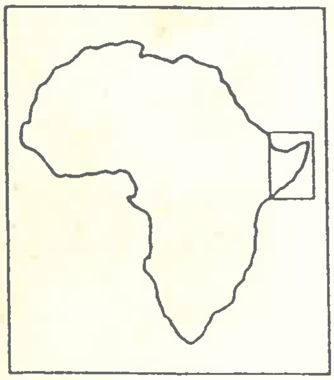
SWEDISH UNIVERSITY OF AGRICULTURAL SCIENCES

Soil Classification and Land Suitability Studies in the Lower Shabelle Region, Somalia



Musse Shaiye Alim

Faculty of Agriculture
Somali National University
Mogadishu, Somalia

June, 1987

A Master's thesis carried out at the SUAS/SLL, Sweden
and as a part of
SAREC/SOMAC PROJEKT: Soil Fertility & Plant Nutrition
Research in Somalia (Phase II)

Professor &
Supervisor: Prof. Reijo Heinonen
Department of Soil Science
Swedish University of Agricultural
Sciences (SUAS)
S-750 07 Uppsala, Sweden

Project Co-
ordinator &
Supervisor: Docent Subrata Ghoshal
Head, Soil Division
National Laboratory for Agricultural
Chemistry (SLL)
S-750 07 Uppsala, Sweden

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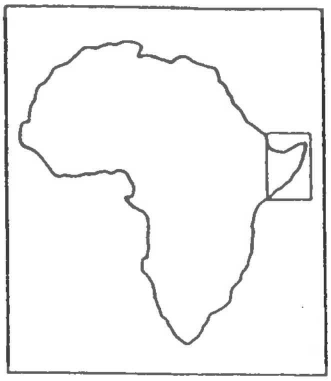

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Abstract
The present study is intended to identify, describe and classify soils according to the U.S. Soil Taxonomy (1975) and to correlate soil taxonomy units with definitions of soil units for the Soil Map of the World (FAO/UNESCO, 1974). It also examines the physical and chemical properties of the Awdheegle-Daarsalaam soils. Evaluation of land suitability for irrigation is included. Finally, pedologic and suitability maps are given.

To my tutor and uncle, Dr. Hassan Alim and his family

CONTENTS

MAPS, FIGURES AND TABLES

1. INTRODUCTION

Since soils constitute an essential part of land resources, the pedological survey is the principal subject of study. From the point of view of soil survey, Somalia is partially covered in the central and southern regions by fundamental survey work at the reconnaissance level conducted by FAO/Lockwood and published in 1968. Some other fragmentary coverage relative to finalized projects has been conducted by various foreign agencies with much more detailed studies.

Since the early years of the 20th century, the surface area in Somalia used for agriculture has been continuously increasing, particularly on the flood plain area along both rivers (Juba and Shabelle) to satisfy the growing needs for crops of the population. Thus, many thousands of hectares have been involved in crop production without knowledge of the nature and properties of soils relative to their limitation for irrigability (e.g. salinity), which have shown, nowadays, their unfavourable condition for further cultivation in some of the remote areas. Some of these areas have been abandoned or are coming close to being spoiled in the foreseeable future. The major factors affecting the soil quality degradation can be indicated as follows:

- lack of sufficient knowledge concerning soil management of the farmers;
- scarce detailed data of physico-chemical properties of soils and of related maps;
- deficiency of water quality data to enable their assessment of suitability for irrigation;
- non-adequate systems of irrigation adopted;
- adverse semi-arid climate of the area, and
- probably the affecting nature of the parent material.

Therefore, all the problems deserve to be studied in greater detail in order to make available useful information to the farmers and decision-makers who are directly or indirectly involved in the management and planning of soil resources and their quality conservation.

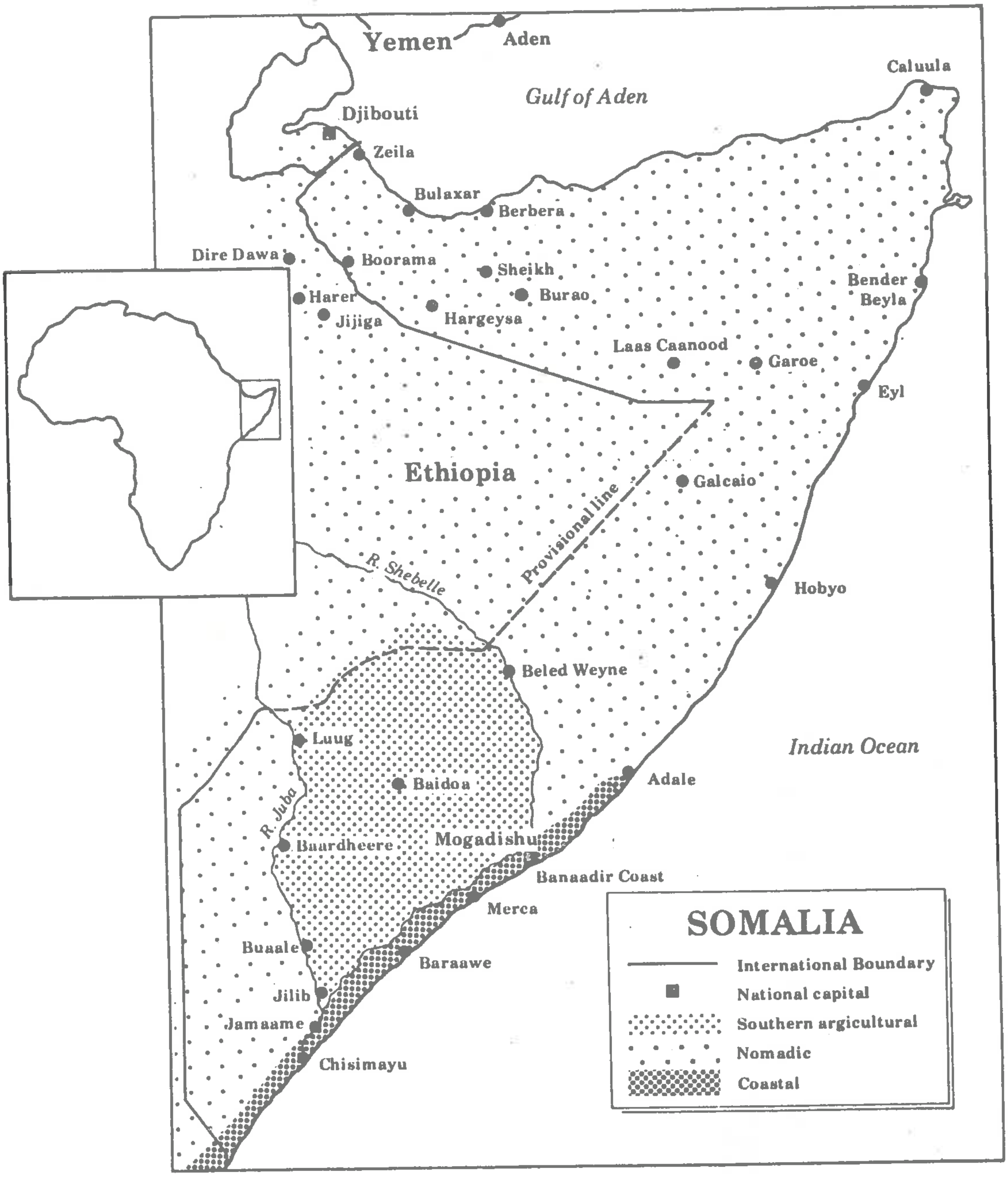
The purpose why the Awdheegle-Daarsalaam area was selected for this study is that the Faculty of Agriculture, Somali National University and the Ministry of Agriculture, Somalia, have established there a joint programme made up of a simplified action-oriented pattern of research-cum-demonstration trials in farmers' fields. The programme intends to encourage and teach the farmers how to promote the agricultural productivity by adopting the scientific methods of practical cropping with high-yielding varieties, fertilizer and pesticide application as well as improved irrigation water management. For that reason there was a need for detailed soil information.

1.1. Scope of work

The objectives of these studies are to:

(i) identify, describe and geographically locate arable land areas,
(ii) classify arable land areas according to suitability for irrigated agriculture,
(iii) prepare a pedologic soil map for the region in accordance with U.S. Soil Taxonomy and correlate units with definitions of soil units for the Soil Map of the World, FAO, 1974,
(iv) these soil maps should show different kinds of soil and their characteristics, all possible information being collected necessary for site selection and planning for irrigated agricultural projects.

Map of Somalia.



MAP 1

2. ARABLE LAND IN SOMALIA

Somalia has a total area of 63.8 million hectares, about 13 % (8.2 million hectares) of the total land is potentially suitable for cultivation. The remainder is pastoral land or desert. Two million hectares of the arable land are in the inter-riverine area between the Juba and Shabelle rivers. Only 160 000 hectares, of the estimated 700 000 hectares of cultivated land in 1980, are devoted to irrigated farming. The area cultivated under controlled irrigation is estimated to about 50 000 hectares, while the remaining 110 000 hectares are under flood irrigation. The rest is under dryland farming (Map 1).

3. LOCATION AND EXTENT OF THE AREA

Soils and land classification studies were carried out in the Awdheegle-Daarsalaam area which lies in the alluvial floodplain of the river Shabelle as a rectangular strip on both banks. The area is about 10 km long and the width extends about 8 km across the river. It stretches from 2°8' to 2°18' latitude North and 44°76' to 44°84' longitude East. The total area is 8 000 hectares. See map 3 (Annex).

4. SOCIO-ECONOMIC STATUS AND LAND USE SYSTEMS

In the study area (Awdheegle-Daarsalaam) in particular and the inter-riverine agricultural Somalia in general, the predominant economic activity is crop agriculture by sedentary farmers and a minor group of partially sedentary herdsmen. The later practice occasional farming, chiefly in marginal land and/or live symbiotically with rural farmers.

Grazing livestock cannot be reared permanently in the riverine area because of the presence of the tse-tse fly, and ticks prevent the keeping of domestic animals, mainly in the wet season. Therefore, grazing takes place in the vicinity of the river mostly in the dry season when water and pasture are scarce elsewhere and the effect of pest damage is minimized in the area close to the river.

The sedentary farmers keep very small stocks of mainly cattle, sheep and chickens for family consumption at their settlements which they mainly feed with leaves, fruits, seed-pods, grass of natural vegetation, crop residues and household wastes. Rather than keeping animals themselves, farmers allow the nomadic herdsmen to exchange gifts of stock or to buy crop residues after harvest and on fallow and to graze their livestock that simultaneously deliver organic manure onto the fields.

Cropping in the area is spatially performed in a way that the intensity of cultivation decreases with increasing distance from the river and villages. Closest to the river are large irrigated farms, with either controlled or uncontrolled irrigation systems, and are permanently cropped with banana, maize, sesame, various vegetables and tree crops such as papaya, mango and coconut, etc. Further away from the river are the near and distant fields, which are applied with supplementary irrigation or are rainfed farmed and produce mainly maize and sesame beans and peas.

Controlled irrigation is practiced close to the river and pumping irrigation systems have been installed by governmental developmental agencies for agriculture, by private corporations, or by farmers participating in local self-help schemes.

The inundation farming system is practiced during high river flow periods, mainly in the Der season whereby water from the river is led to discharge into fields with raised ridges to contain the water or into natural depressions locally termed as "Desheks".

Rainfed cropping takes place where irrigation waters do not reach the floodplain due to local topographic irregularities, long distances from the river or where there are dispersed small-scale holdings of poor farmers who are unable to invest in such expensive irrigation systems.

4.1. Crops:

The principal crops of the area are: maize, sesame, beans, peas, banana and various vegetables. Tree crops occur in limited areas but are mostly sparse and confined to citrus, papaya, mango and coconut.

Maize, peas and beans are cultivated under rainfed as well as irrigated cropping. All other cultivations are under controlled irrigation systems, except sesame plants which are mainly grown under flood irrigation and usually during the "Der" season when more reliable floods occur in the riverine Shabelle area.

4.2. Land tenure

According to agricultural policy measures introduced in 1975 by the Somali government, all lands were declared to belong to the state. However, some security land tenures were to be given to every farmer, family or private corporation as long as they remained involved in agricultural production. Furthermore, traditional systems of clan ownership rights are still used in some remote rural areas where the nomadic mode of life is dominant.

4.3. Different groups of farmers and their main characteristics

The different groups of farmers can be distinguished according to a criteria based on the following major characteristics:

- Degree of commercialization
- Size of holding
- Power source

The important groups of farmers are:

- Subsistence farmers
- Intermediate-scale commercial farmers
- Large-scale commercial farmers

4.3.1. Subsistence farmers

The greatest number of the farmers in the study area belong to this group. They cultivate small plots, usually around 1 hectare, but less than 5 hectares, and mainly grow cereals and oil crops which more or less cover the subsistence needs of the farmer's family. Occasionally they produce a small excess that may be sold in local markets from time to time, to have exchange with other commodities needed, or to pay taxes, etc. The principal crops are: maize, sesame, beans and peas of local varieties. The technology used in cultivating is exclusively by hand (hoe cultivation).

4.3.2. Intermediate-scale commercial farmers

These farmers are the second largest group and produce for their family consumption and for the market. They cultivate 5-50 hectares and mainly produce maize, sesame and various vegetables. The source of power is a combined use of tractors for primary land tillage and hired manpower for the other work.

4.3.3. Large-scale commercial farmers

The farmers of this last group are private, richer, farmers who produce for the market. They employ hired manpower and tractors. They cultivate large farms with sizes ranging up to some hundreds of hectares and mainly grow banana and/or citrus and papaya.

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4.4. Technical and social aspects of the three classes of farmers

The first group, subsistence farmers, conduct all agricultural operations by hand with the hoe as the main tool and without inputs except local seed varieties. Yields are usually low for several reasons such as:

- Use of local low yielding varieties, genetically not improved.
- No use of fertilizers or pesticides.
- Lack of capital investment.
- Lack of conservation measures.
- Low level of technology.

