Cultural and pastoral fitness

A small proportion of these soils is now cropped to sorghum, particularly in the Shekosh region. Improving the efficaciousness of flooding due to temporary rivers by flood-control should allow extending cultivation zones for sorghum and even maize. Nitrogen carriers (ammonium nitrate and ammonium sulphate) would considerably increase the yield.

A more or less dense and much grazed graminea carpet stretches on the largest portion of the extension zone of these soils. Improving the quality and the length of grazing periods on these pastures depends, as in the case of crop-growing, on a better distribution in time of flood water.

C. SOIL-CLASS WITH A CALCAREOUS DIFFERENCIATION

This class includes soils the profiles of which are characterized by a redistribution of limestone. It is only represented here by the soil sub-class with a **pallid horizon**. It consequently includes soils with a too lightly-coloured upper horizon and a too weak content of organic matter to be considered as "melanic". The content of organic matter is generally less than

1 percent for 20 cm.

The two following sub-groups were observed on the field, i.e. :

- sub-group with powdery lime :

lime is not visible but fine earth reacts with hydrochloric acid.

- sub-group with accumulations and nodules :

lime is accumulated at a medium depth or in the depth and forms more or less hard heaps and nodules.

Soil sub-class with a pallid horizon

Soil-group with a powdery lime

8. Yellowish-red soils ; fine sand to loam ; rich in limestone fragments

These soils cover the glacis or "debris slopes" of the limestone hills surrounding the Valley and the heads of thalwegs of the small temporary rivers which flow down to the Fafen from Bircot to Iglole.

The vegetation of Acacia and Commiphora is sometimes dense and presents a discontinuous carpet of ligneous plants.

These soils are rich in coarse elements mainly consisting of weakly subangular and relatively coarse limestone elements which constitute approximately 80 % of the volume of soil.20 % is consequently composed of fine earth used by vegetation.

Pastoral fitness

The pastoral fitness is low during the dry season and medium during the rainy season.

9. Red soils : fine sand and loam to fine and coarse sand

These soils spread on the alluvial deposits of the large temporary rivers which are tributaries of the Fafen Valley from Bircot to Iglole.

The vegetation consists of usually scattered Acacia and Commiphora. The soil cover is very discontinuous and presents small woody plants and gramineae.

These are deep and well drained soils owing to their sandy texture.

Pastoral fitness of soils

It is not considerable even during the rainy season. Nevertheless, in the lower zones, suitable pastures with gramineae and small ligneous plants may be observed.

Group of soils with accumulations and nodules

This group includes two sub-groups :

- carbonated : the profile is wholly calcareous
- calcic : the profile is not calcareous except in the area where nodules are concentrated.

Sub-group of carbonated soils

10. Yellowish-red soils : loam to clay loam

These soils spread on the limestone plateaux stretching along the Fafen Valley from Bircot to Iglole.

These plateaux are relatively extended South of Kebri-Dahar but, in the Kebri Dahar-Shekosh region, they are deeply cut by rivers.

The shrubby vegetation forms dense groups where Commiphora and Acacia prevail. Many sub-ligneous plants also grow as well as a gramineae carpet which is relatively dense in some places.

In this zone, soils are generally shallow. Numerous outcroppings of the limestone in situ may be observed. When soil exists, it presents the following profile :

0-10 cm : Yellowish-red (5 YR 5/6) ; silty loam ; fine subangular blocky structure giving a single-grained structure ; dry very friable and uniform ; numerous angular limestone pebbles. Short transition to :

10-30 cm : Yellowish-red (5 YR 5/8) ; clay loam ; abundant round calcareous nodules approximately 2 cm in diameter and sometimes cemented together and forming a calcareous heap. Sudden and irregular transition to :

30 cm and deeper : Limestone slab in situ.

Pastoral fitness of soils

Limestone plateaus when they are not too narrow, form relatively good pasture zones during and even after the rainy season since part of the gramineae may be grazed in the form of straw.

11. Yellowish-red soils, loam to clay loam

These soils only stretch on the large limestone plateaus which gently slope down to the Dobowein plain, on either side of the latter, and to the East of Iglole plain.

They are characterized by a fine "striped" bush which includes strips with a very dense Acacia and Commiphora vegetation and spaces with small gramineae only.

On these large plateaux, the lower parts are covered with colluvial deposits. In this case, the morphology is the same as for soil series n° 11, but soil is deeper and the fine earth layer covering the horizon with nodules is sometimes more than 50 cm thick. However, in most cases, the limestone slab is less than 30 cm deep from the ground surface

Pastoral fitness of soils

These vast "striped-bush" zones form moderately good grazing areas during the rainy season after which some of the gramineae are eaten in the form of straw by livestock.

12. Red soils : loam to loam and clay

These soils are developed on the large gently sloping colluvium-covered banks of the limestone hills, South of Kebri Dahar and down to Iglole, as well as on the alluvial and colluvial material surrounding the Dobowein plain.

The vegetation is characterized by a "loose striped bush" with relatively tall Acacia and Commiphora. Almost bare spaces prevail with small gramineae which soon dry up after the rainy season.

These soils are usually thick with a large quantity of limestone deeper than 50 cm. In the lower zones, glacis presenting vertic characters may be observed as on the Kebri-Dahar-Shilavo track, 15 km to the East of the Korahe bridge.

Pastoral fitness of soils

These soils form relatively good grazing-grounds during the rainy season but even after the latter, the animals may still graze on dry gramineae.

13. Reddish-yellow soils : medium and coarse sands to medium and coarse sandy clay

These soils may only be observed in the central and higher part of the Dobowein plain which delimits to the East the largest extension zone of the Fafen floods.

This never-flooded zone presents a vegetation consisting of groups of dense gramineae, the stalks of which (50 cm high) form tufts during the dry season.

Morphology

Profile 7-43 Dobowein plain.

Separate gramineae tufts on small 10 to 20 cm high wind-built mounds. Numerous greatly worn quartz pebbles at the surface.

0-10 cm : Reddish-yellow (5 YR 6/6) ; medium and coarse sand ; single-grained ; very friable.

10-60 cm : Yellowish-red (5 YR 4/6) clayey medium, coarse sand ; medium subangular blocky structure ; friable.

60 cm and deeper : Yellowish-red (5 YR 4/6) ; medium and coarse sand and clay ; medium and fine angular blocky ; numerous friable limestone concretions ; relatively friable.

In fact, these soils develop on complex alluvial and wind-transported material mostly derived from the dismantling of the sandstone formation observed in the Shilavo region (Gesoma sandstone).

This explains the large quantity of subangular quartz stones and of dark brown limestone pebbles in the soil. On the ground, numerous quartz pebbles may be seen. Wind erosion has in fact blown away the fine elements and left the coarser quartz.

On aerial photographs, these characteristic white patches must not be mistaken for saline efflorescences.

Pastoral fitness of soils

It is relatively poor. Nevertheless, during the rainy season the tops of gramineae tufts are grazed by livestock.

14. Grey soils : silty loam to fine sand and loam

These grey soils spread in the Fafen Valley, 25 km North of Kebri Dahar and up to Fanhad hill.

On these soils grows a dense vegetation of trees with Acacia mellifera and Acacia tortilis.

Morphology

Profile 7-102, 36 km to the North of the Kebri Dahar. Vegetation of tall Acacia mellifera and a dense graminea carpet.

0-5 cm : Light grey (10 YR 7/1) ; silty loam ; single-grained ; dry and powdery ; short and uniform transition to :

5-60 cm : Grey (10 YR 6/1) ; sandy loam to loam ; single-grained ; dry and loose ; short and uniform transition to :

60-100 cm : Light grey (10 YR 6/1) ; sandy loam to dry loam massive and compact ; relatively numerous calcareous patches forming concretions in some places.

100 - 180 cm : White (10 YR 8/1) and very light brown (10 YR 8/3) striped horizon ; dry, massive and compact ; numerous calcareous nodules forming larger accumulations in some places.

The considerable calcareous accumulation at the base of the profile shows that the ground water table is at less than 1 m depth from the surface for relatively long periods. Besides, the dense and strong vegetation of trees confirms that water exists at a small depth throughout the year.

Pastoral and hydrological fitness of soils

The gramineae vegetation of these soils is relished by animals and constitutes good pastures during most of the year.

The hydrological possibilities of this zone are interesting. Digging a well would allow reaching very quickly the alluvial water table of the Fafen.

Calcic soil-group

15. Bright red soils : coarse and medium sands

These soils exist North of Korahe plain. They form in this region the farthest stretch to the West of colluvial and alluvial deposits resulting from the dismantling of the vast sandstone plateaus of the Shilavo-Warder zone (Gesoma sandstone).

The vegetation is a relatively dense thicket of Gardenieae and Cordia gharaf with a very discontinuous herbaceous carpet.

These soils are deep and very sandy and often present small calcareous nodules in the depth but fine earth is not calcareous, the original material being very poor in calcium carbonate.

Pastoral fitness of soils

These soils are well-drained owing to their coarse structure hence, the sandy deposit zones are scarcely fit for pastures.

D. SOIL CLASS WITH A GYPSUM DIFFERENCIATION

This class includes soils with profiles only characterized by a gypsum redistribution. It is only represented by the sub-class of soils with a pallid horizon. As a matter of fact the upper horizon is always lightly-coloured and its content of organic matter is very low. This class forms two different groups, i.e. :

- a group with powdery gypsum :

gypsum is accumulated in translucent crystals generally more abundant at the base of profiles but never cemented together.

Soil-group with gypsum crust :

Gypsum crystals form a mass which is a regular gypsum crust.

SOIL SUB-CLASS WITH A PALLID HORIZON

Group of soils with powdery gypsum

Modal sub-group

16. Grey soils covered with medium and coarse sands

They occupy two very restricted areas West of the Dobowein plain which are slightly higher than the latter. The vegetation consists of dense gramineae.

These soils are developed on a polyphased material derived from the alluvial deposits of the Fafen and which consist of :

- a light grey very sandy layer rich in shells and approximately 80 cm thick covering :

- a dark brown heavy clay layer with numerous small gypsum crystals.

They are never flooded but nevertheless are affected by the presence of a ground water table since all the surrounding zones are periodically flooded.

Pastoral fitness

The gramineae cover is dense but seems only partly grazed by animals as the tops only of gramineae stalks are eaten up. These pastures are hardly suitable even during the rainy season.

17. Yellowish-grey interstratified soils with medium texture

They spread on the main part of the alluvial zone of the large plain, to the East of Kebri Dahar and to the North West of the Korahe plain.

A relatively dense tree-strewn vegetation with Acacia mellifera and Acacia tortilis occupies the whole plain to the North East of Kebri Dahar. It reveals the presence at a small depth of an artesian water-load during the greatest part of the year and probably permanently. A relatively dense herbaceous carpet covers the soil.

Conversely, the North Western part of the Korahe plain essentially presents a dense herbaceous vegetation.

Morphology

Profile 7-88, Shekosh track, 3 km from Kebri Dahar.

Dense tree-strewn vegetation with Acacia Mellifera and Acacia tortilis. Relatively dense herbaceous carpet.

0-5 cm : Reddish-yellow (7,5 YR 6/6) ; fine sand and loam ; single-grained ; dry and loose ; gradual and uniform transition to :

5-20 cm : Yellowish-red (7,5 YR 5/6) fine sandy clay ; medium and fine well-developed angular structure ; dry and friable ; gradual and uniform transition to :

20-70 cm : Reddish-yellow (7,5 YR 6/6) fine sandy clay : some shrinkage cracks delineating medium prisms with some slickensides; dry and compact ; short and uniform transition to :

70-90 cm : Dark brown (10 YR 4/3) ; clay ; small prismatic fragments with distinct slickensides ; dry and compact ; some gypsum crystals ; short and uniform transition to :

90-140 cm : Grey (10 YR 6/1) ; sandy loam to loam with some yellowish-red clay pockets ; single-grained ; dry and very friable ; some limestone pebbles.

140-200 cm: Light grey (10 YR 7/1) ; sandy loam and loam ; single-grained ; dry and very loose ; some limestone pebbles.

Physico-chemical characteristics

These soils consist of fine interstratifications of loam and of silty clay to which is due a generally medium structure. When the clay horizons are thick enough, vertic features sometimes exist. Gypsum accumulation is always weak and often scarcely visible as small crystals. Conversely, the banks of the Fafen present in the Kebri Dahar region considerable gypsum accumulations sometimes forming a crust. This gypsum concentration seems to result from a progressive impregnation of the banks with calcium sulphate by the Fafen flood water.

Calcium carbonate averages 30 percent.

The content of organic matter is low with 1,4 percent at the surface and less than 1 percent in the depth.

The nitrogen content is weak (less than 1‰) and C/N is approximately 8, showing that humus is soon mineralized.

pH is alkaline and approximately 8,9. The conductivity of the saturation extract is low at the surface and increases with the depth but soil is not alkalinized owing to the great quantity of calcium carbonate and to the presence of gypsum.

The total phosphorous percentage is very high (greater than 2).

The $\frac{\text{Total N}}{\text{Total phosphorous}}$ ratio far less than 2 reveals a considerable unbalance detrimental to nitrogen.

Agricultural and pastoral fitness and water resource of soils

These soils are never flooded and agricultural possibilities are in relation to the importance of rainfall which, in the Kebri-Dahar region, amounts to 300 mm distributed in two seasons. The crop-growing conditions are haphazardous. However on this type of soil some small areas cropped to sorghum present a poor aspect but some exceptionally rainy seasons may possibly give good harvests though the opposite is usually the case.

Pastures are suitable during the rainy season as the herbaceous cover is relatively dense, but they are inadequate during the dry season.

Hydrological possibilities probably exist in the wooded plain situated West and North of Kebri Dahar. The presence of a "wood savannah" with tall trees shows that shallow ground water exists : it is in fact the alluvial water table of the Fafen which supplies Kebri Dahar with water.

18. Grey-soils ; sandy loam and loam to sandy and clay loam

These soils are developed on the narrow strip of alluvial deposits (approximately 300 m broad) of the Fafen, in the gully which links the Dobowein plain to the Iglole plain where this strip widens noticeably.

It constitutes the loss-area of the Fafen.

It terminates in fact in a dead end on the glacis of the Southern hills of Iglole plain. The Fafen bed is reduced to small shallow (50 cm to 1 m deep) braided furrows.

The vegetation consists of a dense tree-strewn savannah with mainly tall Acacia mellifera and a dense herbaceous carpet in the zone where alluvial deposits only cover narrow strips. On the other hand, to the South East where alluvial deposits extend largely, only scattered bushes remain but the herbaceous carpet is still quite dense.

Morphology

Profile 7-52. Loss area of Fafen water, 6400 m to the South East of the Iglole well.

Small watercourses where Fafen water flows. A dense tree-strewn vegetation with Acacia mellifera. Dense gramineae tufts. Some shrinkage cracks in the ground.

0-15 cm : Light brownish-grey (10 YR 6/2) ; silty loam ; medium to coarse crumb structure ; dry and friable ; numerous rootlets ; gradual and uniform transition to :

15-50 cm : Brown (10 YR 5/3) ; silty-clay loam ; small shrinkage cracks delineating small friable subangular blocky fragments giving a fine well-developed subangular blocky structure ; generally dry and friable ; many rootlets ; gradual and steady transition to :

50-120 cm Yellowish-red (5 YR 5/6) and grey (5 YR 5/1) striped ; silty-clay loam ; massive, dry and very compact ; small elongated (2 mm to 5 mm) gypsum crystals ; some rootlets.

Physico-chemical characteristics

These soils are usually grey but sometimes yellowish-grey or brown.

Their texture is scarcely clayey at the surface but turns into silty-clay with depth. The structure is well-developed at the surface and at a moderate depth but at the base of the profile, soil becomes very compact.

The Fafen floods seem weak enough in this zone owing to the two following reasons, i.e. :

- The alluvial layer formed directly by the Fafen is only 50 cm thick in the described profile and the sub-jacent horizon consists of the alluvial deposits of temporary rivers mixed with those of the Fafen.

- The texture of the material deposited by water is fine ; there are no sandy beds (previously existing or recent natural levees) ; flood water has a very slow rate of flow.

Pastoral fitness and water resources

This flood zone seems to present good grazing possibilities during most of the year. Gramineae are abundant and the existence of the Iglole water point is a favourable element.

A shallow ground-water table probably exists in the alluvial deposits of the Fafen from the South of the Dobowein plain down to the end of the track area. A well in this zone would improve the standard of living of the shepherds and their herds.

Vertic sub-group

19. Brown clay soils

These soils cover a very important area East of the Korahe plain. They are mainly formed on the brown alluvia of the Fafen which are now no longer flooded.

The vegetation is merely herbaceous with a very loose gramineae carpet of Cenchrus ciliaris.

Morphology

Profile 7-2 at 4000 m from the Korahe bridge on the Shilavo track. The vegetation consists of tall gramineae forming separate tufts and small gramineae elsewhere.

0-15 cm : Brown (10 YR 4/3) clay ; well-developed crumb structure; dry and friable ; numerous bits of straw and a dense root network ; gradual and uniform transition to :

15-60 cm : Brown (10 YR 4/3) ; clay ; small shrinkage cracks in all directions delimiting medium subangular blocky fragments ; dry and firm ; numerous rootlets ; gradual and uniform transition to :

60-200 cm: Brown (10 YR 4/3) clay ; massive with relatively friable angular blocky fragments with some slickensides ; some gypsum crystals ; some rootlets.

Physical characteristics

These brown clayey soils present a grumosolic structure which is well developed at the surface. They are friable down to a medium depth and compact lower down. The only vertic features are small shrinkage cracks and some slickensides in the depth.

Gypsum accumulation is still not very considerable.

Agricultural and pastoral fitness

The very friable character of the upper horizon of these soils facilitates the tilling of land. Nevertheless, despite their high specific retention, they may not be used easily for cultivation owing to uncertain rainfall conditions.

The grazing possibilities are good during the rainy season because of the presence of gramineae the livestock is fond of. Unfortunately, once again the lack of water does not allow improving the density and duration of the herbaceous cover grazed by animals.

20. Red soils : clay loam :

These soils stretch on all the Eastern part of the Dobowein plain.

They may be observed in the lower area of the plain whereas the soils of series 13 exist in the higher part.

In the weakly flooded Northern area, the vegetation consists of very dense gramineae with small ligneous plants and bushes often growing very closely together.

In the never-flooded Southern area, the vegetative cover mainly consists of gramineae with tufts of tall gramineae growing separately.

Morphology

Profile 7-44 : weakly flooded zone, Dobowein plain ;

Dense vegetation of separate graminea tufts ; pronounced gilgaï microrelief.

0-5 cm : Reddish-yellow (5 YR 6/6) ; loam ; well-developed fine and medium granular structure ; dry and loose ; very few rootlets ; gradual and uniform transition to :

5-60 cm	: Yellowish-red (5 YR 4/3) ; clay loam ; small shrinkage cracks in all directions delimiting friable, medium subangular blocky fragments tending to a very well-developed fine and medium structure ; dry and friable ; numerous rootlets ; gradual and uniform transition to :
60-120 cm	: Red (2,5 YR 4/6) ; clay ; some vertical shrinkage cracks delimiting scarcely friable and relatively flat angular fragments giving a well-developed fine and medium structure ; scarcely distinct slickensides in some places on the angular blocky fragments, some calcareous stains ; some rootlets ; distinct and uniform transition to :
120 cm and deeper	: Red and grey striped layer of very friable accumulated gypsum crystals in a red matrix (2,5 YR 4/6) ; massive, dry and hard.

These soils develop on a red complex alluvial and wind-transported material mainly derived from the Mustahil and Belet Ven limestone surrounding the plain.

Physico-chemical characteristics.

These red loam and clay soils present a very well-developed grumosolic horizon (60 cm in the above-described profile).

The only vertic feature is a broadening of the structure in the depth, and also some shrinkage cracks and slickensides.

The distinct accumulation of gypsum crystals observed in the depth never forms a crust.

Soils have a medium calcium carbonate content (approximately 25 percent).

The content of organic matter is high at the surface (2.4 percent) for the considered area, and progressively decreases with the depth (1.5 percent) owing to the importance of the graminea cover which produces large quantities of straw.

pH is slightly alkaline (approximately 7.8). Conductivity of the saturation extract is low and soil is not alkalinized.

Agricultural and pastoral fitness

Cultivation possibilities are small on these soils ; Nevertheless, in scarcely flooded zones and even in the Dobowein plain, it seems possible to cultivate sorghum if the following measures are taken : flood control (when floods occur) and water holding of rain by means of small earth dams forming squares.

Pastoral possibilities are good during the rainy season in never-flooded zones but they last longer in flood-zones. The rest of the year these pastures may constitute good complementary grazing though the problem of water-points exists, in particular in the South of the plain. The only known water-point is located 10 km beyond the Western limit of this plain.

21. Red soils : Sandy loam and loam to silty loam

They spread on the lower parts of the detrital fans of temporary rivers in the outskirts of the Fafen valley, from the North of Kebri Dahar to Iglole.

They are flooded by the floods of temporary rivers during the rainy season and constitute the traditional cultivation areas of sorghum (machila) in this region and generally in all Lower Ogaden.

The natural vegetation consists of a usually dense herbaceous carpet with a thorny thicket, the thickness of which varies according to sectors.

Morphology

Profile 7-60, approximately 20 km to the South East of Iglole.

Vegetation of small not very dense thorny bushes ;
Dense herbaceous cover with many small ligneous plants.

0-6 cm : Light red (2.5 YR 6/8) ; sandy loam and loam ; crumb structure with a single-grained trend ; dry and loose ; numerous small bits of straw ; short and uniform transition to :

6-25 cm : Red (2.5 YR 4/6) ; sandy loam to slightly clayey loam-crumb to coarse, medium and fine well-developed subangular blocky structure ; dry and friable ; many rootlets ; gradual and uniform transition to :

25-50 cm : Red (2.5 YR 4/6) ; sandy loam to clay loam ; small subvertical shrinkage cracks delimiting flat friable coarse angular blocky fragments giving a well-developed angular blocky structure ; dry and firm ; many small elongated gypsum crystals ; relatively numerous rootlets ; gradual transition to :

50-200 cm : Red (2.5 YR 4/6) clay loam ; medium flat fragments with some slickensides ; massive, dry and compact ; some rootlets ; numerous flat gypsum crystals.

This type of soil is developed on a red material in which predominate fine elements resulting from the weathering of limestone on the neighbouring hills.

Physico-chemical characteristics

These red sandy loam to silty loam soils (and sometimes clayey) present a grumosolic horizon for a 25 cm depth. Below,the structure is larger, soils becomes firm and then compact but at this level vertic features are not pronounced.

A distinct but powdery gypsum accumulation begins approximately below a 50 cm depth.

Soils are calcareous (25 percent)

The content of organic matter corresponds approximately to 2 percent at the surface but is higher than the average content in this zone owing to the importance of the herbaceous cover. It decreases gradually in the depth.

pH is slightly alkaline ; the profile is not alkalinized and the conductivity of the saturation extract is medium in the depth.

Nitrogen content is medium and the phosphorous and potassium percentages are relatively high.

The total N/total $P_2 O_5$ ratio is less than 2 and shows that the balance is detrimental to nitrogen.