The second group, intermediate commercial farmers, use tractors for some of the agricultural operations and supplement them with hired labour. These farmers have some capital for buying better inputs such as fertilizer and seed if available in the market at a suitable price. They produce higher yields than subsistence farming but are usually low according to international and national standards. Reasons for low yield and obstacles to higher production are:

- Inadequate technical knowledge.
- Lack of transport.
- Inadequate land and water management.
- Limited availability of tractors and high prices of spare parts.
- Shortage of labour for primary land preparation and weeding.
- Financial difficulties.
- Inadequate supply of fertilizers, seed, oil and fuel.

Although the total revenue of this group of farmers can provide a satisfactory standard of living, it is still small.

The large-scale commercial farmers have rights to large holding and grow banana and citrus cash crops. They have enough experience and the necessary infrastructure for developing land productivity.

Almost all the cultivations are done by tractor. All yield-improving inputs are used, such as fertilizers and pesticides. The irrigation system is well performed, mechanization is satisfactory and the yield per unit of area is high.

The most important limitations of this mechanized system are:

- High cost of spare parts.
- Shortage of skilled mechanics because they continuously move to the

rich Arabian oil countries.
- Expensive prices of fertilizer and pesticides.
- Sometimes shortage of fuel.

Large-scale commercial farmers are a very small group in the area and have the largest income of all the above-mentioned groups of cultivators.

4.5. Marketing

Most of the agricultural products, except banana and citrus, are used for family consumption. Small amounts are sometimes sold in local markets when farmers need to pay their taxes or to buy other commodities not produced by themselves.

Purchasing and marketing of grain and oilseed crops are organized by a state agency called the Agricultural Development Corporation (ADC), whereas marketing of banana and citrus is organized by the National Banana Board (NBB). Formerly, these agencies used to buy the entire harvest from the farmers at set prices. However, these set prices did not cover the farmers' costs of production because of the frequently increasing rate of inflation. Consequently, many farmers abandoned farming and others reduced their active participation in crop production.

Recently, in 1984, it was felt necessary to introduce new reforms concerning crop marketing systems in order to promote agricultural productivity. Then grain and oilseed farmers were allowed to sell their products at free market prices, but they still have to exchange 5 % of their products with the ADC.

The NBB remained in charge of marketing the banana and citrus fruits and adjusting prices to rates acceptable to the farmers.

4.6. Farming and land-use intensity

Farming in Somalia, particularly in the Shabelle area, varies noticeably in the intensity of land-use. There are extensive systems, such as shifting cultivation, rotational (bush and grass) fallow cultivation and intensive systems such as banana cultivation.

4.6.1. Shifting cultivation

Shifting cultivation is an agricultural system that consists of alteration between cultivation for a number of years in a given area and a lengthy period when the land is abandoned and allowed to restore itself to full fertility.

Shifting cultivation is practiced principally in the high-rainfall areas of humid and sub-humid tropics. But it is found in other types of climate with less precipitation, such as in semi-arid regions (e.g. Somalia).

Shifting cultivation in Somalia exists under completely marginal conditions. Rainfall is low, highly erratic and has a bimodal distribution (from mid-April to mid-June; from October to November) per year. Shifting cultivation is adopted by migrating semi-nomadic farmers as well as sedentary cultivators.

In each case, alternative cropping and fallowing is conducted in an irregular pattern, and there is no regular sequence of a fixed number of fallow years followed by a fixed number of cultivation years. This type of farming operates where the yields from a field have fallen and where further cultivation appears uneconomic owing to depleted soil fertility resulting from the long, continuous period of cropping or through salinity after the long period of inadequate irrigation. The fallow period can be a long rest fallow of 5-20 years or more, in which it is expected that a natural regeneration of soil fertility occurs as well as natural rehabilitation of saline soil since farmers are not capable of reclaiming their land.

4.6.2. A rotational fallow system

As short fallow systems take over, long-fallow systems are emphasized as rotational crop-fallow system. A distinction can be made between different forms of fallow:

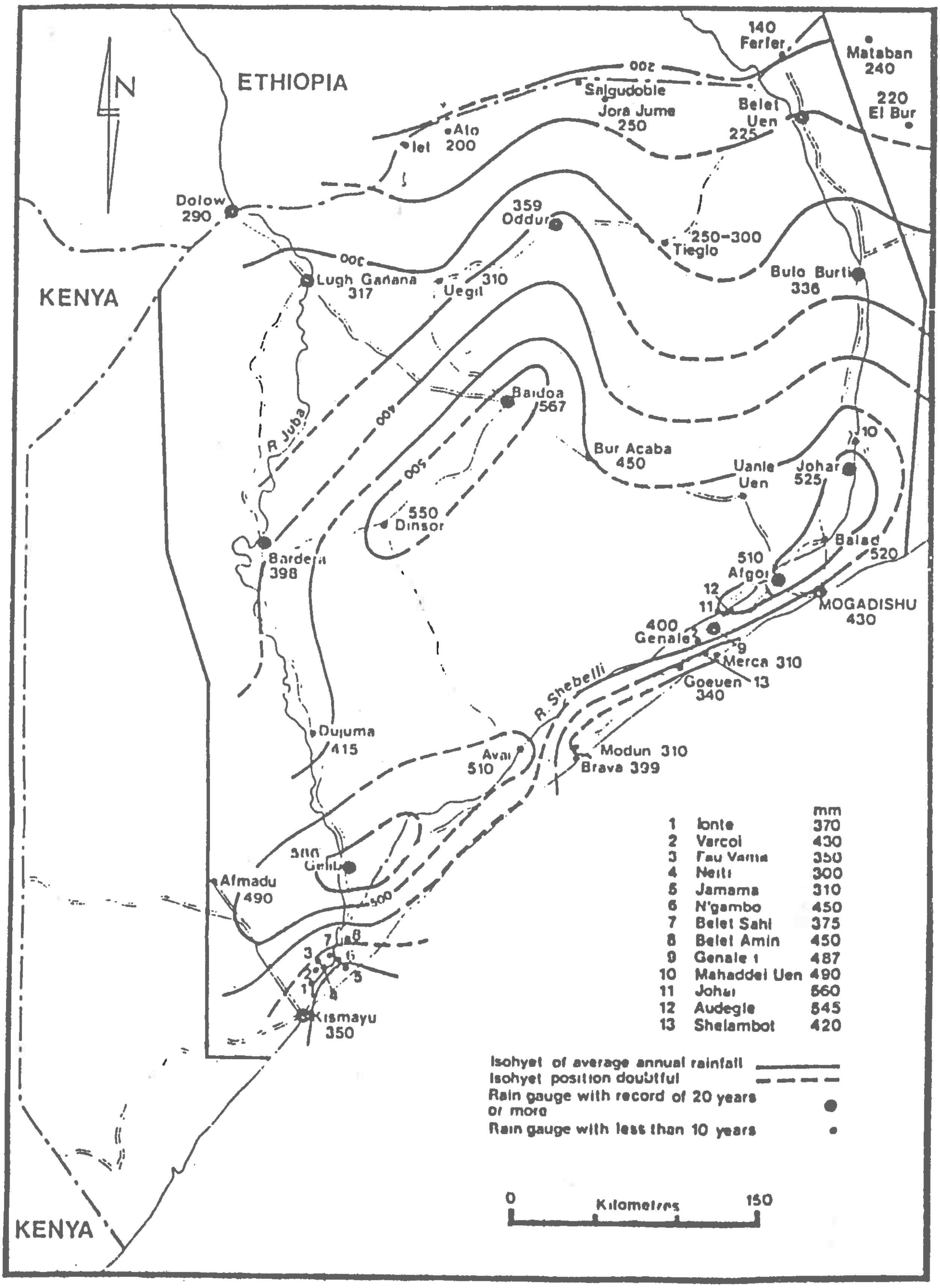
1) A medium-term fallow; when cultivated land is abandoned for 2-5 years in order to restore the fertility and to eliminate weeds.

2) A short-term fallow of 1-2 years caused by unfavourable conditions such as drought or floods, etc.

4.6.3. Intensive system

Whenever the farmer fails to observe problems related to soil properties, but continues cropping permanently, the yields will not fall dramatically but will stabilize at a low level of output unless supported with fertilizers and especially irrigation. Irrigation usually increases the rate

Fig. 1. Isohyets and meteorological stations.



of production per hectare up to six-fold in comparison with rainfed.

5. CLIMATE

The climate of the survey area is tropical semiarid with a bimodal rainfall pattern influenced by the monsoon winds. This area is characterized by having two strongly defined rainy seasons. The first rainy period of the year is locally termed the "Gu" season and occurs during the months of April, May and June. Some lighter showers, called the "Hagai" rains, which effectively lengthen the "Gu" seasons, may occur during the period of July and August. The second rainy season is locally called the "Der" season and occurs during the months of October and November. After that, there is a long dry season from December to March called locally 'Gilal' (see Figures 1, 2). The average annual rainfall of the project area is 545 mm with irregular distribution throughout the years which implies that failure of the rains is not unusual. (Fantoli, A. 1964; FAO & UNSF. 1966; HTS, 1977)

The temperature is rather uniform throughout the year. Average temperatures range from 25° to 30° centigrade. Differences in average daily temperature throughout the year range from 2° to 4° C.

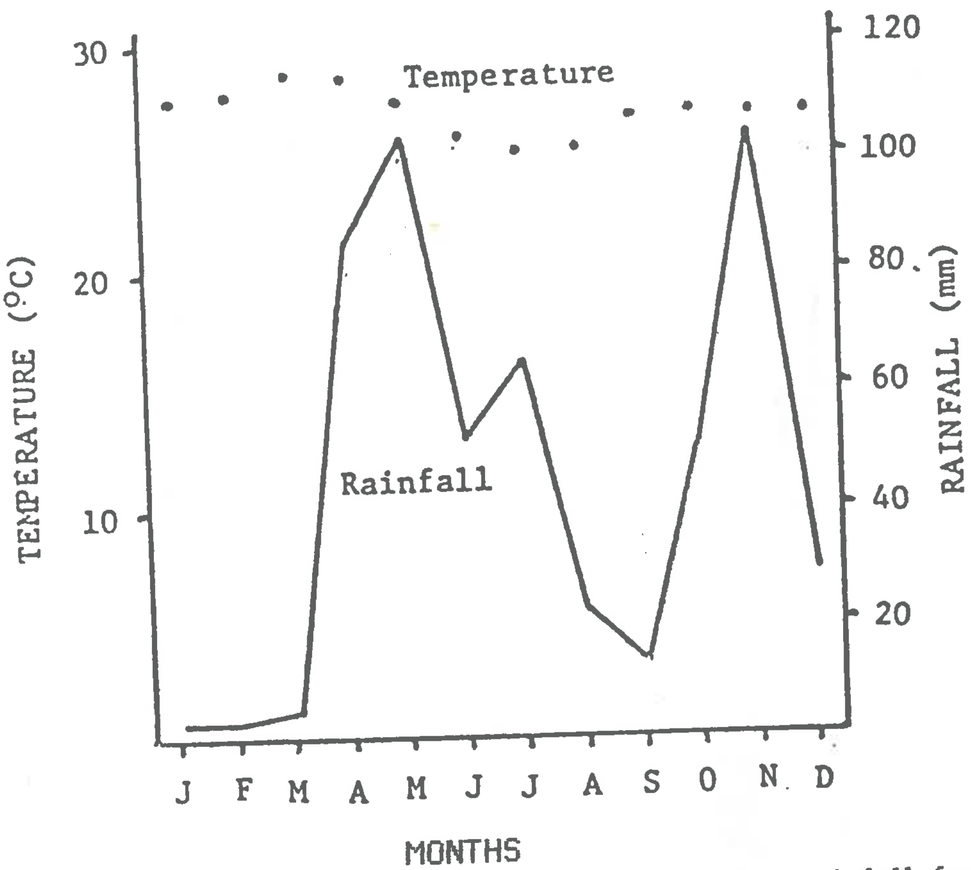


Fig. 2. Mean monthly temperature and mean monthly rainfall for CARS (mean of 23 years). (Adapted from Mokma, D.L. et al., 1984)

5.1. Soil temperature and moisture regime

To classify soils in accordance with the US Taxonomic System (USDA, 1975) it is necessary to determine the soil temperature and moisture regimes in the control section (5 to 100 cm) for definition of certain taxa from a suborder to a family level. The soil temparature and moisture regimes are related to soil biological activity and soil genesis and are important for interpretation in terms of suitability for plant growth.

Because of lacking soil temperature data for the area, it can be estimated from the climatological data of the air temperature (refer to the above-mentioned data, Fig. 2), with precision that suits the present needs of soil survey, just by adding 1°C to the mean annual air temperature (Soil Survey Staff, 1975). Hence, it can be seen that the mean monthly or annual soil temperature of these study soils is always above 22°C and so they are included in the class of "Isohyperthermic" soil temperature regime of USDA (1975).

From Fig. 2 it can be deduced that the moisture available in the control section during certain periods of the years, is limited but capable of supporting vegetation when other conditions are favourable for growth. The control section probably remains continuously moist in some part for at least 90 consecutive days, in the "Gu" and "Hagai" periods. Thus, this area can be classed "Ustic moisture regime" (The Latin word Ustus means burnt, implying dryness) of the USDA System of classification (Soil Survey Staff, 1975; Buringh, P. 1979).

6. WATER RESOURCES OF IRRIGATED FARMING

The climate, being semi-arid, usually restricts agricultural land-use, so the supply of irrigation water is basic for agricultural development. Irrigation increases the yields of crops six-fold compared to rainfed farming (see Table I). Therefore, irrigation can play a vital role in producing good crops that could meet the food requirements of the Somali people if sufficient water supplies became available.

Table I. Estimates of area and yield of major crops in Somalia.

	Area cropped (000 ha)	Yield (t/ha) Rainfed	Irrigated flood	Irrigated controlled	Source*
Food crops					
Sorghum	329	0.3-0.5	0.6-0.9	-	1
Maize	147	0.25-0.4	-	2.5	1.2
Sesame	52	0.25	0.6	-	1
Groundnuts	4	0.3	1.5	-	1
Rice	1	-	-	2.5	1.2
Pulses (a)	-	0.2	-	1.5	1
Cassava	-	7.0	-	-	1
Export crops					
Banana	7-10		-	16	1.2
Citrus	4		2.0	-	1
Agroindustrial crops					
Sugarcane	6		-	45-58	1.2
Cotton	15		0.7	-	1.2
Vegetables					
Onions	-		15		1
Tomatoes	-		10		1

* Sources: 1. Food and Agriculture Oganization of the United Nations. 1977. Water use in irrigated agriculture, Democratic Republic of Somalia, a country brief. Rome, FAO.

2. World Bank 1981b.

(a) Refers to different legumes, including mungbeans, lima beans, and cowpeas.

The water used for irrigation in the study area comes from the Shabelle river. Other possible sources of water for cropping, such as wells, are not yet feasible. The Shabelle water supply is subject to a drastic seasonal fluctuation throughout the year which depends on the climatic conditions, particularly rainfall, of the whole region drained by the river, extending from the Ethiopian highlands, where the main river water catchment basin is located, down to the upstream regions in Somalia where seasonal tributary streams collecting run-off water might flow into the river. The Shabelle river dries up almost every year during the "Gilal" arid season from mid-Janurary to mid-March when water is most needed to irrigate perennial crops. Hence, this irregular water provision restricts the crop production of the irrigated area and further

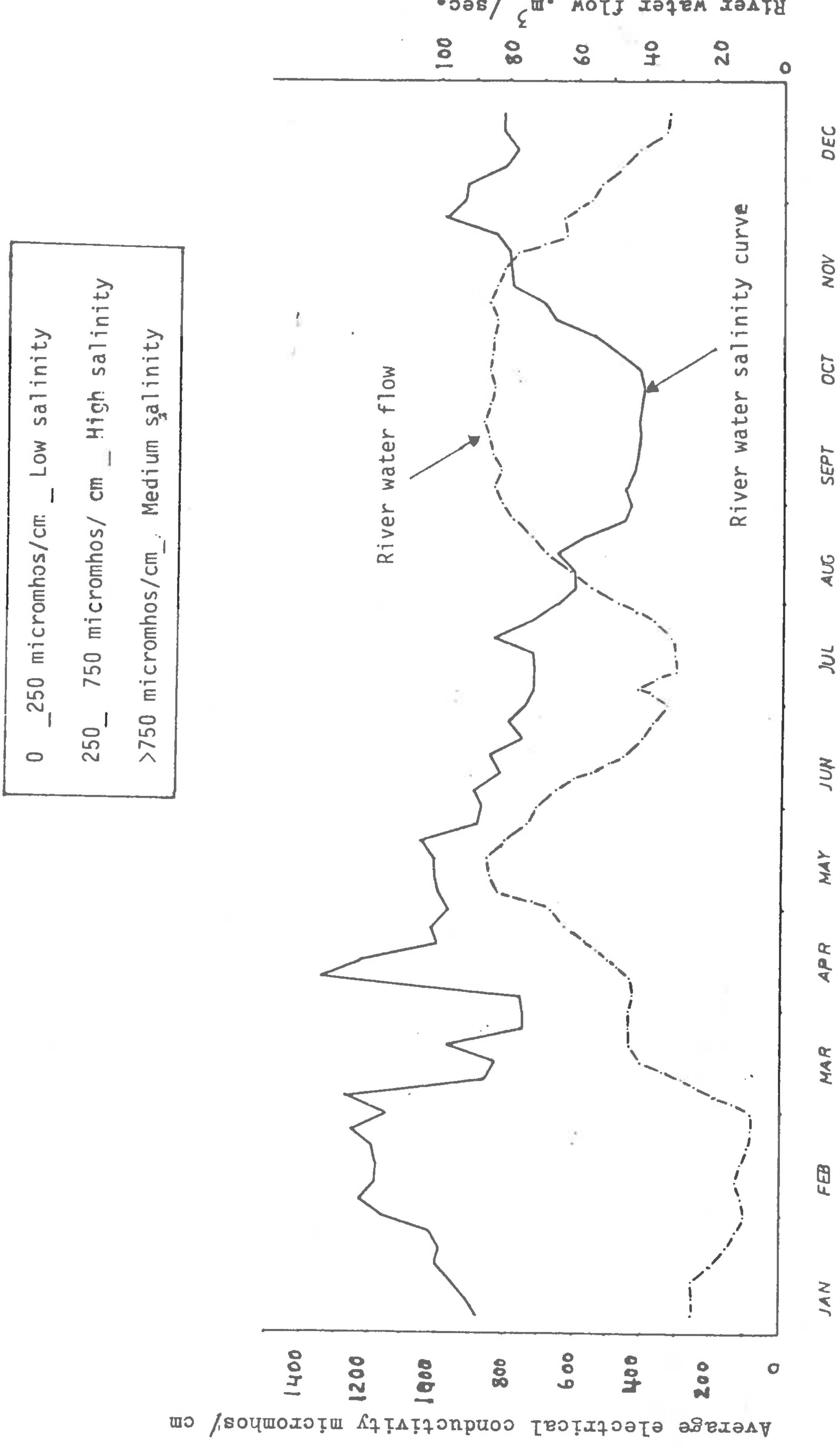


Figure 3. River water salinity in relation to the river water flow (1965-1970).

development of new land for agriculture.

6.1. River water quality

In determining the amount of water in the river available for irrigation, it is also necessary to have information on the quality of the water with regard to its properties and suitability for irrigation. The properties that determine the quality of the Shabelle water depend on the amounts and kinds of soluble salts as well as suspended materials. The contents of salts and types of salt in the river water vary in respect to their origin (surface run-off or infiltration through weathering rocks and soils before reaching the present course of the river). However, information on Shabelle water quality has been neglected since increase of intolerable salinity levels, derived from the long use of indiscriminate irrigation, has led to a progressive loss of cropland (particularly permanently cultivated lands for cash crops such as banana and sugarcane) and has led to reduction in crop production.

According to analyses and data collected from 1965 to 1972 by the Agricultural Research Station at Afgoie, the total salt content in the river water differs seasonally and the river water flow differs from year to year. Usually the salinity content of the waters is in medium (251-750 micromhos(cm) and high salinity (225-750 micromhos/cm) classes.

Usually, the salinity content in the river water is lowest from the first week of July to the first week of November when the waters have an average flow rate and the salinity ranges from 300 - 750 micromhos/cm.

High salinity of the river occurs from November 1 until the first week of July (ranging from 751 - 2 000 micromhos/cm). This period includes the driest season and the most rainy season when respectively, the river almost dries up prior to the spring flood and reaches its highest flow during spring floods. Within this period and during short periods of 1-10 days, any time between mid-March and the end of April, water salinity becomes very high, in the range from 2 000 - 5 000 micromhos/cm. These contents of salinity will be a limiting factor for irrigated lands and their productivity levels unless adequate irrigation methods can simultaneously be developed for the irrigated areas (see Figure 3).

7. GEOLOGY AND MORPHOLOGY

A number of studies have been conducted on the Shabelle River floodplain alluvium (FAO Lockwood, 1968; Hunting Technical Services, 1977; Bingle and Associates, 1985). These reports suggest that deposits of the floodplain are derived mainly from the erosion of soils developed from carbonate and gypsum-rich materials of Jurassic and Cretaceous parent rocks in the upstream portion of the river. The texture of these materials vary from gravel to clay and are most dependent upon the velocity of the water from which it was deposited. The majority of these alluvial deposits are fine-textured but coarser textured material often occurs adjacent to the older river channels and levees.

This zone of the floodplain exhibits a rather uniform surface which has been divided into five main geomorphic units as formally described in FAO/Lockwood (1968) and Hunting Technical Services (1977), namely: floodplain meander, floodplain cover, floodplain channel remnant, floodplain slack water, and floodplain levee.

The full description of these geomorphic units which follows is given in FAO/Lockwood (1968), and Hunting Technical Services (1977).

1. Floodplain meander is a landform of complex land surface meander forming scrolls, levees and ox-bows, which are composed primarily of unconsolidated depositional materials transported in earlier stages by active meandering courses. This deposit constitutes a broad part of the floodplain and is comprised of dark grayish-brown to brown fine textured sediments.

2. Floodplain cover is described as an earlier alluvial plain built by fluvial activity of the Shabelle River subsequently covered by deposits from recent floods of the river since it has been in its present course. This landform presently rarely receives fresh sediments from river flooding and exhibits an almost featureless or level topography. The sediments which comprise this geomorphic unit are reddish-brown, mainly fine textured, material.

3. Floodplain channel remnants are described as a landform developed by abandoned river channel beds and their associated levees. The sediments consist of reddish-brown, stratified and variably textured materials.

4. Flood slack water units are depressional areas adjacent to the present river bed or overflow channels. In these areas water often stands for some time, often as inundations due to the river flooding. These areas are generally composed of fine textured materials of commonly very dark gray to dark gray soils.

5. Floodplain levee unit is the slightly elevated ground of sandy sediment which occurs in connection with the present river banks or abandoned

river courses. These deposits are mainly of stratified, variably textured materials, commonly with reddish-brown to dark brown colours.

8. NATURAL VEGETATION

The area is located within a semiarid climatic zone dominated by natural vegetation of open tree shrub, woodland and grassland. However, the original vegetation has been almost cleared and replaced with cultivation. Some remnant thickets occur in areas remote from tha agricultural zone, and especially along channel remnants or scattered throughout the marginal fields where farming is difficult because of the inaccessibility to irrigation water or where the soil has too low a moisture holding capacity to adequately support cultivated agriculture. Also some reparian forest occurs along the river and sparse bushes and grassland in seasonally flooded swampy areas. The predominant plant types in these areas are:

- Low density tree species: Acacia bussei, Acacia ehrenbergiana, Salvadora persica, Dobera glabra, Ficus sycomorus, Grewia villosa, Balanites Ægyptica.
- Low bush undergrowth: Thespesia persica, Indigofora schimperi, Acacia nubica, Acacia seyal, Cordia spp., Solanum spp., Grewia tenax, Aloe spp.,
- Regeneration of indigenous species: Acacia nilotica, Thespesia danis, Ricinus communis.
- Introduced tree species: Eucalyptus, Cassuarina, Conocarpus, Cocos nucifera.
- Weeds: Heliotropium cinerascensis, Flaveria trinervia, Psoralea corylifolia, Cyperus spp., Cynodon dactolyn, etc.

9. EROSION

The occurrence of erosion either by wind or by water is sometimes noticeable in the area but their effect on degradation of soil resources is limited because the area is mainly dominated by clay soils with almost level topography. Therefore the risks of water erosion by run-off are very low. Well-aggregated clay soils do not very easily disintegrate, hence the impact of rain-drops is reduced.

Wind erosion takes place usually where vegetation cover is almost removed or intensely reduced and the structure of the soil is broken by anthropogenic activity, mostly on silty loam soils. In such places, wind vortexes carry upward finer particles as dust into the higher atmosphere. This usually occurs during the dry seasons of the year.

10. REVIEW OF PREVIOUS STUDIES

Various soil surveys have provided important sources of information in the riverine zone of Shabelle and form the basis for planning decisions. These studies are undertaken either for general-purpose soil surveys or for some special-purpose surveys, notably in connection with specific projects of agricultural and industrial development feasibility studies. These reports are the Inter-River Economic Exploration (ICA, 1961), the Reconnaissance soil surveys-Bulo Marrerto (U.S. AID, 1964), the Reconnaissance soil surveys of the Afgoie Experimental Station (U.S. AID, 1964, the Irrigation Development (F.M. Tileston; 1964), the FAO/Lockwood (1968), the Inter-Riverine Agricultural Study (HTS, 1977), the Genale-Bulo Marerta project (McDonald, 1978), the Soils and Land Evaluation of the Kurtun Warey and Sablaale areas (Bingle and Associates, 1985); the Farjano Settlement project Land Evaluation (McDonald, 1978), etc.

Among these reports, the FAO/Lockwood (1968) study of Southern Somalia and the Inter-Riverine Agricultural study by Hunting Technical Service (1977), include the present project area. In the FAO/Lockwood (1968) study a reconnaissance survey level was conducted to provide a soil inventory for the whole southern part of Somalia and thus only a small field work was carried out along the Shabelle River. Soil and land suitability were mapped at scales of 1:100 000 and 1:500 000. Soils were described and named at series and association level - these soil series nomenclatures were then adapted by subsequent studies as a standard format of their report. Only two soil series were named within the project area, the Saruda and the Goluen series of Shabelle floodplain meander (FPM).

These soils were classified as Grumosols (Vertisols) with low salinity and no sodium hazard and were indicated to have a considerable potential for agricultural development.

10.1. The inter-riverine study (HTS, 1977)

The Inter-Riverine study reviewed the FAO/Lockwood (1968) data in order to be able to adapt the land suitability classification system of USDA. This study has shown that the Saruda and Goluen soil series have an overall suitability for irrigation, but are classed as suitable to marginally suitable.

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11. METHODS OF STUDY

The first phase of this survey involved a review of previous studies conduced by FAO/Lockwood (1968) and Hunting Technical Services (1977), etc., and an examination of aerial photographs of the area from 1982.