Agricultural and pastoral fitness

These soils with a high specific retention are often flooded by temporary rivers during the rainy season and thus constitute the sorghum "reserve" of nomadic populations temporarily settled for the cultivation of this crop.

This crop-growing could be improved :

- by extending the sown areas and increasing the hydrologic balance of soil through flood-control (using gullies and small dykes).

- by using more productive varieties with a shorter cycle

- by spreading (if the expense is justified) nitrogen carriers such as ammonium sulphate, ammonium nitrate and even lime nitrate at the end of the rainy season.

The pastoral aptitudes seem good in these zones which are flooded by temporary rivers during quite a long period. Nevertheless, they would be more profitably used under cultivation as animals can also graze sorghum straw.

Soil group with a gypsum crust

22. Reddish-yellow soils : loam to gypsum-crust at 80 cm's depth

These soils may only be observed in the Iglole plain on a large zone covered with ancient alluvial deposits of temporary rivers which stretches from the glacis of the limestone hills in the South, to the alluvial deposits of the Fafen in the North (soil series 18).

The vegetation consists of small scattered bushes and of a very loose gramineae carpet.

The very fine sandy soils always present a many-coloured friable gypsum crust approximately 80 cm deep.

Because of their low specific retention, these soils present good pastures but only during the rainy season.

E. CLASS OF HYDROMORPHIC SOILS

This class includes soils the evolution of which is mainly affected by the action of an excessive quantity of water due to temporary or permanent waterlogging of part or whole of the profile.

It is only represented in the Lower Valley of the Fafen by the sub-class of moderately organic soils with a single humic group with gley and a single sub-group with powdery limestone.

SUB-CLASS OF MODERATELY ORGANIC SOILS

Group of humic gley soils

Sub-group with powdery limestone

23. Strongly flooded, brown to reddish-brown, moderately organic hydromorphic soils

These soils are only developed to the South East of Maharato on the brown alluvia of the Fafen, in the most highly flooded zone of the Lower Valley of the Fafen.

A vegetation of tall *Acacia mellifera* grows there with a dense graminea carpet which remains green most of the year.

Morphology

Profile 7-15, 15 km, at a bird's eye view, to the South East of Maharato.

Dense vegetation of tall *Acacia mellifera* with a very thick and green gramineae meadow.

0-5 cm : Dark reddish-brown (5 YR 3/3); recent flood deposits ; heavy clay-friable and platy ; distinct and uniform transition to :

5-20 cm : Yellowish-brown (7,5 YR 4/2) ; heavy clay ; very well-developed medium to fine crumb structure ; humid and loose ; dense rootlets ; gradual and uniform transition to :

20-60 cm : Reddish-brown (5 YR 4/3) ; heavy clay ; very friable angular blocky fragments giving a very fine, developed subangular blocky structure ; numerous rootlets ; gradual and uniform transition to :

60-200 cm : Red (2,5 YR 4/6); heavy clay ; massive humid and sticky ; small limestone gravels ; big roots and relatively numerous rootlets.

Physico-chemical characteristics

Soil Series	Depth cm	Tex-ture	CO_3Ca percent	organic matter percent	N ‰	C/N	pH	Conductivity of saturation extract mmhos/cm 25°C	total P2 05 ‰
	0-5	C	27.5	1.4	0.9	9	7.7	2.5	1.37
	5-20	C	33.0	2.7	1.3	12	7.5	2.4	1.20
	20-60	C	25.5	2.7	1.2	13	7.9	1.5	1.12
	60-200	C	28.5	1.0	0.5	12	7.5	1.7	0.92

These yellowish-brown to reddish-brown soils in the upper horizons turn red in the depth. This changing colouring shows that soil is formed on complex material : the upper horizons consist of Fafen alluvial deposits whereas the sub-jacent red alluvial deposits are ancient alluvial deposits of temporary rivers.

This soil is generally very clayey with more than 80 percent clay, but the soil structure is still very divided-up and grumosolic in upper horizons which facilitates an eventual tilling of land.

Soils are calcareous and pH is slightly alkaline which explains the absence of usual hydromorphic features as mobilization and migration of iron is practically impossible. Consequently, no ferruginous concretions or stains resulting from the reduction of iron may be observed.

The only hydromorphic feature is a certain accumulation of organic matter which is considerable for this zone ; the only one in the Lower Valley of the Fafen where the content of organic matter is approximately 2,7 percent for 60 cm.

The nitrogen content is medium and a low C/N shows that humus is soon mineralized.

Conductivity of the saturation extract is weak in the whole profile.

The total phosphorus content corresponds to a mean percentage.

The total N/Total phosphorous ratio is less than 2 and shows a balance detrimental to nitrogen.

Agricultural and pastoral fitness

These are probably the most suitable soils for agriculture in all the Lower Valley of the Fafen. In fact, the specific retention of soils is considerably high and floods are very strong. Besides it would be easy enough to increase the efficiency of floods by means of earth dykes.

Using nitrogen carriers such as ammonium sulphate, ammonium nitrate and even urea, and applying such cultural practices as would maintain the present high content of organic matter, should make this zone fit to produce not only sorghum but also maize and in some seasons, various vegetables such as tomatoes, red pepper etc..... which could be easily marketed in Kebri-Dahar.

From the pastoral point of view, this is a favourable zone for permanent grazing but it is, at present, overgrazed most of the year by a too large number of animals per hectare.

IV - AGRO-PASTORAL POSSIBILITIES IN THE LOWER VALLEY OF THE FAFEN

A. FLOOD ZONES

In this region with a sub-arid climate, agro-pastoral possibilities are mainly linked to the presence of the flood zones of the Fafen and of its tributaries. As a matter of fact, the latter are not real tributaries as they never join the Fafen directly but end forming large detrital fans. In both cases, floods occur twice a year, in March-April-May and October-November.

Therefore, two flood systems without any direct connection exist, i.e. :

- floods due to Fafen water which mainly spread South of Kebri Dahar down to the last loss area of the Fafen.

- flooding due to the local floods of tributaries (temporary rivers), spreading North of Kebri Dahar on large areas, but which is far more limited to the South.

1. Fafen flood zones and their agro-pastoral possibilities

The Fafen "loses" its water successively in three large depressions South of Kebri Dahar, i.e. :

- The Korahe plain

For more details see "Agricultural and pastoral fitness" for each soil series.

- the Dobowein plain
- the Iglole plain.

Between these depressions, the Fafen Valley is narrow and the river either flows in various channels - between Korahe and Dobowein - or in a single and scarcely marked bed in the gully separating the Dobowein and Iglole plains.

1.1. Korahe plain

(see map at 1/60.000, sheets of the Korahe plain and South Korahe), practically only consists of brown clay alluvial deposits. The Southern area of this plain is by far the zone of the Lower Valley of the Fafen presenting the best agro-pastoral possibilities.

It consists of an area of permanent pastures with a strongly flooded zone (organic hydromorphic soils series 23) corresponding to 4400 ha, and a highly flooded zone (grumosolic vertisols, series 5) of 29.500 ha.

The quality of soil and the importance of flooding allows considering, after some installations are undertaken (earth dykes, canals for the diversion of flood water), the cultivation of food crops such as sorghum and maize and of vegetables to supply the Kebri Dahar market. Soil series 23 seems the most suitable for agricultural speculations. For both types of soils, the improvement of the yield depends on :

- keeping the percentage of organic matter in soils high enough (at least 2 percent) by burying the crop residues (which is not always possible as these are often eaten by livestock).

- using nitrogen carriers such as ammonium nitrate and sulphate as well as urea. Lime-nitrate could also be used after the last flood.

1.2. Dobowein plain

(see map at 1/60.000 - Dobowein plain sheet)

In this vast plain of approximately 75.000 ha , the Eastern area only (consisting a brown clay alluvial deposits from the Fafen) is flooded.

The importance and duration of flooding is less considerable here than in the Korahe plain but two zones may nevertheless be distinguished, i.e. :

- a flood zone with grumosolic vertisols (series 5) and modal soils with powdery gypsum (series 18). It covers approximately 13.300 ha and constitutes good semi-permanent pastures.

- a weakly flooded zone with grumosolic vertisols (series 6) and vertic soils (series 20) which corresponds approximately to 12.200 ha with moderately good temporary pastures.

The grazing possibilities would last longer if earth-dykes were built in the South of the plain, thus preventing water from flowing towards the Iglole plain which is unsuitable for pastures.

The non-flooded western area of the Dobowein plain is occupied by an herbaceous cover of tall gramineae growing in tufts and which could be left as a pasture reserve (40.000 ha).

1.3. Iglole plain

(see map at 1/60.000 sheet of Iglole plain).

Fafen floods are very limited in this plain which is the last "loss-area" of Fafen water. It covers approximately 3.900 ha (modal gypsum soils, series 18). Pastures are poor and temporary.

2. Flood zones of the Fafen tributaries (temporary rivers) and their agro-pastoral possibilities

The flood zones of the Fafen tributaries are large, North of Kebri Dahar and considerably more limited in the South.

2.1. North of Kebri Dahar

The flood zones stretch beyond Fanhad hill, 45 km to the North of Kebri Dahar, on red grumosolic vertisols (series 7). Flooding is important and favourable for the development of a dense and practically perennial herbaceous vegetation. Between Bircot and South Shekosh, the floods even reach the Fafen which is well embanked here and without floods.

This is a semi-permanent grazing zone corresponding to 14.700 ha for North Shekosh and 17.800 ha for South Shekosh. Improvement of the quality and length of grazing depends on a better distribution on the land of flood water.

A small area in this zone is at present cropped to sorghum in the Shekosh region. Flood control of temporary rivers should enable extending the cultivation zones for sorghum as well as for maize. Nitrogen carriers such as ammonium nitrate and ammonium sulphate would considerably increase the yield, especially if selected varieties are used.

2.2. South of Kebri Dahar

From Kebri-Dahar to the South of the plain, floods only concern the lower parts of the detrital fans of temporary rivers in the outskirts of the valley where vertic gypsum soils (series 21) exist.

These zones constitute a sorghum granary for nomadic populations who settle there to cultivate this crop.

The latter can be improved if the conditions determined in the paragraph on "Agricultural and pastoral fitness" of series 21 are met.

Pastures are suitable but should be replaced by the cultivation of food crops according to requirements.

B. NON-FLOODED ZONES

Some non-flooded zones may present pastoral possibilities or water resources.

Good possibilities exist as regards grazing during and after the rainy season, i.e. :

- on wind transported soils (series 4), particularly between Kebri-Dahar and the Dobowein plain.

- on grey soils (series 14), South of Fanhad hill.

Shallow ground water tables, the presence of which is emphasized by a dense tree strewn vegetation, exist in the alluvial zones situated to the East and North-West of Kebri Dahar (soil series 17) and South of Fanhad hill (grey soil series 14).