An initial stereoscopic investigation was made of the 1:30 000 scale aerial photographs and the images of all environmental features that can be related with soil characteristics, such as morphology and vegetation that could benefit when planning a field survey, were detected and tentatively classified on the basis of recognizable landscape boundaries or interpolated where delineation lacked external expression. The boundaries of those features were drawn on templates overlain the photos. Each landform unit has been annotated with a corresponding legend describing it in technical terms and used to represent a basic mapping unit for the soil survey.

Field work was carried out over 8 000 hectares, from July 13 until August 15, 1985.

To obtain a wide view of a representative area, evenly distributed observations could be made with adequate coverage for each individual area. Because of poor accessibility to the zone, fund limitations and fuel problems, it was not feasible to cut trace lines within the area at that time. However, attempts were made to get maximum benefitable use of existing tracks and roads, and the area was walked through whenever needed.

For accurate location finding, air photos of the area with a preliminary sketch of photointerpretation and a 1:100 000 scale base map were used in the field and the necessary corrections were made.

The alluvial floodplain of the project area exhibits a rather uniform landscape and the variation in relief is minor. Tone variations were used to delineate the differences. The former river levees appeared as light gray but slight depressions were dark gray. The remainder of the zone was flat, so topographic changes were not easily delineated without additional field observations. Relief, surface colour of the soil and natural vegetation were noted in the field and some correlation between topography and soil types was often possible. These evident variations related to soil aspects were used to select appropriate representative sites in the soil by digging pits, generally to a depth of 1.5 m.

A total of 26 profiles were examined and described according to the USDA Soil Survey Manual (1951) and soil samples were taken from each horizon.

Many other ground controls were also conducted. Some 105 soil samples were taken for analysis in the laboratory.

The locations of all profiles are indicated on the map in the annex, and all described observations are given in the section site and profile descriptions.

11.1. Soil Mapping

The soil boundaries were first delineated in respect to their individual external landform expressions on the aerial photographs. Where aerial photo-interpretation could not show where to set up the soil boundaries then dividing lines were interpolated between the sites after field checks had been made. From the corrected sketch photo-interpretation, a soil mosaic map was made with a scale similar to that of the air photos (1:30 000 scale) and boundaries were then easily transferred to a base map of 1:30 000 scale developed from enlarging a topographic map of 1:100 000 scale.

Each soil unit is indicated, in respect to its landform unit, with a specific symbol. Complexes are mapped where necessary.

12. FACTORS OF SOIL DEVELOPMENT

12.1. Soil development processes

Soil development or pedogenesis began to take place on the Shabelle alluvial material as soon as it had been sedimented and exposed to the influence of the environment. The five major soil formation factors are, (1) the climate, (2) the parent material, (3) the topography and drainage, (4) the biological activity, and (5) the length of time for pedogenetic evolution. As the environmental conditions favoured the pedogenesis, a process of ripening (or initial soil formation) started. This comprises three kinds of ripening (physical, chemical and biological) that usually proceed simultaneously and influence each other. Considering as a whole the Awdheegle-Daarsalaam area, the soil material appears to bear different stages of ripening relative to the geomorphological position (or high and low-lying parts) in the landscape. Ripening is more advanced where sedimentation is complete and the water table is periodically low, particularly on older floodplains or higher parts of recent alluvium. Hence, these soils are totally homogenized by a high degree of biological activity. On the other hand, in the depressions or swamps, where the soil-forming processes are restricted, soil ripening is less progressed and soils are semi-ripe or unripe.

Among the various interacting factors involved in soil formation, only the parent material, the topography and the moisture regimes are discussed below:

12.1.1. Parent material

The alluvial sediments are extensive in the whole area and occur adjacent to the river course - some of the lower depressional levels are inundated almost every year, when the river Shabelle reaches its maximum flow during and after the rainy Gu and Der seasons. Consequently, fresh deposits are laid upon the older surface layers of these low-lying places. As waters recede and give place to dense grassland during the dry seasons, the area is utilized for pasture. The higher and older floodplains which are no longer flooded, are mainly used for arable farming. The alluvial soils of the area are characterized by a variable texture, ranging from medium coarse to very fine.

12.1.2. Topography

The topographic and slope conditions of the area exhibit negligible differentiation in short distances but in long distances slight changes of elevation may be visible. The soil of the area occurs at elevations running from 68 to 77 m above sea level. Topography is mostly level to gently undulating and sloping. Most often there are microreliefs called gilgai, which consist of an alternating pattern of low mounds and shallow depressions. Gilgai features occur particularly in the fine-textured soils having clay minerals with a high proportion of montmorillonite type of clay which, as result of changing wetness and dryness, develop properties of swelling and shrinking respectively in moist and dry seasons.

12.1.3. Drainage

Soils are generally moderately well drained throughout the profiles in the higher (older and recent) floodplains which are not inundated by the river. However, it would be expected that the movement of water in the fine-textured subsoils is slowed after heavy rainstorms or excess irrigation, due to their low permeability and internal drainage.

In low-lying areas where flooding occurs in each year, soils are poorly or imperfectly drained. Water stands on the surface for shorter or longer times in the low-lying depressions and swamps or in the small depressions between the gilgai mounds.

Taking into account the above-mentioned conditions, the five major geomorphic units suggested by FAO/Lockwood (1968) have been modified for convenience of application. Thus, the landscape has been divided into four broader landform units (as adopted by Bingle Land Associates, 1985, for areas at the lower ends of the Shabelle floodplain) as follows: (1) Upper cover floodplain, (2) lower cover floodplain, (3) recent alluvial depression and (4) swamp areas.

Upper cover flood: slightly elevated ground, may be older levee and often with level surface without gilgai or surface mulch (in other words no vertisolic properties), possibly gently sloping at the edges. Soil profiles mostly show stratified deposition with varying texture from moderately coarse to moderately fine surface and moderately fine to fine at depth. Calcium carbonate occurs all through the profile. The soils present variable surface colours ranging from dark reddish brown, reddish brown, dark brown and brown. This unit compares to the meander floodplain or floodplain levee of the previous studies.

Lower cover floodplain: may be formed from older or recent alluvial plain not presently subject to flooding. Many of the soils, due to ripening and homogenization, have developed vertisolic properties such as self-mulching, gilgai, and sinkholes, as well as wide and deep cracks (see below).

In these cover floodplains there may occur lighter textured soil horizons that originate from previous channel remnants and associated levees covered by the later depositions. In such horizons the range of textures varies from moderately coarse to moderately fine. This landform unit corresponds to floodplain cover of the preceding system.

Recent alluvial depressions: these soils occur in the flat depressions which are rarely flooded in some years. The soils are mostly clay textured and exhibit vertisolic properties such as gilgai microrelief if not disturbed, self-mulching characteristics and surface cracking reaching into deeper layers. Shell fragments usually occur on the surface but calcium carbonate is found distributed throughout the soil layers and mostly increases in the subsoil.

Swamp areas: are often waterlogged as they were when the survey was conducted. These soils become inundated in almost all the wet seasons of each year. At present the soils have limited profile development but probably may develop into soils similar to those in the recent alluvial depressions if they become sufficiently drained. These latter two may form units corresponding to the floodplain slack water unit of the former landform units (FAO/Lockwood, 1968).

13. THE SYSTEM OF SOIL CLASSIFICATION

The soils of Awdheegle-Daarsalaam area have been classified and grouped according to the system of USDA (Soil Taxonomy, 1975, see Table 2). In addition, the correlation with FAO/UNESCO, 1974, legend of Soil Map of the World has been given in Table 3. The classification is based primarily on the identification and mapping of soil families. The individual soil families include soils which have originated from similar parent material and manifest similar profile characteristics defined within restricted ranges. The family names refer to each principal differential of particle size distribution, mineralogy and soil temperature in horizons of major biological activity and recognize all of the class definitions used in the higher categories. This mapping will be used subsequently as the basis for the classification of the land into its suitability classes of use for irrigated agriculture. During the process of this study, twelve soil families were recognized and mapped as simple single families or complexes of two soil family units. The soil mapping units are shown on a map of 1: 30 000 scale (Map no. 3, Appendix).

The two soil series reported to occur in the area within the previous studies of the FAO/Lockwood (1968), and the Hunting Technical Service Ltd. (1977), i.e. the Saruda and the Goluen, were not easily distinguished or correlated with the new system of Soil Taxonomy. Therefore, those soil series are excluded from the newly adopted nomenclature of Soil Taxonomy, although the soils are Grumosols as defined in the earlier studies. The individual soil families associated with the present study area are defined separately and detailed descriptions of representative soil profiles are given within the section of site and profile descriptions.

The classified and mapped twelve soil families in the Awdheegle-Daarsalaam area consist of three major categories of orders, namely, Vertisols, Entisols and Aridisols. Each of these orders and its subdivision down the level of the mapped familes is described in the following:

Vertisols. (Latin word *verto*, meaning to turn).

The soils are situated on the cover floodplain or recent alluvium depressions (see Table 9, Appendix). They are deep clayey soils (having ≥ 30 % clay) which have vertisolic properties such as gilgai microrelief, self-mulching, sinkholes and cracks. The formation of these properties is mainly related to the nature of the clay fractions, which are dominated by an expandible clay type of montmorillonite, and the monsoonal type of climate which characterizes the area with alternating dry and wet seasons each year. The expandible clay in these soils tends to shrink and swell in relation to the wetting and drying. During a wetting period the clay expands which consequently results in closure of the cracks formed in earlier dry periods as washed materials from the upper surface and collapsing walls of the same cracks will fill the openings. At the same time the self-mulching and the sinkholes will disappear. But in the subsoil the expanding clay of the peds exerts considerable pressure on the opposite sides. So when further compressions cannot occur, the peds slide on each other by moving in opposite upward and downward directions. As a result, wedge-shaped peds and shining polished surfaces of slickensides and pressure faces are developed in the subsoil. Reverse processes, that lead the clay minerals to contract as water continues to be lost by leaching or by evaporation, occur in the dry season. Then the soil surface shows the gilgai features, reopening of the cracks and sinkholes as well as the formation of surface mulch by drying. Hence, the profiles usually appear to be uniform and present a soft crumb aggregation at the surface that overlies prismatic structure breaking to blocks or blocky structure in the subsurface. However, in the subsoil, the pressure face and slickensides are relatively common. Calcium carbonate is found throughout the profile. As the result of the higher amount of clay, and consequent swelling pressure occurring in the subsoil, the profiles range from moderately to very poorly drained.

All the vertisols found in the study area have an ustic soil moisture regime and hence have been classified in the sub-order of usterts and the great group of chromusterts. The chromusterts have been distinguished into two main subgroups, namely Entic Chromusterts and the Udic Chromusterts. Each of the above subgroups has been subdivided into two families distinguished by texture in the principal name differential. The two subgroups of families are named: fine, montmorillonitic (calcareous), isohyperthermic and fine-loamy, montmorillonitic (calcareous), isohyperthermic.

Entisols

The soils, which occupy mostly the higher landscape positions of either older or recent alluvium levees in the floodplain, have been classified as Entisols. These soils show less development of pedogenetic horizons, in other words they remain young, due to the nature of the fluvial deposit which is characterized to reflect varied kinds of stratified sediments in the profiles which result in differences in texture and have irregular distribution of organic matter and calcium carbonates with depth. The relief is often undulating and the profiles are well to moderately well drained. These soils have been included in the suborder of Fluvents and the great group of Ustifluvents (for their Ustic regime). All these Ustifluvents have been found to fall in the same subgroup of Typic Ustifluvents which in turn have been subdivided into four main differently mapped family units as below:

Fine-loamy, mixed (calcareous), Isohyperthermic
Loam, mixed (calcareous), Isohyperthermic
Coarse-loamy, mixed (calcareous), Isohyperthermic
Fine-silty, mixed (calcareous), Isohyperthermic

Aridisols

Aridisols are defined as soils of arid and semi-arid regions. As such, soils developed in the depressions flanking the present levees alongside the river course or older land surface formed in the alluvial plain have been classified in this order of Aridisols. These soils exhibit stratified profiles of variable texture due to the heterogeneity of the deposited fluviatile. The surface soil, as well as the deeper layers, has accumulations of soluble salts, possibly due to their closeness to the river that causes the water table to rise during the periodical high tides. Then as water rises continuously by capillarity and is lost by evaporation, salt is left behind in the upper layers. Profiles present calcium carbonates distributed all through the layers, and are moderately to imperfectly drained. The Aridisols are included in the suborder of Orthids (as they contain $\geq$ 2 % of soluble salts). Within the Orthids, two large distinct groups have been recognized, namely Salorthids and Gypsiorthids. The Salorthids present a salic horizon within 75 cm of the surface and may remain saturated with water within 1 metre of the soil surface for at least 1 month in most years. The Salorthids were distinguished into two subgroups: Typic Salorthids and Aquollic Salorthids. Each of them consists of one mapped family unit. These family units are:

Fine, mixed (calcareous), Isohyperthermic, typic Salorthids.
Fine, loam, mixed (calcareous) Isohyperthermic, Aquollic Salorthids.

The Gypsiorthids are those placed far from the river in the older alluvium and have a gypsic horizon within 50 cm depth where gypsum and carbonate have been more accumulated since formerly there has not been sufficient available moisture which could cause leaching of the carbonate and gypsum into the deeper layers. The Gypsiorthids occur as only one subgroup, named Typic Gypsiorthids, and one mapped family unit defined as Fine-loamy, gypsic, Isohyperthermic.

Table 2 Soil classification.

No	Mapped symbol	Landform	Topography	Soil classification at family level (USDA)	Soil drainage
1	CU/FL	Recent Shabelle alluvium	Flat depression	Fine-loamy, montmorillonitic (calcareous), Isohyperthermic, Udic Chromusterts	Poor to very poor
2	CU/F		Flat depression	Fine, montmorillonitic (calcareous), Isohyperthermic, Udic Chromusterts	Very poor
3	CE/F	Recent Shabelle alluvium	Level, slight gilgai	Fine, montmorillonitic (calcareous), Isohyperthermic, Entic Chromusterts	Moderate
4	CE/FL		Level, slight gilgai	Fine-loamy, montmorillonitic (calcareous), Isohyperthermic, Entic Chromusterts	Moderate
2	CU/F		Flat depression	Fine, montmorillonitic (calcareous), Isohyperthermic, Udic Chromusterts	Moderate
1	CU/FL		Level, slight gilgai	Fine-loamy, montmorillonitic (calcareous), Isohyperthermic, Udic Chromusterts	Moderate
5	FT/FL		Level to flat depression	Fine-loamy, mixed (calcareous), Isohyperthermic, Typic Ustifluvents	Moderate
6	ST/F		Gently sloping	Fine, mixed (calcareous), Isohyperthermic, Typic Salorthids	Poor to imperfect
7	SA/FL		Level	Fine-loamy, mixed (calcareous), Aquollic Salorthids	Poor to imperfect
4	CE/FL	Older alluvial lower cover floodplain	Level	Fine-loamy, montmorillonitic (calcareous), Isohyperthermic, Entic Chromusterts	Moderate
8	CU/LF		Level to gently sloping	Fine, montmorillonitic (calcareous), Isohyperthermic, Udic Chromusterts	Moderate
9	GT/FL		Level	Fine-loamy, gypsic (calcareous), Isohyperthermic, Typic Gypsiorthids	Moderate
10	FT/L	Older alluvial upper cover floodplain	Level	Loam, mixed (calcareous), Isohyperthermic, Typic Ustifluvents	Well drained
11	FT/CL			Coarse-loamy, mixed (calcareous), Isohyperthermic, Typic Ustifluvents	Well drained
5	FT/FL		Level to gently sloping	Fine-loamy, mixed (calcareous), Isohyperthermic, Typic Ustifluvents	Moderate
12	FT/FS		Level	Fine-silty, mixed (calcareous), Isohyperthermic, Typic Ustifluvents	Moderate

Table 3

USDA Soil Taxonomy and correlation with FAO/UNESCO System at the category level of great groups.

USDA (1975) Soil Taxonomy	FAO/UNESCO soil units 1974
Chromusterts	Chromic Vertisols
Ustifluvents	Calcaric Fluvisols
Salorthids	Orthic Solonckaks
Gypsiorthids	Gypsic Yermosols

14. SOIL PHYSICAL AND CHEMICAL PROPERTIES

14.1. The physical properties have been fully treated within the section on morphological description of the soil profiles, but here only the texture will be commented upon.

Texture: The texture of this study area of alluvial plain is variable both in the horizontal soil surface and the vertical distribution or downward in the profiles (Table 8, Appendix).

Among the classified soils, the Vertisols generally contain higher clay contents, more than 30 % in the upper horizons within 50 cm depth, but may change in the deeper horizons depending on the type of parent sediment. Most often, the soil texture classes vary from sandy loam, loam, silty clay loam, clay loam to clay, and rarely with sand and silty intercalation in the lower profiles. These differences are due to the nature of the parent materials which are variable with respect to the origin of the sediment rather than to soil formation. The silt proportions in these soils vary from 9 to 62 per cent. Also, the sand fraction ranges from 15 to 76 per cent with predominantly fine sand. Skeletal and gravel fractions are absent or negligible.

14.2. Chemical properties

14.2.1. Soil reaction (pH)

The pH values, as measured in the saturation extract, range from 7.1 to 8.7 with an average of 8. This high pH level is related to the composition of the parent material, which associates substantial amounts of calcium carbonate and often moderate levels of soluble salts, together with the semi-arid climate and topographic conditions. Such pH levels may render the heavy metals (Zn, Cu, Mn and Fe) sensitive to immobilization and may reduce the availability of phosphorus. Also boron may be affected as well.

14.2.2. Soil salinity and alkalinity

Soil salinity and alkalinity (or sodicity) are referred to excessive concentrations of either soluble salts or exchangeable sodium or both accumulated in the root zone of the soil, whether by natural processes or as a result of irrigation. These have a detrimental effect on crop growth : (1) by increasing the osmotic pressure of the soil solution and thus interfering with uptake of water by roots, (2) by accumulating specific ions which induce toxicity to plant tissue, and (3) by modifying the availability of mineral nutrients for the plants.

14.2.3. Soil salinity

The field observations in the study area indicated that soil salinity problems varied considerably. Most areas exhibited no visible evidence of salts, but others presented a white inflorescence on the surface, or an oily-looking surface, or both. Besides, in certain areas plants showed a stunted growth or were severely damaged.

However, to verify these field observations, analyses were conducted on 105 soil samples collected horizon-wise from the 26 profiles studied. The electrical conductivity (EC) measurements of the extract in a saturated paste of the soil samples were used as a measure of total quantities of soluble salts expressed in mS/cm. The results are shown in Table 8 (Appendix). Although few areas with soils classified as Salorthids are highly salt-affected, the data generally show that the salinity in these soils is low. Electrical conductivity (EC) values are often lower in the upper horizons, ranging from 3.4 to 0.5 mS/cm, but mostly increase downward and rarely reach or exceed 8 mS/cm. The figures of the EC of those salt-affected soils vary between 7.8 and 25.5 mS/cm in the surface horizons and between 12.5 and 17.0 mS/cm down the soil profile. In other words, the salinity is usually lower in the upper horizons. With the exception of the salt-affected soil families within the Salorthids, the soil families including the great groups of Chromusterts, Ustifluvents and Calciorthids, show that salinity values are generally slightly higher in the deeper subsoil of those soils derived from older floodplain alluvium than those of recent alluvium. Remarkably, there is not much difference in the surface salinity. This tendency of increasing salinity with depth might have been due to leaching of the soluble salts in earlier periods. As a result of high salinity, the Salorthids are naturally not favourable for the common crops. Hence, these soils are left abandoned or are used to a limited extent.

14.2.4. Salinity hazard classes

The critical EC levels or classes were derived from the more widely used interpretations of USDA (US Salinity Laboratory Staff, 1954), indicating the response of crops to increasing salinity hazard expressed as EC values as given below.

EC mS/cm		Class of salinity hazard	Crop response
< 2	0	No	Salinity effects mostly negligible
2-4	1	Low	Yields of very sensitive crops may be restricted
4-8	2	Medium	Yield of many crops restricted
8-16	3	High	Only tolerant crops yield satisfactorily
> 16	4	Very high	Only a few very tolerant crops yield satisfactorily

The results of salinity distribution, at three arbitrarily selected ranges of depth in each soil profile of the studied soil families are illustrated in Table 4.

Table 4. General indication of salinity distribution levels in the profiles of the studied soil families in Awdheegle-Daarsalaam area at different depths.

Profile No	Mapped symbol	Surface 0-50 cm	Subsurface 50-100 cm	Subsoil 100-150 cm
1	CE/F	No	No	Low
2	CU/F	No	No	No
3	FT/L	Medium	High	High
4	CE/F	No	Low	Low
5	FT/FL	No	No	No
6	ST/F	Very high	High	High
7	FT/FL	No	Low	Low
8	CU/F	No	Medium	Medium
9	CU/F	No	Low	Low
10	SA/FL	Very high	Very high	Very high
11	CU/FL	No	Low	Low
12	CU/F	Low	Low	Medium
13	FT/CL	No	No	Low
14	FT/FL	Low	Low	Medium
15	GT/FL	No	Low	Low
16	FT/FS	No	Medium	Medium
17	CU/FL	Low	No	No
18	FT/FL	Low	Low	Medium
19	FT/FL	No	No	No
20	CU/FL	No	Low	Low
21	CU/F	No	Low	Low
22	FT/FL	Low	Low	Low
23	CU/FL	No	No	No
24	CE/FL	No	Low	Low
25	CU/FL	No	Low	Low
26	CU/FL	No	Low	Low

14.2.5. Composition of soluble salts

The soluble salts consist of different cations and anions with variable ratios of calcium, magnesium, sodium and potassium, as well as chloride, sulphate, bicarbonate and carbonate. Total analyses of the individual soluble salts were carried out for all the soil samples in order to evaluate their relative contents of cations and anions that effectively contribute to the soil salinity. The results are given in Table 8 (Appendix). Among the soluble ions in these soils, calcium and magnesium are the dominant cations, while sulphate is the prevalent anion. Potassium occurs to a lesser extent than any other cation. Sodium and chloride are both at relatively higher proportions in saline soils. Hence, these neutral salts seem to contribute greatly to the higher salinities in these soils. Bicarbonates occur usually in minor amounts as compared to sulphate and chloride. Carbonate ions are quite seldom present in insignificant amounts.

14.2.6. Cation exchange capacity (CEC)

The CEC of a soil is a measure of the negatively charged sites of the colloidal surface that include the clay and organic matter colloids. When determining CEC, the negative charges are counterbalanced by cations. Hence, the quantity of held cations expressed in milliequivalents per 100 g soil is defined as the cation exchange capacity of the soil. All soil samples were analysed for CEC. This is an important chemical property closely relatable to the fertility of the soil as it varies with the nature of the soil type of development. As a whole, the analytical values of CEC are often high and sometimes indicate irregular distribution through the profile due to the variable nature of the alluvial deposits in respect of the quantity and the type of mineral colloids. Normally the higher values of CEC indicate the presence of considerable amounts of 2:1 mineral colloids. The CEC values range between 47 meq/100 g and 5.8 meq/100 g. The complete data are given in Table 8 (Appendix).

14.2.7. Exchangeable sodium (Na)

Sodium does not seem to be particularly essential as a plant nutrient element. Therefore, its absence or presence in very low concentrations does not usually affect plants adversely. However, higher concentrations of Na can be toxic and directly detrimental to many sodium-sensitive crops. Also high concentration of Na can indirectly render negative effects due to deterioration of physical conditions along with unbalanced nutrient status in the soil.

In order to evaluate the potential content of Na in the exchangeable form in the soils of the study area, nearly all soil samples have been analysed for exchangeable sodium. Finally, the exchangeable sodium percentage (ESP), defined as the percentage of the ratio between the exchangeable Na and the CEC, has been calculated. ESP is a widely used measure of the effect of high sodium levels or hazard of salt-affected soils. ESP values greater than 15 are indicated as sodic soils. Accordingly, the results of the various soil families examined reveal that those families included within the great group of Salorthids have ESP values higher than 15, while the others have lower values which quite seldom exceed 5, in other words the upper limit considered for favourable physical properties in Vertisols (Dudal, 1965; Mc Donald, 1978), in the deeper horizons. Besides the sodicity, the soil families of Salorthids have very high figures of EC_e greater than 4 and alkaline pH lower than 8.5. As a result of these combined processes of salinization and alkalinization, these soils are defined saline-sodic.

14.2.8. Potassium (K)

Total available potassium is referred to the potassium present in the soil solution and held in an exchangheable state by soil colloids. The analytical data indicate that the content of K in these soils is relatively high as total and exchangeable K, but low as soluble K. As a whole, the different classes show no difference in K content. However, the values are generally higher in the surface horizons than in the lower horizons. Compared to the known critical value of available K in soils, which is 0.5 meq/100 g soil, the mean available K value of all the soils tested is 1.7 meq/100 g soil, indicating no deficiency as such. Further, because of the high pH and high contents of Ca and Mg in these soils, a significant response to K fertilization should be rather unlikely to occur.

14.2.9. Organic matter

The importance of organic matter in this subtropical agricultural land is relevant, as in any other region. It improves soil structure, water retention capacity, root penetration, erosion resistance and nutrient storage, all of which contribute to the fertility of the soil. The quantity of organic matter in the soil is dependent upon the impact of the surrounding environmental conditions. The most determining factors are the presence of natural vegetation cover, the moisture and the temperature regimes.

Besides, there is the effect of the type of agricultural use. The organic matter content of this area of the Shabelle floodplain is generally low or very low. Higher percentages have been recorded in swamps and seasonally flooded depressions with dense grassland cover which have a medium content. In general the organic matter of the surface soil ranges from 0.9 to 7.9 per cent with a mean value of 2.2 per cent. The majority of the examined sites have values lower than 2 per cent and often decrease with soil depth even though irregular increases may occur in certain profiles. All the samples from the field sites examined have been analysed and organic matter and carbon values are given as percentage by horizons (see Table 8, Appendix).

14.2.10. Nitrogen (N)

The total nitrogen of all the surface horizons and the nitrate nitrogen determined for the majority of all horizons of investigated profiles indicate that their level is very low or low in most of the soils. The mean value for total N is 0.1 % (SD = 0.08), while the nitrate nitrogen is usually lower than 10 ppm. The nitrate nitrogen values are often much lower for those soils with poor drainage and that confirms what was suggested earlier about the limited decomposition of organic matter and subsequent nitrification.

14.2.11. Carbon-nitrogen ratio (C/N)

The properties of the organic matter in the soil are often characterized by the carbon-nitrogen ratio. The ratio of total carbon percentage to total nitrogen percentage in the soils of the Awdheegle-Daarsalaam area are more or less similar to those reported for other tropical soils. The C/N ratio of the surface horizons of the 26 profiles tested varies between 4 and 38, and the mean value is 15.5. However, the majority (65 %) of the sites have values lower than the average value. This means that the organic matter is well decomposed and gives a satisfactory mineralization of nitrogen for plant growth. On the other hand, since the ratio in fresh plant residues is higher, the higher C/N ratio indicates that organic matter mineralization is suppressed due to impaired drainage. This fact occurs in the inundated depressions and swamp areas.

14.2.12. Phosphorus (P)

The phosphorus was determined as available phosphorus. The analytical data indicate a low level of this component in all the soils of the study area. Although the cultivation history is different, the soils seem to have insignificant diversity in terms of their available phosphorus status. The values are commonly lower than 7.2 ppm. These results are more or less similar to those reported (Macdonald, 1978) for other alluvial soils along the river Shabelle.