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IMPERIAL ETHIOPIAN GOVERNMENT

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V

SOILS MAP - CARTE DES SOLS

Fafen Valley - Vallée du Fafen

NORTH-SHEKOSH

JUNE 1973
MAP N°1

ORSTOM

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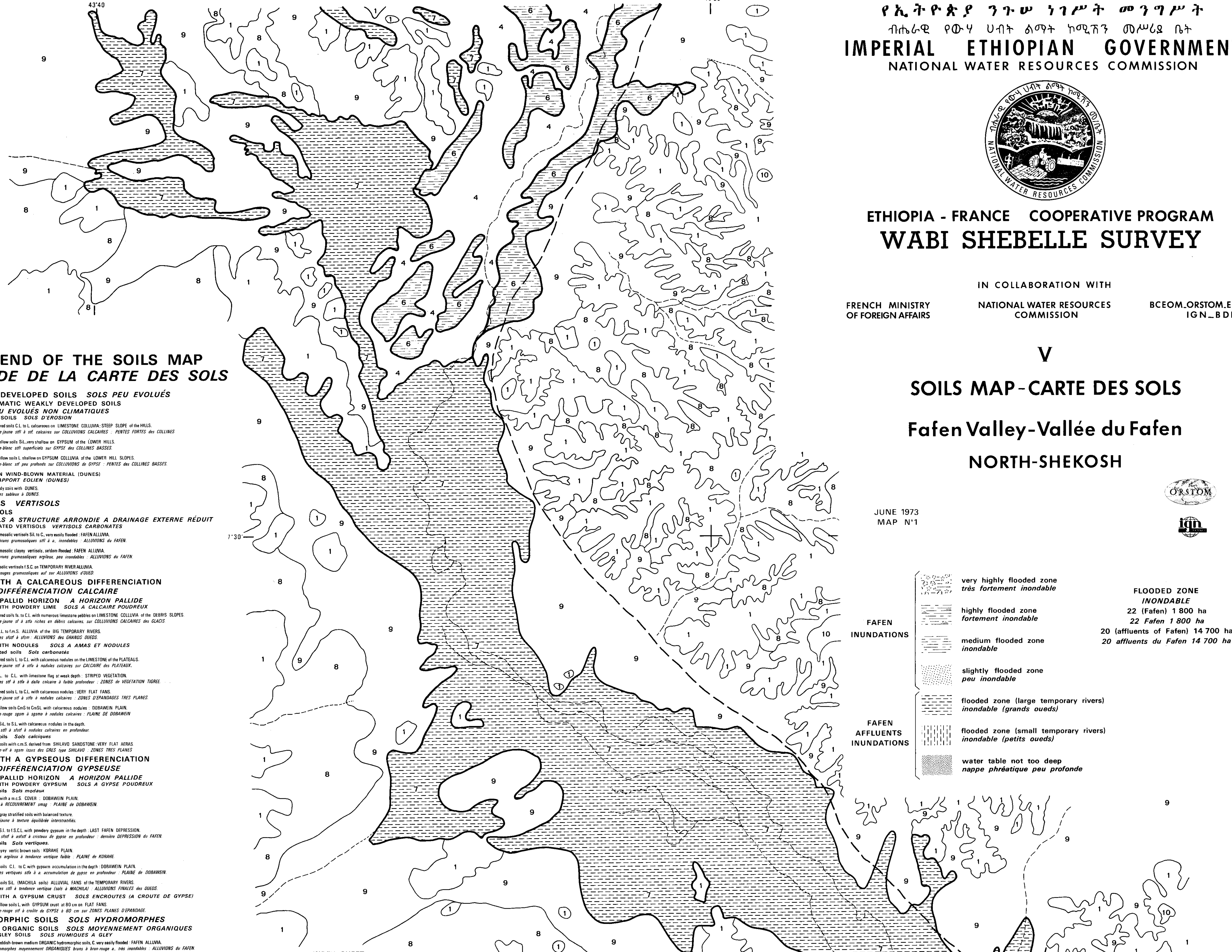

LEGEND OF THE SOILS MAP
LEGENDE DE LA CARTE DES SOLS

WEAKLY DEVELOPED SOILS *SOLS PEU EVOLUÉS*

NON CLIMATIC WEAKLY DEVELOPED SOILS
SOLS PEU EVOLUÉS NON CLIMATIQUES

ERODED SOILS *SOLS D'EROSION*

1 Yellowish-red soils C.L. to L. calcareous on LIMESTONE COLLUVIA: STEEP SLOPE of the HILLS.
Sols rouge-jaune stfl à stf, calcaires sur COLLUVIONS CALCAIRES : PENTES FORTES des COLLINES

2 Whitish-yellow soils SiL.very shallow on GYPSUM of the LOWER HILLS.
Sols jaune-blanc stfl superficiels sur GYPSE des COLLINES BASSES.

3 Whitish-yellow soils L. shallow on GYPSUM COLLUVIA of the LOWER HILL SLOPES.
Sols jaune-blanc stf peu profonds sur COLLUVIONS de GYPSE : PENTES des COLLINES BASSES.

SOILS ON WIND-BLOWN MATERIAL (DUNES)
SOLS D'APPORT EOLIEN (DUNES)

4 Yellow sandy soils with DUNES.
Sols jaunes sableux à DUNES.

VERTISOLS *VERTISOLS*

GRUMOSOLS
VERTISOLS A STRUCTURE ARRONDIE A DRAINAGE EXTERNE RÉDUIT

CARBONATED VERTISOLS *VERTISOLS CARBONATES*

5 Brown grumosolic vertisols SiL to C., very easily flooded : FAFEN ALLUVIA.
Vertisols bruns grumosoliques stfl à a., inondables : ALLUVIONS du FAFEN.

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7 Red grumosolic vertisols f.S.C. on TEMPORARY RIVER ALLUVIA.
Vertisols rouges grumosoliques asf sur ALLUVIONS d'OUED.

SOILS WITH A CALCAREOUS DIFFERENCIATION
SOLS A DIFFÉRENCIATION CALCAIRE

WITH A PALLID HORIZON *A HORIZON PALLIDE*

SOILS WITH POWDERY LIME *SOLS A CALCAIRE POUDREUX*

8 Yellowish-red soils fs. to C.L. with numerous limestone pebbles on LIMESTONE COLLUVIA of the DEBRIS SLOPES.
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9 Red soils S.L. to f.m.S. ALLUVIA of the BIG TEMPORARY RIVERS.
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Sols jaune-rouge sgsm à sgsma à nodules calcaires : PLAINE DE DOBAWEIN

14 Gray soils SiL. to S.L. with calcareous nodules in the depth.
Sols gris stfl à sfstf à nodules calcaires en profondeur.

Calcic soils *Sols calciques*

15 Bright red soils with c.m.S. derived from SHILAVO SANDSTONE : VERY FLAT AERAS.
Sols rouge-vif à sgsm issus des GRES type SHILAVO : ZONES TRES PLANES

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Sols gris à RECOUVREMENT smsg : PLAINE de DOBAWEIN.

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22 Reddish-yellow soils L. with GYPSUM crust at 80 cm on FLAT FANS.
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Sols hydromorphes moyennement ORGANIQUES bruns à brun-rouge a., très inondables : ALLUVIONS du FAFEN.

ABREVIATIONS

f.S. Fine sand
sf sableux à sables fins
L. Loam
stf sableux à sables très fins
S.i.L. Silty loam
stfl sablo-limoneux à sables très fins
S.L.L. Sandy loam to loam
sfstf sableux à sables fins et sables très fins
f.m.S. Fine and medium sand
sfsm sableux à sables fins et sables moyens
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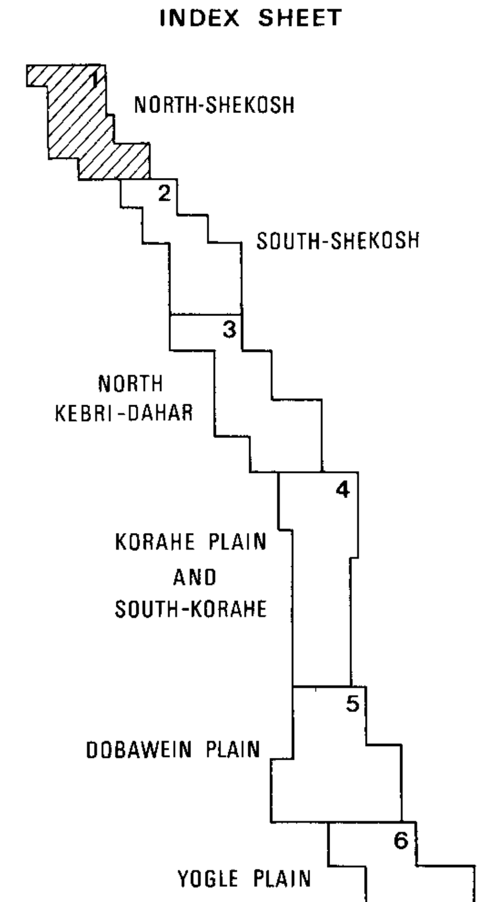

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- very highly flooded zone / *très fortement inondable*
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FAFEN AFFLUENTS INUNDATIONS
- flooded zone (large temporary rivers) / *inondable (grands oueds)*
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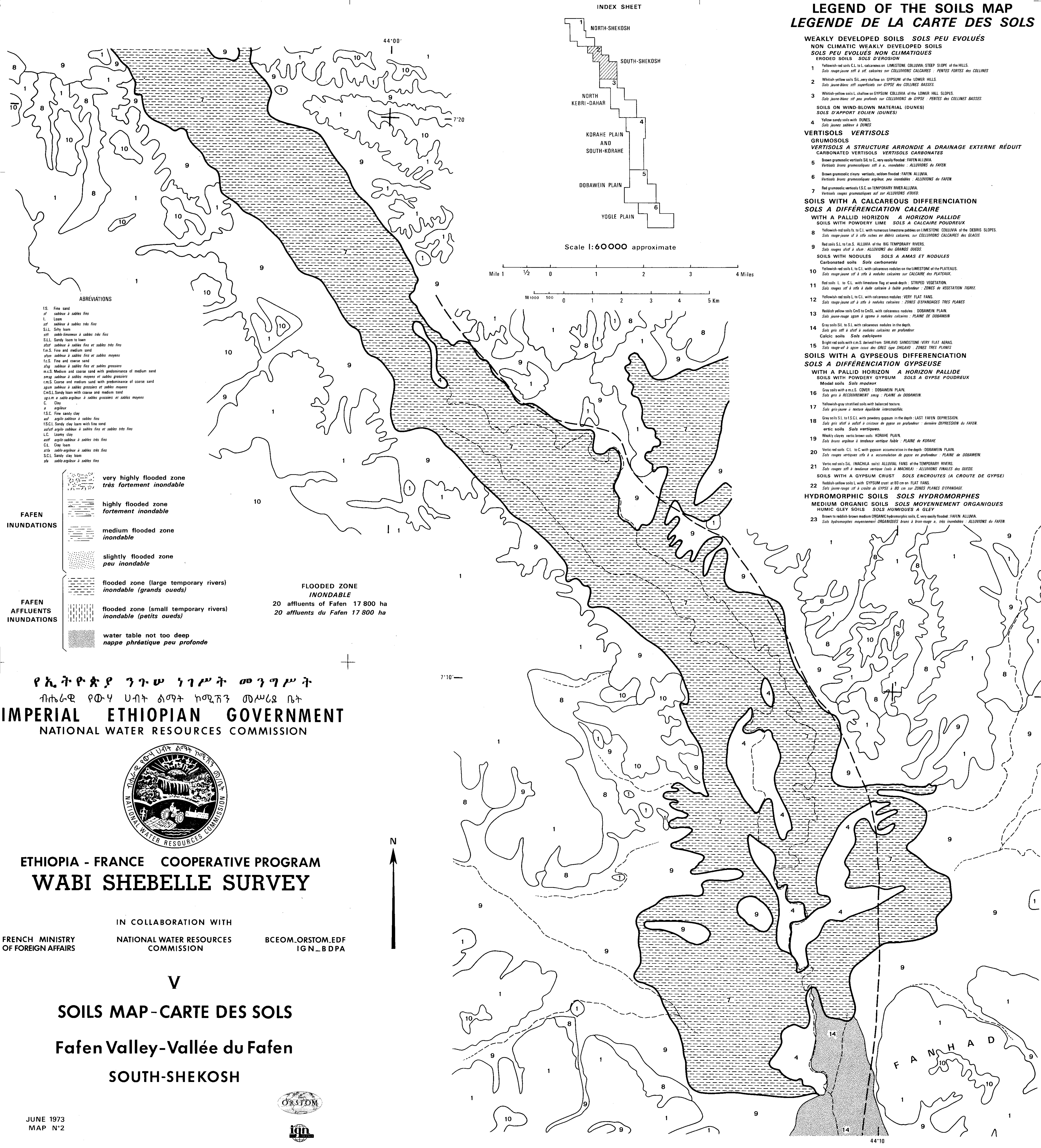
- water table not too deep / *nappe phréatique peu profonde*

FLOODED ZONE
INONDABLE
22 (Fafen) 1 800 ha
22 Fafen 1 800 ha
20 (affluents of Fafen) 14 700 ha
20 affluents du Fafen 14 700 ha

Scale 1:60000 approximate

Mile 1 ½ 0 1 2 3 4 Miles

M1000 500 0 1 2 3 4 5 Km



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IMPERIAL ETHIOPIAN GOVERNMENT
NATIONAL WATER RESOURCES COMMISSION

ETHIOPIA - FRANCE COOPERATIVE PROGRAM
WABI SHEBELLE SURVEY

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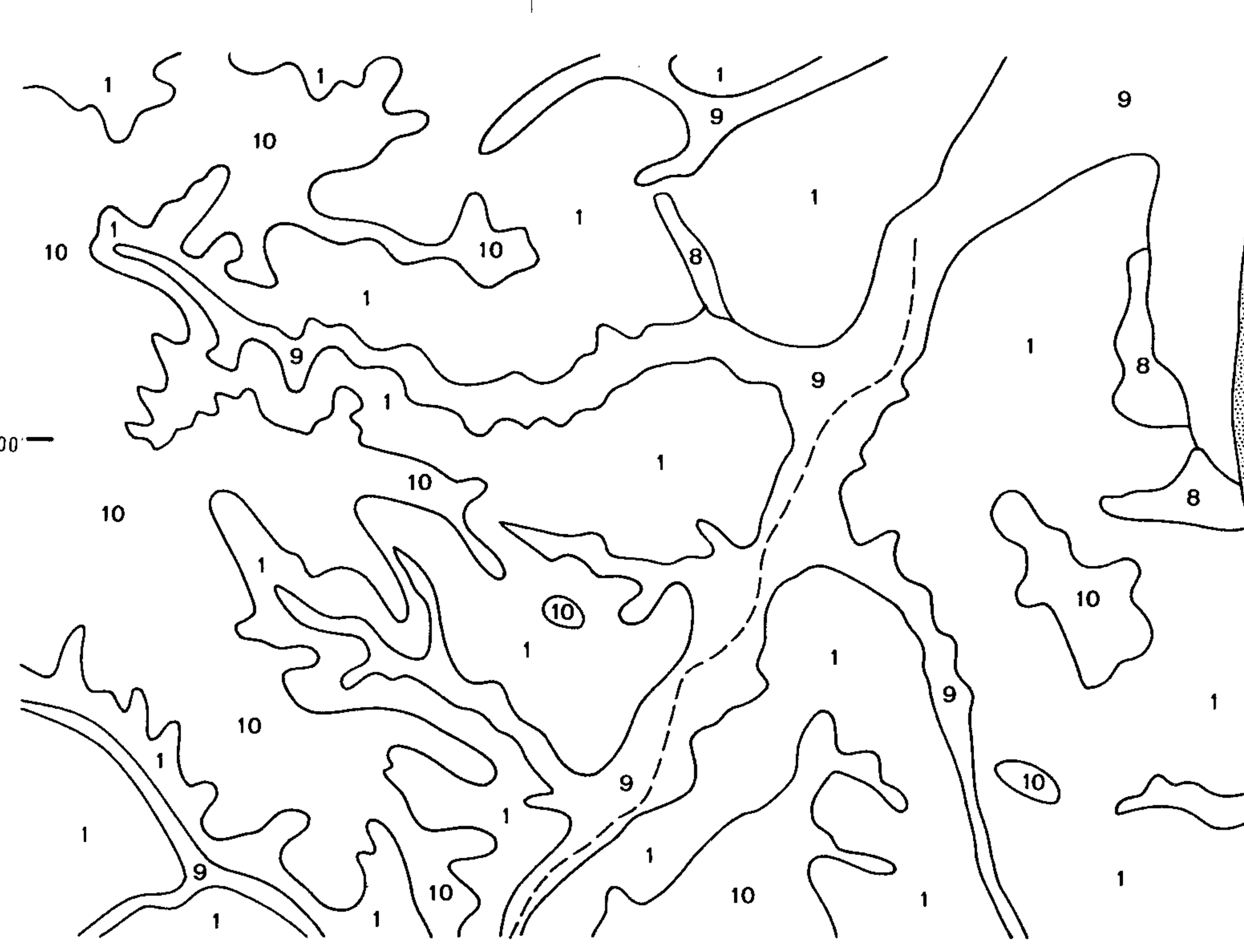
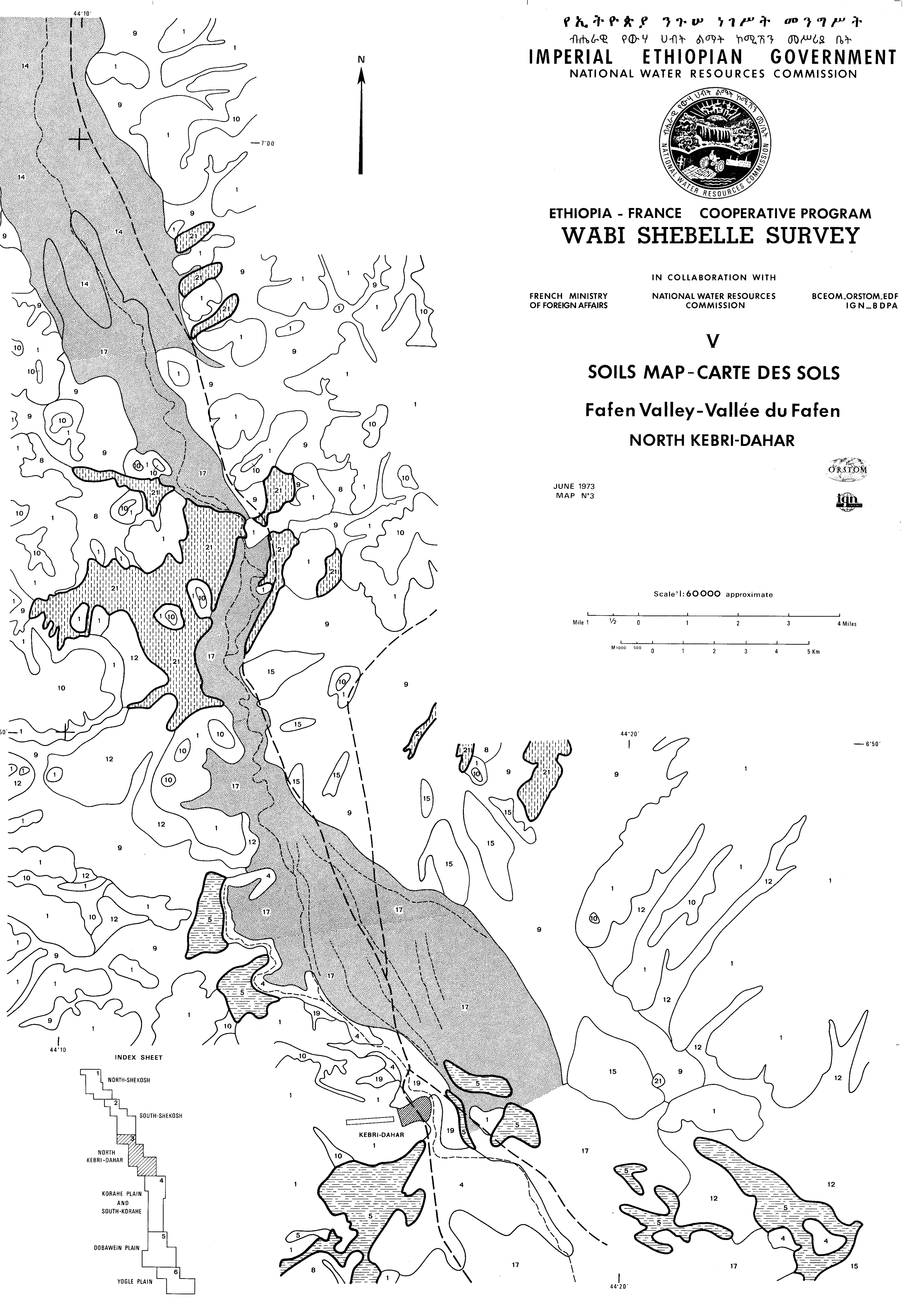
V
SOILS MAP - CARTE DES SOLS
Fafen Valley - Vallée du Fafen
SOUTH-SHEKOSH

JUNE 1973
MAP N°2





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V

SOILS MAP - CARTE DES SOLS

Fafen Valley - Vallée du Fafen

NORTH KEBRI-DAHAR

JUNE 1973
MAP N°3

ORSTOM

ign

Scale 1:60000 approximate

Mile 1 ½ 0 1 2 3 4 Miles

M 1000 500 0 1 2 3 4 5 Km

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astf argilo-sableux à sables très fins
C.L. Clay loam
stfa sablo-argileux à sables très fins
S.C.L. Sandy clay loam
sfa sablo-argileux à sables fins

FLOODED ZONE
INONDABLE

21 Fafen and 10 (affluents of Fafen) 3 400 ha
21 Fafen et 10 affluents du Fafen 3 400 ha

FAFEN INUNDATIONS

very highly flooded zone
très fortement inondable

highly flooded zone
fortement inondable

medium flooded zone
inondable

slightly flooded zone
peu inondable

FAFEN AFFLUENTS INUNDATIONS

flooded zone (large temporary rivers)
inondable (grands oueds)

flooded zone (small temporary rivers)
inondable (petits oueds)

water table not too deep
nappe phréatique peu profonde

Scale 1:60000 approximate

Mille 1 ½ 0 1 2 3 4 Miles

M 1000 500 0 1 2 3 4 5 Km

FAFEN INUNDATIONS
- very highly flooded zone / *très fortement inondable*
- highly flooded zone / *fortement inondable*
- medium flooded zone / *inondable*
- slightly flooded zone / *peu inondable*

FAFEN AFFLUENTS INUNDATIONS
- flooded zone (large temporary rivers) / *inondable (grands oueds)*
- flooded zone (small temporary rivers) / *inondable (petits oueds)*
- water table not too deep / *nappe phréatique peu profonde.*

HIGHLY FLOODED ZONE
FORTEMENT INONDABLE
21 Fafen 10 (affluents of Fafen) 29 500 ha
21 Fafen 10 affluents du Fafen 29 500 ha
VERY HIGHLY FLOODED ZONE
TRES FORTEMENT INONDABLE
23 (Fafen) 4 400 ha
23 Fafen 4 400ha

ABREVIATIONS

f.S. Fine sand
sf sableux à sables fins
L. Loam
stf sableux à sables très fins
S.i.L. Silty loam
stfl sablo-limoneux à sables très fins
S.L.L. Sandy loam to loam
sfstf sableux à sables fins et sables très fins
f.m.S. Fine and medium sand
sfsm sableux à sables fins et sables moyens
f.c.S. Fine and coarse sand
sfsg sableux à sables fins et sables grossiers
m.c.S. Medium and coarse sand with predominance of medium sand
smsg sableux à sables moyens et sables grossiers
c.m.S. Coarse and medium sand with predominance of coarse sand
sgsm sableux à sables grossiers et sables moyens
CmS.L. Sandy loam with coarse and medium sand
sgs.m. a sablo-argileux à sables grossiers et sables moyens
C. Clay
a argileux
f.S.C. Fine sandy clay
asf argilo-sableux à sables fins
f.S.C.L. Sandy clay loam with fine sand
asfstf argilo-sableux à sables fins et sables très fins
L.C. Loamy clay
astf argilo-sableux à sables très fins
C.L. Clay loam
stfa sablo-argileux à sables très fins
S.C.L. Sandy clay loam
sfa sablo-argileux à sables fins

LEGEND OF THE SOILS MAP
LEGENDE DE LA CARTE DES SOLS

WEAKLY DEVELOPED SOILS *SOLS PEU EVOLUÉS*
NON CLIMATIC WEAKLY DEVELOPED SOILS
SOLS PEU EVOLUÉS NON CLIMATIQUES
ERODED SOILS *SOLS D'EROSION*

1 Yellowish red soils C.L. to L. calcareous on LIMESTONE COLLUVIA: STEEP SLOPE of the HILLS.
Sols rouge-jaune stfl à stf, calcaires sur COLLUVIONS CALCAIRES : PENTES FORTES des COLLINES

2 Whitish-yellow soils SiL. very shallow on GYPSUM of the LOWER HILLS.
Sols jaune-blanc stfl superficiels sur GYPSE des COLLINES BASSES.