15. LAND SUITABILITY CLASSIFICATION

The aims of the land suitability classification are to rank lands as to their fitness for the types of agricultural development which are economically feasible under relevant environmental conditions in a given area.

To satisfy increased food requirements it will be necessary to increase productivity by bringing new lands into production, by introducing irrigation into new farming areas in order to alleviate potentially damaging droughts, and by improving existing irrigated agriculture in the area. The primary objectives of the present study are to evaluate land potentials and problems in soil management with reference to the quality of land for irrigation use, and to provide guidelines on land-use planning purposes for farmers and decision-makers.

To derive a system of land suitability classification adequate for the study area, the system of the United States Bureau of Reclamation (USBR 1954) for irrigated land-use was adopted. The criteria used for placing general soil characteristics into land classes of irrigation suitability are adapted from Beatty et al. (1979), applied to Californian soils.

The major characteristics of the lands within each suitability class are evaluated on the basis of their economic payment capacity under irrigation. The land characteristics considered are soil (S), topography (T) and drainage (D). The factors of each characteristic are listed below:

Soil: texture, structure, horizon arrangement, depth, salinity and alkalinity.

Topography: microrelief and macrorelief.

Drainage: surface and subsurface drainage.

Some of the soil properties, such as water-holding capacity, infiltration and drainability, are not measured directly, but are inferred from other soil data.

The USBR Basic Classes of land used to identify the arable lands according to their suitability for irrigated agriculture are four classes with relative subclasses and defined as follows.

15.1. Generalized land classification system

a. Basic Classes of Land. - Four basic classes are used to identify the arable lands according to their suitability for irrigated agriculture, and one class to eventually identify the nonarable lands. The first three classes represent lands with progressively lower potential for irrigated agriculture. The number of classes mapped in the particular investigated area depends upon the diversity of the land conditions encountered and other requirements as dictated by the objectives of the particular investigation.

Class 1 - Highly arable: lands in this class are highly suitable for irrigation farming, being capable of producing sustained and relatively high yields of a wide range of climatically adapted crops at reasonable cost. They are smooth-lying with gentle slopes. The soils are deep and of medium to moderately fine texture. Roots, air and water penetrate the soil readily. It is moderately permeable, well drained and has good available moisture capacity. These soils are free from harmful accumulations of soluble salts and can be readily reclaimed. Both soil and topographic conditions are such that no specific farm drainage requirements are anticipated, minimum erosion will result from irrigation, and land development can be accomplished at relatively low cost.

Class 2 - Arable: this class comprises lands of moderate suitability for irrigation farming, being measurably lower than Class 1 in productive capacity, adapted to a somewhat narrower range of crops, more expensive to prepare for irrigation, and more costly to farm. They are not so desirable nor of such high value as lands of Class 1 because of certain correctable or noncorrectable limitations. They may have a lower available moisture capacity, as indicated by coarse texture or limited soil depth; they may be only slowly permeable to water because of clay layers or compaction in the subsoil, or they may be moderately saline which may limit productivity or involve moderate costs for leaching. Topographic limitations include uneven surfaces requiring moderate costs for leveling, short slopes requiring shorter lengths of runs, or steeper slopes necessitating special care and greater costs to irrigate and prevent erosion. Farm drainage may be required at moderate cost, or loose rocks may have to be removed from the surface. Any of these limitations may be sufficient to reduce the land from Class 1 to Class 2 but frequently a combination of two or more of them is operating.

Class 3 - Arable: this class comprises lands that are suitable for irrigation development but are approaching marginality for irrigation and are of distinctly restricted suitability because of more extreme deficiencies in the soil, topographic, or drainage characteristics than described for Class 2 lands. They may have good topography, but because of inferior soils have restricted crop adaptability, require larger amounts of irrigation water or special irrigation practices, and demand greater fertilization or more intense soil improvement practices. They may have uneven topography, moderate to high concentration of salts, or restricted drainage, susceptible to correction but only at relatively high cost. Generally, greater risk may be involved in farming Class 3 lands than the better classes of land.

Class 4 - Limited arable or special use: lands are included in this class only after special economic and engineering studies have shown them to be arable.

Class 5 - Nonarable: lands in this class are nonarable under existing conditions, but have potential value sufficient to warrant tentative segregation for special study prior to completion of the classification, or they are lands in existing projects whose arability is dependent upon additional scheduled project construction or land improvements. They may have a specific soil deficiency such as excessive salinity, very uneven topography, inadequate drainage, or excessive rock or tree cover. Special agronomic, economic, or engineering studies are required to provide adequate information, such as extent and location of farm and project drains, or probable payment capacity under the anticipated land use, in order to complete the classification of the lands. The designation of Class 5 is tentative and must be changed to the proper arable class or Class 6 prior to completion of the land classification.

Class 6 - Nonarable: lands in this class include those considered nonarable because of failure to meet the minimum requirements for the other classes of land. Generally, Class 6 comprises steep, rough, broken, or badly eroded land; lands with soils of very coarse or fine texture, or shallow soils over gravel, shale, sandstone, or hardpan; and lands that have inadequate drainage and high concentrations of soluble salts or sodium.

b. Basic Subclasses - The reasons for placing a class lower than Class are indicated by appending the letters "s", "t", and "d" to the class numbe to show whether the deficiency is in "soils", "topography", or "drainage The interaction of accumulative effects of deficiencies may justif placing the land in question in a lower class. Any combination involving a Class 3 deficiency with another deficiency of either Class 2 or 3 level will generally result in placing the land in Class 4, 5 or 6. The basic subclasses of the land classes are s, t, d, st, sd, td and std.

15.2. Land suitability mapping

The mapping of each land suitability class was performed on the basis of the methods defined before, taking into consideration the relevant limitation of each unit of land depending upon the soil physical factors (s) (such as texture, infiltration, available water, drainability (d), the salinity and sodicity hazard (a), the topography (t) and flood hazard (f)). The examined limitations of the identified soil family units were ranked according to the land specification in Tables 5 and 6 and the results of the individual land suitability classes and subclasses are given in Table 7. From this data basis, the delineation of the land suitability classes and subclasses was derived as shown on a 1:30 000 scale map (map 4) of the study.

15.3. Results of land suitability mapping units

The results of the identified land suitability classes and subclasses for the different soil families are described below as follows:

Class 1: Highly suitable land for irrigation

No class 1 land is found in the study area due to the major limitations that stem from (1) the dominant type of fine texture in the subsoil which affects poor drainability due to low hydraulic conductivity, (2) problems of slowed infiltration relative to the silty surface textures, as well as (3) salinity and alkalinity, and (4) flooding hazards, etc. All these factors are reasons for downgrading the land use into the lower potential suitability classes.

Class 2: Suitable land for irrigation

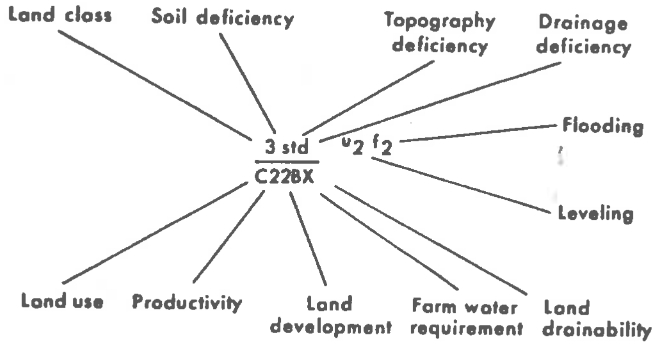
This class is predominantly mapped in the areas where the soils are developed on levees of recent and older alluvium and are exclusively classified within the families of the Entisols order. The land can be separated into four categories as follows:

a) *Lands with class 2 d:* These lands include the soil family of coarse-loamy, mixed (calcareous), Isohyperthermic, Typic Ustifluvents

Table 5. General soil characteristics for Class 1, 2 and 3 of irrigation suitability (adapted from Beatty et al., 1979).

Soil Characteristics	Class 1 - Arable	Class 2 - Arable	Class 3 - Arable
		Soil	
Texture	Sandy loam to friable clay loam	Loamy sand to very permeable clay	Loamy sand to permeable clay
Depth			
To sand, gravel, or cobble	90 cm plus of fsl or finer or 105 cm of sl	60 cm plus fsl or finer 75 cm sl to ls	45 cm plus fsl or finer or 60 cm of coarser
To shale or similar material 15 cm less to rock	150 cm plus 135 cm with minimum of 15 cm gravel overlying impervious material or sandy loam throughout	120 cm plus or 105 cm with minimum of 15 cm gravel	105 cm plus or 90 cm with minimum of 15 cm of gravel overlyin impervious material or loamy sand throughout
To penetrable lime horizon	45 cm with 150 cm penetrable pH is <9.0	35 cm with 120 cm penetrable	25 cm with 90 cm penetrable
Alkalinity	Unless soil is calcareous, total salts are low and evidence of black alkali is absent	pH 9.0 or less unless soil is calcareous, salts are low, and evidence of black alkali is absent	pH 9.0 or less unless so is calcareous, total sa are low, and evidenc of black alkali is abs
Salinity	Total salts not to exceed 0.2%	Total salts not to exceed 0.5%	Total salts not to exce 0.5%
		Topography	
Slopes	Smooth slopes up to 4% in reasonably large size areas	Smooth slopes up to 8% in general gradient	Smooth slopes up to 12% in general gradi
Surface	Even enough to require only small amount of leveling no heavy grading	Moderate grading required but feasible at reasonable cost	Heavy and expensive grading in spots but i amount found feasibl
Cover (loose rocks)	Clearing cost small	Sufficient to reduce productivity and inter-fere with cultural practices, clearing required but at moderate cost	Present in amounts to require expensive but feasible clearing
		Drainage	
Soil and topography	Soil and topographic conditions such that no specific farm drainage requirement is anticipated	Some farm drainage will probably be required; reclamation by artificial means feasible at reasonable cost	Significant farm drainag required; reclamation by artificial means expensive but feasible

Table 6. Examples of standard mapping symbols and components for land classification surveys of the U.S. Bureau of Reclamation (adapted from Olson, 1974).



Basic land classes and subclasses:
- Arable Class 1: 1
- Arable Class 2: 2s, 2t, 2d, 2st, 2sd, 2td, 2std
- Arable Class 3: 3s, 3t, 3d, 3st, 3sd, 3td, 3std
- Limited Arable Class 4: pasture—4Ps, 4Pt, 4Pd, 4Pst, 4Psd, 4Ptd, 4Pstd
  - Similar subclasses for fruit 4F, rice 4R, truck 4V, suburban 4H, sprinkler 4S, and subirrigation 4U
- Tentatively Nonarable Class 5:
  - Pending investigation: 5s, 5t, 5d, 5st, 5sd, 5td, 5std
  - Pending reclamation: 5(1), 5(2s), 5(2t), etc.
    - Project drainage: 5d(1), 5d(2s), 5d(2t), etc.
    - Similar subclasses for flooding: 5f
  - Pending investigation or reclamation
    - Isolated: 5i(1), 5i(2s), 5i(2t), etc.
    - Similar subclasses for high 5h and low 5l

Nonarable Class 6: 6s, 6t, 6d, 6st, 6sd, 6td, 6std
- Isolated: 6i(1), 6i(2s), 6i(2t), etc.
- Similar subclasses for high 6h, low 6l, and water right 6W (6W denotes water rights encountered in the classification)

Subclass designations:
- s—soils
- t—topography
- d—farm drainage

Soils appraisals:
- k—shallow depth to coarse sand, gravel, or cobbles
- b—shallow depth to relatively impervious substrata
- z—shallow depth to concentrated zone of lime
- v—very coarse texture (sands, loamy sands)
- l—moderately coarse texture (sandy loams, loams)
- m—moderately fine texture (silt loams, clay loams)
- h—very fine texture (clays)
- e—structure
- n—consistence
- q—available moisture capacity
- i—infiltration
- p—hydraulic conductivity
- r—stoniness
- y—soil fertility
- a—salinity and alkalinity

Topographic appraisals:
- g—slope
- u—surface
- j—irrigation pattern
- c—brush or tree cover
- r—rock cover

Drainage appraisals:
- f—surface drainage—flooding
- w—subsurface drainage—water table
- o—drainage outlet

Land use:
- C—irrigated cultivated
- L—nonirrigated cultivated
- P—irrigated permanent grassland
- G—nonirrigated permanent grassland
- B—brush or timber
- H—suburban or homestead
- W—waste or miscellaneous

ROW—right of way
- Productivity and land development:
  - 1, 2, 3, 4, or 6 denote land class level of factor, such as: Class 2 productivity, Class 2 development cost—"22"
- Farm water requirement:
  - A—low
  - B—medium
  - C—high
- Land drainability:
  - X—good
  - Y—restricted
  - Z—poor or negligible

Table 7. Land suitability properties of soil mapping units. Classes of limitation ratings.