3 Whitish-yellow soils L. shallow on GYPSUM COLLUVIA of the LOWER HILL SLOPES.
Sols jaune-blanc stf peu profonds sur COLLUVIONS de GYPSE : PENTES des COLLINES BASSES.

SOILS ON WIND-BLOWN MATERIAL (DUNES)
SOLS D'APPORT EOLIEN (DUNES)

4 Yellow sandy soils with DUNES.
Sols jaunes sableux à DUNES.

VERTISOLS *VERTISOLS*
GRUMOSOLS
VERTISOLS A STRUCTURE ARRONDIE A DRAINAGE EXTERNE RÉDUIT
CARBONATED VERTISOLS *VERTISOLS CARBONATES*

5 Brown grumosolic vertisols SiL to C., very easily flooded : FAFEN ALLUVIA.
Vertisols bruns grumosoliques stfl à a., inondables : ALLUVIONS du FAFEN.

6 Brown grumosolic clayey vertisols, seldom flooded : FAFEN ALLUVIA.
Vertisols bruns grumosoliques argileux, peu inondables : ALLUVIONS du FAFEN.

7 Red grumosolic vertisols f.S.C. on TEMPORARY RIVER ALLUVIA.
Vertisols rouges grumosoliques asf sur ALLUVIONS d'OUED.

SOILS WITH A CALCAREOUS DIFFERENCIATION
SOLS A DIFFÉRENCIATION CALCAIRE
WITH A PALLID HORIZON *A HORIZON PALLIDE*
SOILS WITH POWDERY LIME *SOLS A CALCAIRE POUDREUX*

8 Yellowish-red soils fs. to C.L. with numerous limestone pebbles on LIMESTONE COLLUVIA of the DEBRIS SLOPES.
Sols rouge-jaune sf à stfa riches en débris calcaires, sur COLLUVIONS CALCAIRES des GLACIS.

9 Red soils S.L. to f.m.S. ALLUVIA of the BIG TEMPORARY RIVERS.
Sols rouges sfstf à sfsm : ALLUVIONS des GRANDS OUEDS.

SOILS WITH NODULES *SOLS A AMAS ET NODULES*
Carbonated soils *Sols carbonatés*

10 Yellowish-red soils L. to C.L. with calcareous nodules on the LIMESTONE of the PLATEAUS.
Sols rouge-jaune stf à stfa à nodules calcaires sur CALCAIRE des PLATEAUX.

11 Red soils L. to C.L. with limestone flag at weak depth : STRIPED VEGETATION.
Sols rouges stf à stfa à dalle calcaire à faible profondeur : ZONES de VEGETATION TIGREE.

12 Yellowish-red soils L. to C.L. with calcareous nodules : VERY FLAT FANS.
Sols rouge-jaune stf à stfa à nodules calcaires : ZONES D'EPANDAGES TRES PLANES.

13 Reddish yellow soils CmS to CmSL. with calcareous nodules : DOBAWEIN PLAIN.
Sols jaune-rouge sgsm à sgsma à nodules calcaires : PLAINE DE DOBAWEIN

14 Gray soils SiL. to S.L. with calcareous nodules in the depth.
Sols gris stfl à sfstf à nodules calcaires en profondeur.

Calcic soils *Sols calciques*

15 Bright red soils with c.m.S. derived from SHILAVO SANDSTONE : VERY FLAT AERAS.
Sols rouge-vif à sgsm issus des GRES type SHILAVO : ZONES TRES PLANES

SOILS WITH A GYPSEOUS DIFFERENCIATION
SOLS A DIFFÉRENCIATION GYPSEUSE
WITH A PALLID HORIZON *A HORIZON PALLIDE*
SOILS WITH POWDERY GYPSUM *SOLS A GYPSE POUDREUX*
Modal soils *Sols modaux*

16 Gray soils with a m.c.S. COVER : DOBAWEIN PLAIN.
Sols gris à RECOUVREMENT smsg : PLAINE de DOBAWEIN.

17 Yellowish-gray stratified soils with balanced texture.
Sols gris-jaune à texture équilibrée interstratifiés.

18 Gray soils S.L. to f.S.C.L. with powdery gypsum in the depth : LAST FAFEN DEPRESSION.
Sols gris sfstf à asfstf à cristaux de gypse en profondeur : dernière DEPRESSION du FAFEN.

Vertic soils *Sols vertiques.*

19 Weakly clayey vertic brown soils : KORAHE PLAIN.
Sols bruns argileux à tendance vertique faible : PLAINE de KORAHE.

20 Vertic red soils C.L. to C. with gypsum accumulation in the depth : DOBAWEIN PLAIN.
Sols rouges vertiques stfa à a. accumulation de gypse en profondeur : PLAINE de DOBAWEIN.

21 Vertic red soils SiL. (MACHILA soils) ALLUVIAL FANS of the TEMPORARY RIVERS.
Sols rouges stfl à tendance vertique (sols à MACHILA) : ALLUVIONS FINALES des OUEDS.

SOILS WITH A GYPSUM CRUST *SOLS ENCROUTES (A CROUTE DE GYPSE)*

22 Reddish-yellow soils L. with GYPSUM crust at 80 cm on FLAT FANS.
Sols jaune-rouge stf à croûte de GYPSE à 80 cm sur ZONES PLANES D'EPANDAGE.

HYDROMORPHIC SOILS *SOLS HYDROMORPHES*
MEDIUM ORGANIC SOILS *SOLS MOYENNEMENT ORGANIQUES*
HUMIC GLEY SOILS *SOLS HUMIQUES A GLEY*

23 Brown to reddish-brown medium ORGANIC hydromorphic soils, C. very easily flooded : FAFEN ALLUVIA.
Sols hydromorphes moyennement ORGANIQUES bruns à brun-rouge a., très inondables : ALLUVIONS du FAFEN.

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ብሔራዊ የውሃ ሀብት ልማት ኮሚሽን መሥሪያ ቤት
IMPERIAL ETHIOPIAN GOVERNMENT
NATIONAL WATER RESOURCES COMMISSION

ETHIOPIA - FRANCE COOPERATIVE PROGRAM

WABI SHEBELLE SURVEY

IN COLLABORATION WITH

FRENCH MINISTRY OF FOREIGN AFFAIRS — NATIONAL WATER RESOURCES COMMISSION — BCEOM_ORSTOM_EDF IGN_BDPA

V

SOILS MAP - CARTE DES SOLS

Fafen Valley - Vallée du Fafen

KORAHE PLAIN AND SOUTH-KORAHE

JUNE 1973
MAP N°4

LEGEND OF THE SOILS MAP
LEGENDE DE LA CARTE DES SOLS

WEAKLY DEVELOPED SOILS *SOLS PEU EVOLUÉS*

NON CLIMATIC WEAKLY DEVELOPED SOILS
SOLS PEU EVOLUÉS NON CLIMATIQUES

ERODED SOILS *SOLS D'EROSION*

1 Yellowish-red soils C.L. to L. calcareous on LIMESTONE COLLUVIA: STEEP SLOPE of the HILLS.
Sols rouge-jaune stfl à stf, calcaires sur COLLUVIONS CALCAIRES : PENTES FORTES des COLLINES

2 Whitish-yellow soils SiL.very shallow on GYPSUM of the LOWER HILLS.
Sols jaune-blanc stfl superficiels sur GYPSE des COLLINES BASSES.

3 Whitish-yellow soils L. shallow on GYPSUM COLLUVIA of the LOWER HILL SLOPES.
Sols jaune-blanc stf peu profonds sur COLLUVIONS de GYPSE : PENTES des COLLINES BASSES.

SOILS ON WIND-BLOWN MATERIAL (DUNES)
SOLS D'APPORT EOLIEN (DUNES)

4 Yellow sandy soils with DUNES.
Sols jaunes sableux à DUNES.

VERTISOLS *VERTISOLS*

GRUMOSOLS
VERTISOLS A STRUCTURE ARRONDIE A DRAINAGE EXTERNE RÉDUIT

CARBONATED VERTISOLS *VERTISOLS CARBONATES*

5 Brown grumosolic vertisols SiL to C., very easily flooded : FAFEN ALLUVIA.
Vertisols bruns grumosoliques stfl à a., inondables : ALLUVIONS du FAFEN.

6 Brown grumosolic clayey vertisols, seldom flooded : FAFEN ALLUVIA.
Vertisols bruns grumosoliques argileux, peu inondables : ALLUVIONS du FAFEN.

7 Red grumosolic vertisols f.S.C. on TEMPORARY RIVER ALLUVIA.
Vertisols rouges grumosoliques asf sur ALLUVIONS d'OUED.

SOILS WITH A CALCAREOUS DIFFERENCIATION
SOLS A DIFFÉRENCIATION CALCAIRE

WITH A PALLID HORIZON *A HORIZON PALLIDE*

SOILS WITH POWDERY LIME *SOLS A CALCAIRE POUDREUX*

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Sols rouge-jaune sf à stfa riches en débris calcaires, sur COLLUVIONS CALCAIRES des GLACIS.

9 Red soils S.L. to f.m.S. ALLUVIA of the BIG TEMPORARY RIVERS.
Sols rouges sfstf à sfsm : ALLUVIONS des GRANDS OUEDS.

SOILS WITH NODULES *SOLS A AMAS ET NODULES*

Carbonated soils ***Sols carbonatés***

10 Yellowish-red soils L. to C.L. with calcareous nodules on the LIMESTONE of the PLATEAUS.
Sols rouge-jaune stf à stfa à nodules calcaires sur CALCAIRE des PLATEAUX.

11 Red soils L. to C.L. with limestone flag at weak depth : STRIPED VEGETATION.
Sols rouges stf à stfa à dalle calcaire à faible profondeur : ZONES de VEGETATION TIGREE.

12 Yellowish-red soils L. to C.L. with calcareous nodules : VERY FLAT FANS.
Sols rouge-jaune stf à stfa à nodules calcaires : ZONES D'EPANDAGES TRES PLANES.

13 Reddish yellow soils CmS to CmSL. with calcareous nodules : DOBAWEIN PLAIN.
Sols jaune-rouge sgsm à sgsma à nodules calcaires : PLAINE DE DOBAWEIN

14 Gray soils SiL. to S.L. with calcareous nodules in the depth.
Sols gris stfl à sfstf à nodules calcaires en profondeur.

Calcic soils ***Sols calciques***

15 Bright red soils with c.m.S. derived from SHILAVO SANDSTONE : VERY FLAT AERAS.
Sols rouge-vif à sgsm issus des GRES type SHILAVO : ZONES TRES PLANES

SOILS WITH A GYPSEOUS DIFFERENCIATION
SOLS A DIFFÉRENCIATION GYPSEUSE

WITH A PALLID HORIZON *A HORIZON PALLIDE*

SOILS WITH POWDERY GYPSUM *SOLS A GYPSE POUDREUX*

Modal soils ***Sols modaux***

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Sols gris à RECOUVREMENT smsg : PLAINE de DOBAWEIN.

17 Yellowish-gray stratified soils with balanced texture.
Sols gris-jaune à texture équilibrée interstratifiés.

18 Gray soils S.L. to f.S.C.L. with powdery gypsum in the depth : LAST FAFEN DEPRESSION.
Sols gris sfstf à asfstf à cristaux de gypse en profondeur : dernière DEPRESSION du FAFEN.

Vertic soils ***Sols vertiques.***

19 Weakly clayey vertic brown soils : KORAHE PLAIN.
Sols bruns argileux à tendance vertique faible : PLAINE de KORAHE.

20 Vertic red soils C.L. to C. with gypsum accumulation in the depth : DOBAWEIN PLAIN.
Sols rouges vertiques stfa à a. accumulation de gypse en profondeur : PLAINE de DOBAWEIN.

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Sols rouges stfl à tendance vertique (sols à MACHILA) : ALLUVIONS FINALES des OUEDS.

SOILS WITH A GYPSUM CRUST *SOLS ENCROUTES (A CROUTE DE GYPSE)*

22 Reddish-yellow soils L. with GYPSUM crust at 80 cm on FLAT FANS.
Sols jaune-rouge stf à croûte de GYPSE à 80 cm sur ZONES PLANES D'EPANDAGE.

HYDROMORPHIC SOILS *SOLS HYDROMORPHES*

MEDIUM ORGANIC SOILS *SOLS MOYENNEMENT ORGANIQUES*

HUMIC GLEY SOILS *SOLS HUMIQUES A GLEY*

23 Brown to reddish-brown medium ORGANIC hydromorphic soils, C. very easily flooded : FAFEN ALLUVIA.
Sols hydromorphes moyennement ORGANIQUES bruns à brun-rouge a., très inondables : ALLUVIONS du FAFEN.

INDEX SHEET

1 NORTH-SHEKOSH
2 SOUTH-SHEKOSH
3 NORTH KEBRI-DAHAR
4 KORAHE PLAIN AND SOUTH-KORAHE
5 DOBAWEIN PLAIN
6 YOGLE PLAIN

ABREVIATIONS

f.S.	Fine sand
sf	*sableux à sables fins*
L.	Loam
stf	*sableux à sables très fins*
S.i.L.	Silty loam
stfl	*sablo-limoneux à sables très fins*
S.L.L.	Sandy loam to loam
sfstf	*sableux à sables fins et sables très fins*
f.m.S.	Fine and medium sand
sfsm	*sableux à sables fins et sables moyens*
f.c.S.	Fine and coarse sand
sfsg	*sableux à sables fins et sables grossiers*
m.c.S.	Medium and coarse sand with predominance of medium sand
smsg	*sableux à sables moyens et sables grossiers*
c.m.S.	Coarse and medium sand with predominance of coarse sand
sgsm	*sableux à sables grossiers et sables moyens*
CmS.L.	Sandy loam with coarse and medium sand
sg s.m. a	*sablo-argileux à sables grossiers et sables moyens*
C.	Clay
a	*argileux*
f.S.C.	Fine sandy clay
asf	*argilo-sableux à sables fins*
f.S.C.L.	Sandy clay loam with fine sand
asfstf	*argilo-sableux à sables fins et sables très fins*
L.C.	Loamy clay
astf	*argilo-sableux à sables très fins*
C.L.	Clay loam
stfa	*sablo-argileux à sables très fins*
S.C.L.	Sandy clay loam
sfa	*sablo-argileux à sables fins*

FLOODED ZONE
INONDABLE
21 and 15 (Fafen) 13 300 ha
21 et 15 Fafen 13 300 ha
NEARLY FLOODED ZONE
PEU INONDABLE
12 and 22 (affluents of Fafen) 12 200 ha
12 et 22 affluents du Fafen 12 200 ha

FAFEN INUNDATIONS

- very highly flooded zone / *très fortement inondable*
- highly flooded zone / *fortement inondable*
- medium flooded zone / *inondable*
- slightly flooded zone / *peu inondable*

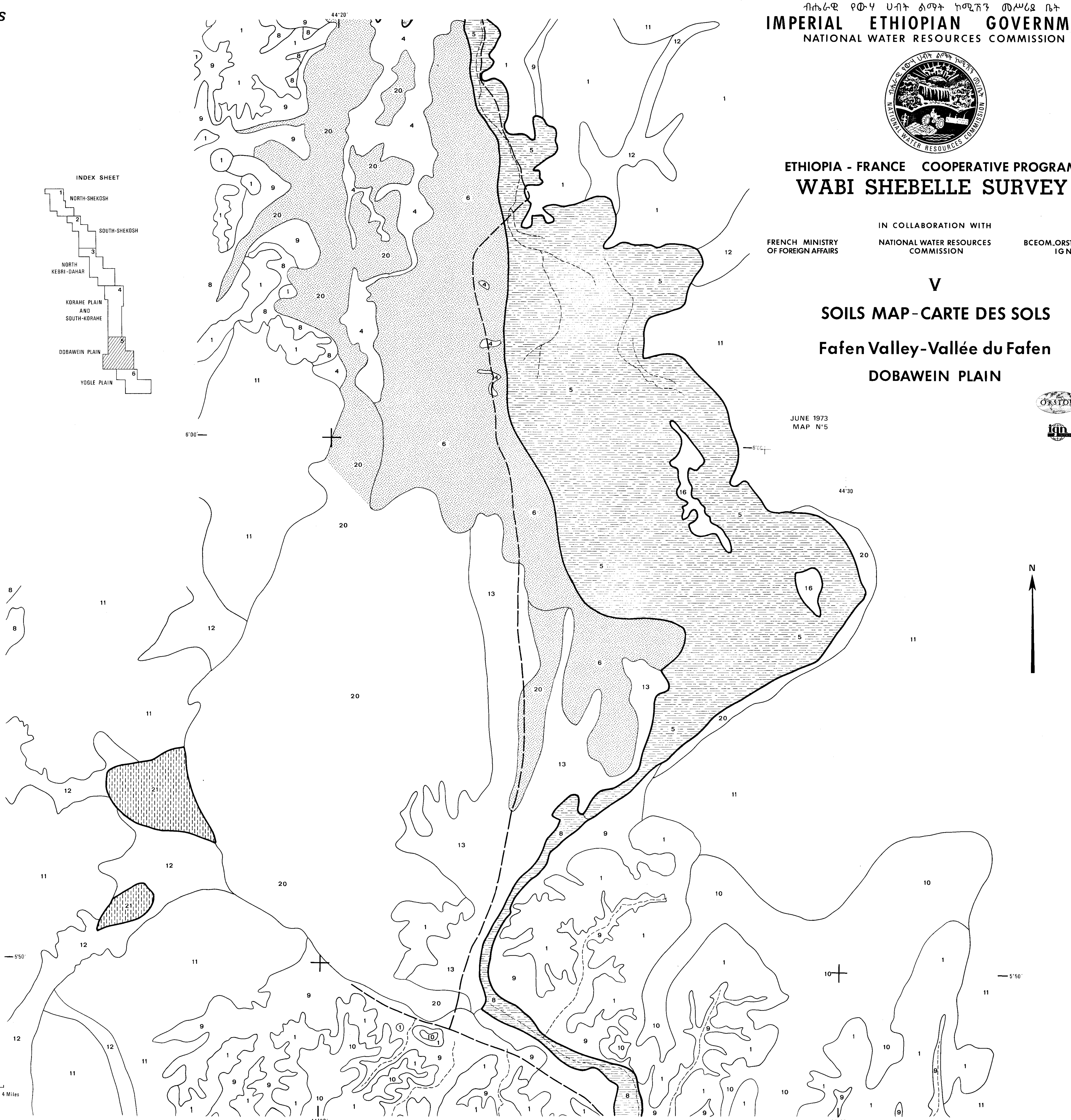
FAFEN AFFLUENTS INUNDATIONS

- flooded zone (large temporary rivers) / *inondable (grands oueds)*
- flooded zone (small temporary rivers) / *inondable (petits oueds)*
- water table not too deep / *nappe phréatique peu profonde*

Scale 1:60000 approximate

Mile 1 ½ 0 1 2 3 4 Miles

M1000 500 0 1 2 3 4 5 Km



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ብሔራዊ የውሃ ሀብት ልማት ኮሚሽን መሥሪያ ቤት

IMPERIAL ETHIOPIAN GOVERNMENT
NATIONAL WATER RESOURCES COMMISSION

ETHIOPIA - FRANCE COOPERATIVE PROGRAM
WABI SHEBELLE SURVEY

IN COLLABORATION WITH

FRENCH MINISTRY OF FOREIGN AFFAIRS	NATIONAL WATER RESOURCES COMMISSION	BCEOM_ORSTOM_EDF IGN_BDPA

V
SOILS MAP - CARTE DES SOLS
Fafen Valley-Vallée du Fafen
DOBAWEIN PLAIN

JUNE 1973
MAP N°5

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IMPERIAL ETHIOPIAN GOVERNMENT