		Characteristics of the profile (s)			Drainage	Salinity & alkalinity hazard (a)				Land suitability
Soil family mapped symbol	Sites No.	Texture	Infiltration	Availability	Drainability (d)	Salinity class	Sodicity ESP	Topography (t)	Flooding (f)	Suitability class
1 CU/FL	11, 20, 26, 23, 25	3	2	2	3	0-1	1	1	3	4 sd/f
2 CU/F	12, 21	3	2	2	3	0-1	1	1	1-2	3 sd/f
3 CE/F CU/F	1, 2, 4, 9, 8, 17	3	2	2	3	0-1	1	1	1	3 sd
4 CE/FL	24	3	2	2	3	0	1	1	2	3 sd/f
5 FT/FL	19, 22	2	2	2	2	1-2	1	1	1-2	2 sd/a
6 ST/F	6	3	2	2	3	3	3	2	1	4 std/a
7 SA/FL	10	3	2	2	3	3	3	1	1	4 sd/a
8 FT/L	3	2	2	2	2	1	1	2	0	2 std
9 FT/CL	13	1	1	1	2	0	1	1	0	2 d
10 FT/FS	16	2	2	2	3	1	1	2	0	3 std
11 FT/FL GT/FL	5,7,14 15, 18	2	2	2	2	1	1	1	0	2 sd

(9FT/CL) which are characterized by a fairly good profile quality of class 1, but a permanent deficiency of drainability may result from low hydraulic conductivity in the subsoil. Other deficiencies are minor and easily rectifiable.

b) *Land with class 2 sd:* These soils comprise the soil family of fine-loamy, gypsic (calcareous), Isohyperthermic, Typic Gypsiorthids (11FT/FL, GT/FL). They have lower quality of suitability for irrigation than the preceding, class 2 d, due to the additional permanent deficiencies of the profile characteristics.

c) *Land with class 2 sd/af:* These soils comprise the soil family of fine-loamy, mixed (calcareous), Isohyperthermic, Typic Ustifluvents. These lands are inferior to the previous classes due to the additional problems of salinity hazard class 2 in some profiles or possible occasional floodings during very high river flows.

d) *Land with class 2 std:* The quality of these soils is downgraded due to the associated permanent and rectifiable deficiencies of the soil factors, and further constraints of class 2 topography. The soils are those classified as fine-silty, mixed (calcareous), Isohyperthermic, Typic Ustifluvents. (8FT/L)

Class 3: Marginally suitable for irrigation

This class comprises the soils developed from older or recent alluvium which are identified and mapped within majority families of Vertisols, but there are also Entisols:

- Fine, montmorillonitic (calcareous), Isohyperthermic, Udic Chromusterts (2CU/F)
- Fine, montmorillonitic (calcareous), Isohyperthermic, Entic Chromusterts (3CE/F, CU/F)
- Fine-loamy montmorillonitic (calcareous), Isohyperthermic, Entic Chromusterts (4CE/FL)
- Fine-silty, mixed (calcareous), Isohyperthermic, Typic Ustifluvents (10FT/FS).

These soils have clay profiles which are relatively impermeable due to problems of poor aggregate stability, slow infiltration and low hydraulic conductivity. These permanent deficiencies which result in class 3 limitations of both soil profile and drainability, as well as sometimes flooding hazard or topographic constraints, limit their flexibility and thus they are downgraded to 3sd, 3sd/f, 3std, respectively.

Class 4: Limited suitable

This class is mapped in areas of recent alluvium located in the seasonally flooded depressions and swamp areas or in areas flanking the present levees of the river course. They are classified within the Vertisols or Aridisols.

The present family of Vertisols is fine-loamy, montmorillonitic (calcareous), Isohyperthermic, Udic Chromusterts CU/FL. These soils have the same limitations as the previous class 3, but, in addition, the flooding hazard is so frequent to be in class 3. Hence, the land is downgraded into class 4, but if the flooding can be controlled the land may become upgraded to class 3.

On the other hand, the present families of Aridisols are:

- Fine, mixed (calcareous), Isohyperthermic, Typic Salorthids (6ST/F).
- Fine-loamy, mixed (calcareous), Isohyperthermic, Aquollic Salorthids (SA/FL).

These soils also have the same limitations as the preceding class but, in addition, they have class 3 salinity and alkalinity hazard and possibly artificial drainage is unlikely to favour the leaching of salts from the land due to the permanent deficiency of the fine texture and the poor drainaibility. However, these soils can have special use for cultivation of, for example, Cocos nucifera, otherwise, they may include non-arable class 6.

16. SOIL MANAGEMENT

Most of the land in the study area is cultivated and is either under rainfed or irrigated agriculture. Rainfed farming is practiced where there is no access to irrigation. Thus, farmers are forced to optimize the utilization of the rainfall obtained in this semi-arid tropical region with low and relatively unreliable rainfall. Farmers usually undertake land preparation a short time before the start of the rainy periods although there are difficulties in working the heavy clay textured soil and specifically the Vertisols due to their becoming hard or sticky respectively when dry or wet. The farmers establish small square-formed chains of microcatchments on the field surface to minimize run-off and erosion and to ensure adequate water storage. This kind of management practice is suitable to harvest water but may result sometimes in crop damage after heavy rainstorms if short-term waterlogging takes place in the depression between the ridges of the microreliefs or in the prepared basins due to the lack of aeration. However, it is difficult to suggest alternative measures to overcome the waterlogging, such as establishing adequate drains, due to the limited possibilities of the farmers.

Irrigated agriculture is usually confined to a relatively narrow area stretching about 1 to 4 kilometres away from the Shabelle river. So, further development of permanent irrigated agriculture in the area is necessary to increase crop production. The experience based on lessons of the past has shown the permanence of successful irrigation agriculture, since early civilizations in Egypt and in China, and the failure in others, like Mesopotamia between the Tigris and Euphrates Rivers, as well as many types more recently developed throughout the world (for example, Middle Shabelle, Jawhar, Somalia). These successes or failures have been indicated to result from the combination of factors involving climate, soil nature, water quality, type of crops and management practices. However, successful irrigation agriculture may mainly depend upon reasonably good quality water available for use and good management practices that include the establishment of appropriate drainage systems. On the other hand, the failures have been mainly attributed to waterlogging and salinization due to indiscriminate use of poor quality water and lack of drainage in the fine-textured soils of low permeability.

Regarding soil conditions of the present study area, only small areas have been abandoned due to salinity problems. Salinity occurs specifically among the soils previously classified as soil families of the great group of Salorthids and which support only salt-tolerant species of grass and sparse shrubs. In the other soils, salinity is commonly absent or low in the upper horizons, but some fields present a medium potential salinity level in the deeper horizons. Also, the area is dominated by fine-textured soils, either Vertisols or Entisols, and they are characterized by slow internal drainage.

Furthermore, the Shabelle water has a poor quality in certain periods, as mentioned earlier (refer to Figure No. 1), due to the high content of dissolved salts which is a limiting factor of its indiscriminate use for irrigation. Nowadays, there is no establishment of drainage systems and no problems of water logging except in the river-flooded area and there is less salt-affected soil. Therefore, with regard to the physical limitations of the soils and the poor quality water, it will be required in the future to undertake efficient measures for improving the situation in the long-run, in the form of better water management, building of modern drainage systems and efficient water utilization. In other words, there is a need to overcome the most common problems on fields such as (1) absence of field distribution systems like water-courses and field channels, (2) poor land levelling and consequent uneven water spreading, (3) failure to apply the exact amounts of crop water requirements to sustain plant growth, (4) restricted drainage and (5) high water tables which result in salinity.

17. LABORATORY METHODS OF ANALYSIS

Physical and chemical analysis of the soil samples were carried out at the Faculty of Agriculture Laboratory, Somali National University, the Central Agriculture Research Station, Afgoiye, and the National Laboratory of Agricultural Chemistry, Uppsala, Sweden.

The methods of analysis used are described briefly below and for their complete descriptions the following references would be of use:

USDA Handbook No. 60 (1954), FAO Soils Bulletin No. 10 (1970), FAO Soils Bulletin No. 38/2 (1982), Hesse P. R. (1971) and C. A. Black et al., Part 1, Part 2 (ASA, 1965).

17.1. Soil Preparation

Soil samples were first spread on trays, air dried, ground by hand with the help of a mortar, mixed thoroughly and passed through a 2 mm sieve.

17.II. Physical Analysis

1. Particle size distribution analysis

Test soil samples were dispersed chemically with Calgon and shaken mechanically with a high speed horizontal shaker in distilled water for two and a half hours. The samples were transferred into cylinders of half litre size. The volume was made up with distilled water and then stirred for 2 minutes with a special plunger. After that the time for sedimentation was recorded. Taking into consideration temperature in the sample, the desired fractions were sampled by the pipette method at 10 cm depth; first clay plus silt and then clay alone. The pipetted samples were collected in clean beakers of known weight, oven-dried at 105°C, cooled in desiccators and weighed. The weights were corrected with regard to the content of the dispersing agent prior to the determination of silt and clay fractions. Finally, the sand fraction was calculated by the difference method (A. C. Black et al., ASA, 1965).

2. Saturated soil paste extracts and saturation percentage determination

A saturated soil paste was made by adding distilled water to 200 g of air dry soil mixing with a spatula until the characteristic saturation endpoint was reached. The amount of water added to the air dry soil, and a correction factor with regard to the hygroscopic moisture content of the soil was used to calculate the saturation percentage of moisture content. The saturated soil paste was allowed by employing suction with the help of a vacuum pump.

The saturation extracts were tested for the following parameters: Electrical conductivity (E.C.), pH, soluble cations and anions.

17.III. Chemical Analysis

1. Total salts

As a direct indication the total salt content of the saturation extracts, the electrical conductivity measurement (mS cm^{-1}) was employed using a standard wheatstone bridge.

2. pH measurement

The pH of the saturation extract was determined using a pH-meter of type Corning with glass electrodes.

3. Cation exchangeable capacity (Bascombe's method)

Barium chloride solution buffered at pH 8.1 was used to saturate the soil samples with barium. After centrifuging and discarding the original solution, the excess amount of barium was removed by repeated washing with distilled water. A magnesium sulphate solution was used to exchange barium with magnesium. The exchanged barium was removed as barium sulphate precipitate. The remaining magnesium in the test sample was titrated against EDTA, and the CEC was calculated employing the difference method between the amount of magnesium added and the magnesium remaining in the soil solution.

4. Exchangeable cations (Ca^{2+}, Mg^{2+}, Na^+ and K^+)

Soil samples were saturated with ammonium acetate solution buffered at pH 7. The concentration of Ca^{2+}, Mg^{2+} and Na^+ in the filtrate was determined by atomic absorption, while flame photometry was used for K^+. (A. C. Black et al., Part 2, 1965).

5. Exchangeable sodium percentage (ESP)

Exchangeable sodium percentage was directly calculated using the following ratio between exchangeable sodium and cation exchange capacity per cent.

$$ESP = \frac{Na}{CEC} \times 100$$

6. Water soluble cations

6.1 Calcium and magnesium (Ca + Mg)

Ca and Mg in the saturation extracts were determined according to the methods available in FAO Soil Bulletin No. 10 (1970), where a buffer solution of ammonium chloride - ammonium hydroxide (approximately 10 drops) was used together with 1 ml of 2% potassium cyanide as stabilizer. The indicator used was Eriochrome black T of approximately 3 to 4 drops and titrated against 0.05 N EDTA.

6.2 Potassium and sodium

K and Na in the saturation extracts were determined by flame photometry.

6.3 Sodium adsorption ration (SAR)

Sodium adsorption in soil is related to the relative activity in exchange reaction and the sodium adsorption ratio is defined by equation:

$SAR = Na+/\sqrt{Ca^{2+} + Mg^{2+}/2}$

where Na^+, Ca^{2+} and Mg^{2+} represent the concentrations in meq/l.

7. Water soluble anions

7.1 Chlorides (Mohr titration method)

The chlorides were titrimetrically determined in the saturation extracts against 0.01 N silver nitrate solution using potassium chromate as the indicator (ASA, 1965).

7.2 Carbonate and bicarbonates (Acidimetric titration method)

The titration of the saturation extract was here carried out against H_2SO_4 where the indicators used were phenolphthalein for carbonate and methyl orange for bicarbonates (USDA, Handbook No. 60, 1954).

7.3 Sulphates and nitrate (ion chromatographic determination)

The calcium chloride extractable fraction of sulphate in soil was determined by ion chromatography. As control, sulphate contents in a few of the samples extracted with water were gravimetrically determined (described by USDA, 1972).

The same extract was utilized for the determination of nitrate in the samples by ion chromatography.

8. Calcium Carbonate - Calcimeter

Taking into consideration any variations occurring in room temperature, soil samples (1 g) were treated with dilute hydrochloric acid and the amount of carbon dioxide released from carbonates was measured volumetrically. The carbonate determination was made using a calcimeter of type De Asis from Italy.

9. Total nitrogen (Kjeldahl method)

Soil samples were digested with a concentrated sulphuric acid - salycilic acid mixture using a catalyst + mixture of K_2SO_4 and selenium. Concentrated NaOH as added to the digest before steam distillation. The ammonia released was trapped in a solution of boric acid and the titration was made against 0.01 N hydrochloric acid using mixed indicators of methyl red and bromcresol green (FAO Soils Bulletin No 38/2, 1982).

10. Organic carbon and organic matter (Walkly-Black method)

The organic carbon was determined by digesting soil samples with an excess of potassium dichromate in a medium composed of sulphuric and phosphoric acids. The excess potassium dichromate was determined by titration against ferrous ammonium sulphate solution in the presence of diphenylamine indicator.

The organic matter content in the soil was calculated from the percentage of organic carbon after multiplying by the Van Bemmelen conversion factor (% organic carbon x 1.724) (FAO Soils Bulletin No. 10, 1970).

11. Available phosphorus

The extraction of available phosphorus from the soil samples was done according to the Bray and Kurtz No. 2 method using 0.1 N HCl and 0.03 N NH_4F solution. The phosphorus content in the extracted solutions was read off spectrophotometrically with an autoanalyzer (FAO Soils Bulletin No. 38/2, 1982).

12. Gypsum

The presence of gypsum in saturation extracts was qualitatively evaluated by precipitation with acetone.

10. SITE AND PROFILE DESCRIPTIONS

During the course of this survey, 26 representative profiles of the identified soil families were described in greater detail and the position of each profile in the landscape is shown on the soil map (Map 3). The profile descriptions are given below.