NATIONAL WATER RESOURCES COMMISSION

ETHIOPIA - FRANCE COOPERATIVE PROGRAM

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IN COLLABORATION WITH

FRENCH MINISTRY OF FOREIGN AFFAIRS — NATIONAL WATER RESOURCES COMMISSION — BCEOM_ORSTOM_EDF IGN_BDP

V

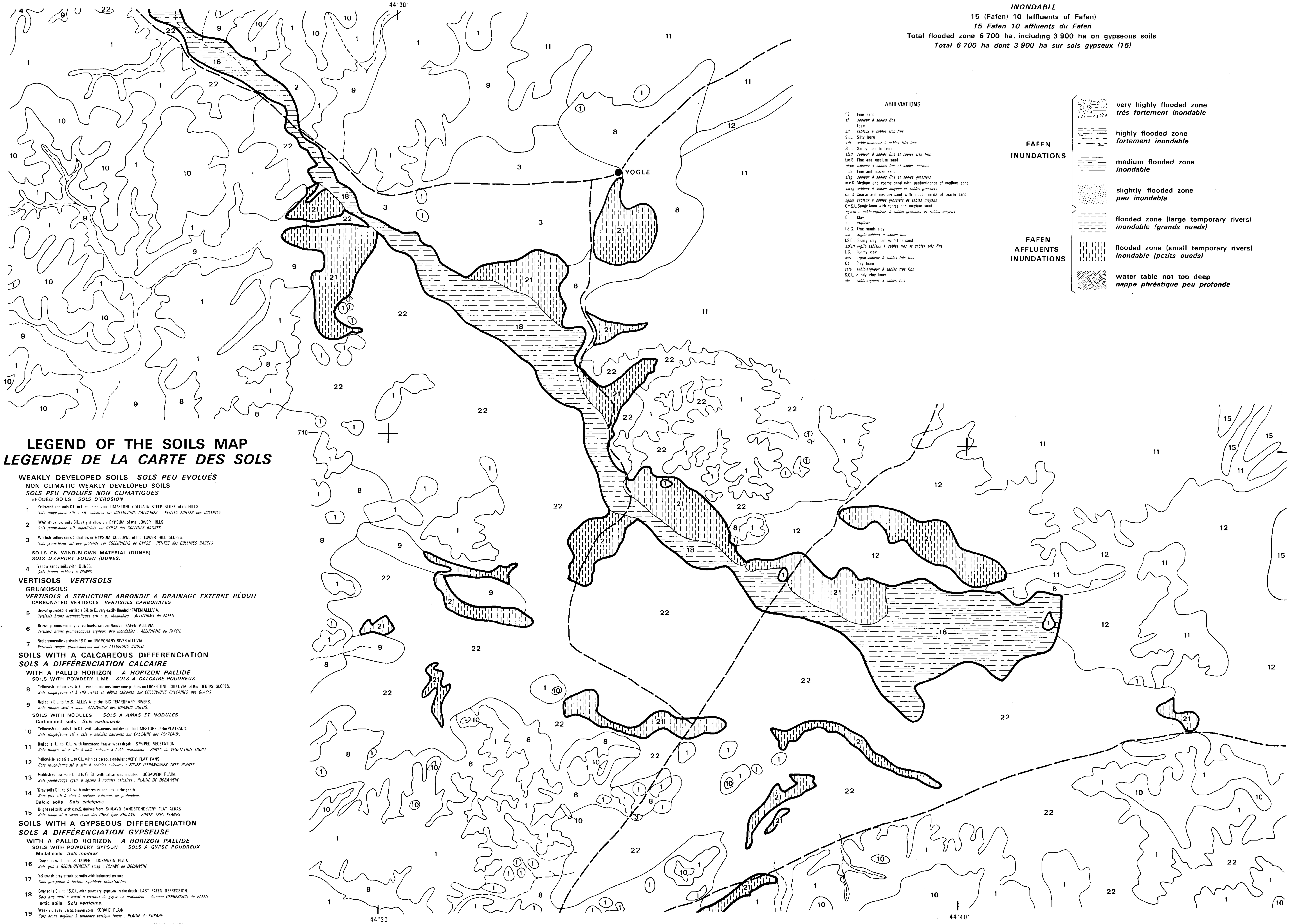
SOILS MAP - CARTE DES SOLS

Fafen Valley - Vallée du Fafen

YOGLE PLAIN

LAST DEPRESSION OF FAFEN

JUNE 1973
MAP N°6



FLOODED ZONE
INONDABLE
15 (Fafen) 10 (affluents of Fafen)
15 Fafen 10 affluents du Fafen
Total flooded zone 6 700 ha, including 3 900 ha on gypseous soils
Total 6 700 ha dont 3 900 ha sur sols gypseux (15)

FAFEN INUNDATIONS
- very highly flooded zone — *très fortement inondable*
- highly flooded zone — *fortement inondable*
- medium flooded zone — *inondable*
- slightly flooded zone — *peu inondable*

FAFEN AFFLUENTS INUNDATIONS
- flooded zone (large temporary rivers) — *inondable (grands oueds)*
- flooded zone (small temporary rivers) — *inondable (petits oueds)*
- water table not too deep — *nappe phréatique peu profonde*

ABREVIATIONS

f.S. Fine sand
sf sableux à sables fins
L. Loam
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sgsm sableux à sables grossiers et sables moyens
CmS.L. Sandy loam with coarse and medium sand
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C. Clay
a argileux
f.S.C. Fine sandy clay
asf argilo-sableux à sables fins
f.S.C.L. Sandy clay loam with fine sand
asfstf argilo-sableux à sables fins et sables très fins
L.C. Loamy clay
astf argilo-sableux à sables très fins
C.L. Clay loam
stfa sablo-argileux à sables très fins
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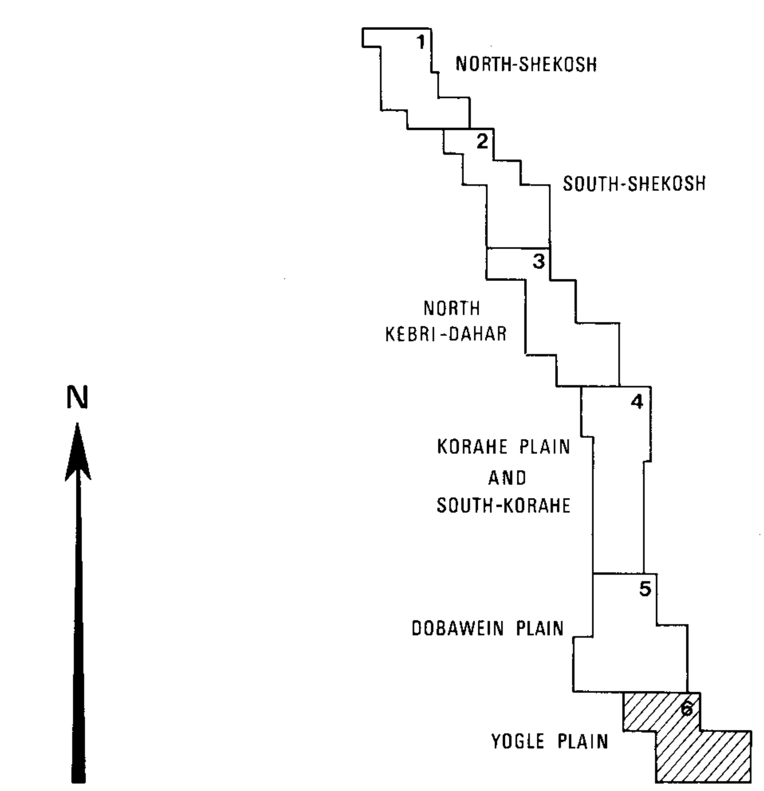
sfa sablo-argileux à sables fins

Scale 1:60000 approximate

Mile 1 ½ 0 1 2 3 4 Miles
M1000 500 0 1 2 3 4 5 Km

INDEX SHEET



LEGEND OF THE SOILS MAP
LEGENDE DE LA CARTE DES SOLS

WEAKLY DEVELOPED SOILS *SOLS PEU EVOLUÉS*
NON CLIMATIC WEAKLY DEVELOPED SOILS
SOLS PEU EVOLUÉS NON CLIMATIQUES
ERODED SOILS *SOLS D'EROSION*

1 Yellowish-red soils C.L. to L. calcareous on LIMESTONE COLLUVIA; STEEP SLOPE of the HILLS.
Sols rouge jaune stfl à stf calcaires sur COLLUVIONS CALCAIRES · PENTES FORTES des COLLINES

2 Whitish-yellow soils SiL. very shallow on GYPSUM of the LOWER HILLS.
Sols jaune-blanc stfl superficiels sur GYPSE des COLLINES BASSES

3 Whitish-yellow soils L. shallow on GYPSUM COLLUVIA of the LOWER HILL SLOPES.
Sols jaune blanc stf peu profonds sur COLLUVIONS de GYPSE · PENTES des COLLINES BASSES

SOILS ON WIND-BLOWN MATERIAL (DUNES)
SOLS D'APPORT EOLIEN (DUNES)

4 Yellow sandy soils with DUNES.
Sols jaunes sableux à DUNES.

VERTISOLS *VERTISOLS*
GRUMOSOLS
VERTISOLS A STRUCTURE ARRONDIE A DRAINAGE EXTERNE RÉDUIT
CARBONATED VERTISOLS *VERTISOLS CARBONATES*

5 Brown grumosolic vertisols SiL to C., very easily flooded : FAFEN ALLUVIA.
Vertisols bruns grumosoliques stfl à a., inondables : ALLUVIONS du FAFEN.

6 Brown grumosolic clayey vertisols, seldom flooded : FAFEN ALLUVIA.
Vertisols bruns grumosoliques argileux, peu inondables . ALLUVIONS du FAFEN.

7 Red grumosolic vertisols f.S.C. on TEMPORARY RIVER ALLUVIA.
Vertisols rouges grumosoliques asf sur ALLUVIONS d'OUED.

SOILS WITH A CALCAREOUS DIFFERENCIATION
SOLS A DIFFÉRENCIATION CALCAIRE
WITH A PALLID HORIZON *A HORIZON PALLIDE*
SOILS WITH POWDERY LIME *SOLS A CALCAIRE POUDREUX*

8 Yellowish-red soils fs. to C.L. with numerous limestone pebbles on LIMESTONE COLLUVIA of the DEBRIS SLOPES.
Sols rouge-jaune sf à stfa riches en débris calcaires. sur COLLUVIONS CALCAIRES des GLACIS.

9 Red soils S.L. to f.m.S. ALLUVIA of the BIG TEMPORARY RIVERS.
Sols rouges sfstf à sfsm : ALLUVIONS des GRANDS OUEDS.

SOILS WITH NODULES *SOLS A AMAS ET NODULES*
Carbonated soils *Sols carbonatés*

10 Yellowish-red soils L. to C.L. with calcareous nodules on the LIMESTONE of the PLATEAUS.
Sols rouge-jaune stf à stfa à nodules calcaires sur CALCAIRE des PLATEAUX.

11 Red soils L. to C.L. with limestone flag at weak depth : STRIPED VEGETATION
Sols rouges stf à stfa à dalle calcaire à faible profondeur . ZONES de VEGETATION TIGREE

12 Yellowish-red soils L. to C.L. with calcareous nodules : VERY FLAT FANS.
Sols rouge-jaune stf à stfa à nodules calcaires : ZONES D'EPANDAGES TRES PLANES.

13 Reddish yellow soils CmS to CmSL. with calcareous nodules : DOBAWEIN PLAIN.
Sols jaune-rouge sgsm à sgsma à nodules calcaires : PLAINE DE DOBAWEIN

14 Gray soils SiL. to S.L. with calcareous nodules in the depth.
Sols gris stfl à sfstf à nodules calcaires en profondeur.

Calcic soils *Sols calciques*

15 Bright red soils with c.m.S. derived from SHILAVO SANDSTONE : VERY FLAT AERAS
Sols rouge vif à sgsm issus des GRES type SHILAVO : ZONES TRES PLANES

SOILS WITH A GYPSEOUS DIFFERENCIATION
SOLS A DIFFÉRENCIATION GYPSEUSE
WITH A PALLID HORIZON *A HORIZON PALLIDE*
SOILS WITH POWDERY GYPSUM *SOLS A GYPSE POUDREUX*
Modal soils *Sols modaux*

16 Gray soils with a m.c.S. COVER DOBAWEIN PLAIN.
Sols gris à RECOUVREMENT smsg : PLAINE de DOBAWEIN.

17 Yellowish-gray stratified soils with balanced texture.
Sols gris-jaune à texture équilibrée interstratifiés.

18 Gray soils S.L. to f.S.C.L. with powdery gypsum in the depth : LAST FAFEN DEPRESSION.
Sols gris sfstf à asfstf à cristaux de gypse en profondeur · dernière DEPRESSION du FAFEN.

ertic soils *Sols vertiques.*

19 Weakly clayey vertic brown soils : KORAHE PLAIN.
Sols bruns argileux à tendance vertique faible : PLAINE de KORAHE.

20 Vertic red soils C.L. to C. with gypsum accumulation in the depth : DOBAWEIN PLAIN.
Sols rouges vertiques stfa à a. accumulation de gypse en profondeur . PLAINE de DOBAWEIN.

21 Vertic red soils SiL. (MACHILA soils) ALLUVIAL FANS of the TEMPORARY RIVERS.
Sols rouges stfl à tendance vertique (sols à MACHILA) : ALLUVIONS FINALES des OUEDS.

SOILS WITH A GYPSUM CRUST *SOLS ENCROUTES (A CROUTE DE GYPSE)*

22 Reddish-yellow soils L. with GYPSUM crust at 80 cm on FLAT FANS.
Sols jaune-rouge stf à croûte de GYPSE à 80 cm sur ZONES PLANES D'EPANDAGE.

HYDROMORPHIC SOILS *SOLS HYDROMORPHES*
MEDIUM ORGANIC SOILS *SOLS MOYENNEMENT ORGANIQUES*
HUMIC GLEY SOILS *SOLS HUMIQUES A GLEY*

23 Brown to reddish-brown medium ORGANIC hydromorphic soils, C. very easily flooded : FAFEN ALLUVIA.
Sols hydromorphes moyennement ORGANIQUES bruns à brun-rouge a., très inondables : ALLUVIONS du FAFEN.