Site 1

Classification: Entic Chromustert, fine, montmorillonitic (calcareous) Isohyperthermic.
Location: 2 km southwest of Aw Deegle on the west bank of Shabelle River.
Physiographic location: Recent alluvial floodplain, elevation about 72 m a.s.l.
Drainage: Moderately well drained.
Topography: Flat, micro-relief slightly gilgai.
Vegetation: Cereal crops; maize, sesame.
Parent material: Alluvial clay.
Sampled by: M. Alim.
Date: 16/7/85.
Colours are for moist soil unless otherwise stated.

BRIEF DESCRIPTION OF PROFILE NO. 1

A deep, moderately well drained, clay textured soil with mainly reddish brown to dark reddish brown in the upper layers and mixed reddish brown with very dark gray or dark reddish gray with reddish brown. The upper horizons are well cracked to a depth of 50 cm, with weak fine platy structure overlying moderate fine to medium subangular blocky structure. Below 50 cm the profile is compact with slickensides. Roots penetrate to 50 cm depth. The profile is calcareous throughout the horizons. The soil has a Class 1 salinity hazard and is placed in irrigation suitability Class 3sd due to profile deficiencies such as low infiltration, hydraulic conductivity and available water capacity.

Profile 1

Ap 0-20 cm Reddish brown (5YR 4/3) clay, weak fine platy structure; very friable (moist), weakly cemented when dry; Frequent very large to large cracks; fine pores common; plentiful very fine to medium roots; slightly calcareous; pH 8.4;

gradual smooth boundary.

A 12 20-35 cm Dark reddish brown (5YR 3/4) clayey moderate fine to medium subangular blocky; hard when dry; plentiful very fine to medium roots; slightly calcareous; pH 8.4; gradual irregular boundary. Frequent very large to large cracks.

A 13 35-50 cm Reddish brown (5Yr 4/4) clay; moderate fine to medium subangular block; firm moist; few large cracks; pressure faces; few fine roots; calcareous; pH 8.2; gradual irregular boundary.

A 14 50-80 cm Reddish brown (5YR 4/3) clay; moderate medium angular black; firm (moist); large slickensides common, few fine roots, calcareous; pH 8.3; diffuse; irregular boundary.

AC 85-125 cm Mixed reddish brown (5YR) 4/3) and very dark grey (5YR 3/1), clay; moderate fine to medium angular blocky; friable (moist); calcareous; pH 8.2; diffuse irregular boundary.

C 125-150 cm Mixed dark reddish grey (5YR 4/2) and reddish brown (5YR 4/3) clay; firm when moist; very friable; calcareous, pH 8.

Site 2

Classification; Udic Chromustert, fine, montmorillonitic (calcareous) Isohyperthermic.

Location: 2 km southwest of Aw Deegle, 100 m west of Shabelle River.

Physiographic Location: Recent alluvial flood plain, elevation about 71 m a.s.l.

Drainage: Moderately well drained.

Topography: Slight depressional area, surface flat, large cracks.

Vegetation: Grasses and sparse shrubs.

Parent material: Sandy clay loam alluvium.

Soil surface: Large cracks.

Date: 16/7/85.

Colours are for moist soil unless otherwise stated.

BRIEF DESCRIPTION OF PROFILE NO. 2

Deep alluvial profile, moderately well drained with dominant clay loam texture, but includes a layer of sandy loam at 50 cm depth. Colours are reddish brown. Evidence of pronounced cracks occur from the upper horizon to a depth of 80 cm. Moderately well developed prismatic structure in the upper horizon and underneath subangular blocky structure. Roots penetrate to 80 cm. The profile is calcareous throughout. The soil has no salinity hazard and the land is given a Class 3 sd rating.

Profile 2

A 11 0-50 cm	Reddish brown (5 YR 4/3) clay loam; moderate very coarse to coarse prismatic; hard dry moderately cemented; frequent large to very large cracks; micro to fine roots common; calcareous; pH 8.4; gradual wavy boundary.
A 12 50-80 cm	Reddish brown (5YR 4.5/4) sandy loam; moderate fine to medium subangular blocky; hard dry moderately cemented; scarce large cracks; fine roots common; calcareous; pH 8.2; gradual wavy boundary.
C 80-140 cm	Reddish brown (5YR 4/3) sandy clay loam; structureless, massive; friable moist; calcareous; pH 8.0.

Site 3

Classification: Typic Ustifluvent, loam, mixed (calcareous) Isohyperthermic.
Location: 4.25 km west of Awdheegle.
Physiographic location: Levee of old alluvial plant, about 73 m a.s.l.
Drainage: Well drained.
Topography: Level, raised level of flood plain.
Vegetation: Sparse shrubs.
Parent material: Alluvial clay with a loamy veneer.
Soil surface: Termites.
Date: 18/7/85.
Colours are for moist soil unless otherwise indicated.

BRIEF DESCRIPTION OF PROFILE NO. 3

A two-layered deep soil, with loam overlaying a clay loam subhorizon, with weakly developed crumb structure in the upper horizon and compacted structureless subsoil. Roots develop in the upper 30 cm but some fine roots also penetrate down to 70 cm. Soft nodules of carbonate are found in layers below 30 cm. The soil has no salinity hazard (Class 0) and is placed in land class 2 std on the basis of profile deficiences in terms of slow infiltration, hydraulic conductivity and raised topography.

Profile 3

A 11 0-30 cm	Brown (7.5YR 4.5/4 dry) loam; weak medium to fine crumb;

	soft (dry); weakly cemented; very fine pores common; many medium to fine roots; slightly calcareous; pH 8.3; abrupt wavy boundary.
A 12 30-70 cm	Brown (7.5YR 4.5/4 dry) clay loam; massive; slightly hard (dry); many very fine to fine pores; many fine roots; medium to fine soft nodules of carbonates; strongly calcareous; pH 8.1; abrupt wavy boundary.
AC 70-100 cm	Dark brown (10YR 4/3) sandy loam; massive; slightly hard (dry); medium to fine soft nodules of carbonates; strongly calcareous; pH 8.5; abrupt smooth boundary.
C 100-135 cm	Dark brown (7.5YR 3/2 dry) clay loam; massive; firm (dry); weakly cemented; medium to fine soft nodules of carbonates; strongly calcareous; pH 8.1.

Site 4

Classification: Entic Chromustert, fine, montmorillonitic (calcareous) Isohyperthermic.

Location: 3.5 km west-northwest of Jawhar-Awdheegle and 3.0 km northeast of Darasalaam.

Physiography location: Recent alluvial flood plain, about 72 m a.s.l.

Drainage: Moderately well drained.

Topography: Level.

Vegetation: Former farmland now abandoned and covered by thick shrubs.

Parent material: Sandy clay loam alluvium.

Soil surface: Sink-holes, self-mulching, large cracks.

Date: 18/7/85.

Colours are moist soil unless otherwise indicated.

BRIEF DESCRIPTION OF PROFILE NO. 4

A deep, moderately well drained, with alternating clay, clay loam and silty clay horizons and reddish brown to dark reddish brown and dark gray colours. Weak, very coarse prismatic breaking to fine and medium subangular blocky and massive underlying horizon. Large cracks from the surface reach down to 80 cm but visible pressure faces from 60 cm down to the subsoil provide evidence of some degree of compaction of the profile. Roots penetrate to 100 cm. The site is calcareous throughout. The soil has no salinity hazard class and is placed in land class 2 sd due to subsoil deficiencies of texture and structure and consequent slow infiltration/hydraulic conductivity. Salinity is Class 1 and the land is given a Class 3 sd rating.

Profile 4

A 11 0-60 cm	Reddish brown (5YR 4/3) clay; weak very coarse prismatic breaking to fine to medium subangular blocky; slightly hard (dry), large cracks; fine pores common; fine to large roots; calcareous; pH 8.4; gradual wavy boundary.
A 12 60-80 cm	Reddish brown to dark reddish brown (5YR 3.5/3) clay loam; moderate coarse prismatic; slightly hard (dry); weakly cemented; large cracks, few pressure faces; fine pores common; fine to large roots; calcareous; pH 8.2; clear smooth boundary.
C1 80-100 cm	Dark grey (10YR 4/1) silty clay; massive; slightly hard (dry) weakly cemented; few pressure faces; few fine roots; calcareous; pH 8.2; abrupt smooth boundary.
C2 100-150 cm	Reddish brown (5YR 4.5/4) clay loam; massive; firm (moist); weakly cemented; few fine roots; calcareous; pH 8.1.

Site 5

Classification: Typic Ustifluvents, fine-loamy, mixed (calcareous) Isohyperthermic.
Location: 1.0 km north northwest of Darsalaam.
Physiographic location: Recent alluvial flood plain, about 72 m a.s.l.
Drainage: Moderately well drained.
Topography: Level.
Vegetation: Recently cleared farmland.
Parent material: Alluvial clay with a layer of loamy sand in the subsurface.
Soil surface: Fine cracks, termites.
Date: 21/7/85.

BRIEF DESCRIPTION OF PROFILE NO. 5

A deep, moderately well drained soil with predominant clay loam to clay texture and reddish brown colours. Weak, very coarse, prismatic breaking to fine crumbs overlying moderate fine to medium subangular blocky structured horizons. The soil is compact in the lower horizons. Roots penetrate deep to 90 cm. The profile is calcareous throughout and has a Class 1 salinity and is given a land class 2 sd rating.

Profile 5

A11 0-40 cm Reddish brown (5YR 4/3) clay loam; weak very coarse prismatic breaking to weak fine crumb; friable; weakly cemented; fine cracks, fine pores common; medium to fine roots; calcareous; pH 7.7; gradual wavy boundary.

A 12 40-70 cm Reddish brown (5YR 4/3) clay loam; moderate fine to medium subangular blocky; friable moist weakly cemented; fine pores common; few medium to fine roots; calcareous; pH 8.2; gradual irregular boundary.

A 13 70-90 cm Reddish brown (5YR 4/3) clay; moderate fine to medium subangular blocky; firm moist weakly cemented; few fine pores; few fine roots; calcareous; pH 7.5; abrupt smooth boundary.

IIC1 90-120 cm Yellowish brown (7.5YR 5/4) sandy loam; massive; very friable; moist weakly cemented; few very fine roots; calcareous; pH 8.3; abrupt smooth boundary.

IIIC2 120-150 cm Reddish brown to dark reddish brown (5YR 3.5/3) clay; massive; firm; weakly cemented; calcareous; pH 8.2.

Site 6

Classification: Typic salorthids, fine, mixed (calcareous) Isohyperthermic.
Location: 0.25 km west of Jawhar-Awdheegle.
Physiographic location: Recent alluvial flood plain.
Drainage: Poorly to imperfectly drained.
Topography: Gently sloping edge at depressional part of floodplain.
Vegetation: Poor production of maize due to salinity.
Parent material: Alluvial clay.
Soil surface: Appears moist with salinity efflorescences.
Date: 21/7/85.
Colours are for moist soil unless otherwise indicated.

BRIEF DESCRIPTION OF PROFILE NO. 6

A deep, poorly to imperfectly drained, profile with alternating alluvial deposition of clay loam and clay textures with reddish brown and dark reddish brown colours. The profile is massive throughout with white soft powdery salts. Roots penetrate deep to 90 cm. The soil has poor textural characteristics and possibly a high water table has influence during higher flows of the river. The soil has Class III salinity, resulting in it being given a Class 4 std/a.

Profile 6

A 11 0-55 cm Reddish brown (5YR 4/4) clay loam; massive; firm (moist); weakly cemented; many fine pores; fine roots common; white powdery soft salts; calcareous; pH 7.8; abrupt smooth boundary.

C 1 55-90 cm Dark reddish brown (5YR 3/4) clay loam; massive; firm (moist); weakly cemented; few fine pores; fine roots common; white powdery salts; calcareous; pH 8; clear smooth boundary.

C 2 90-150 cm Dark reddish brown (5YR 3/4) clay; massive; firm (moist); weakly cemented; calcareous; pH 7.7.

Site 7

Classification: Typic Ustifluvents, fine loamy, mixed (calcareous) Isohyperthermic.

Location: 0.75 km northeast of Daarsalaam, about 0.25 km north of the Shabelle River, about 68 m a.s.l.

Physiographic location: Recent alluvial flood plain.

Drainage: Moderately well drained.

Topography: Level depression.

Vegetation: Recently cleared of bush.

Parent material: Sandy loam alluvium.

Date: 22/7/85.

BRIEF DESCRIPTION OF PROFILE NO. 7

A deep alluvial profile with alternating sandy clay loam, clay, sandy clay loam and clay loam textures and dark reddish gray to brown colours. Fine cracks occur in the upper horizon to 25 cm depth. Roots penetrate to 100 cm depth where imperfect drainage may take place during part of the year. The profile is calcareous throughout. The soil has salinity Class I and is downgraded in land class 2 sd due to subsoil drainage limitations such as hydraulic conductivity.

Profile 7

A 11 0-25 cm Dark reddish gray (5YR 4/2) sandy clay loam; moderate medium prismatic; firm (slightly moist); fine cracks;

many fine pores; large to fine roots common; calcareous; pH 7.7; gradual wavy boundary.

A 12 25-45 cm Dark reddish gray to reddish brown (5YR 4/2.5) clay; moderate medium subangular blocky; hard (dry); weakly cemented; few fine pores; many fine roots; calcareous; pH 7.2; clear smooth boundary.

AC 45-50 cm Brown (7.5YR 5/4) sandy clay loam; massive; very friable (dry); weakly cemented; many fine pores; few fine roots; calcareous; pH 7.1; abrupt smooth boundary.

C 1 50-100 cm Reddish gray to reddish brown (5YR 5/2.5) clay loam, with reddish yellow mottles (7.5YIR 6/8); massive; hard (dry); weakly cemented; few fine roots; calcareous; pH 7.8; clear smooth boundary.

IIC2 100-150 cm Brown (7.5YR 5/4) sandy loam; massive; slightly moist; weakly cemented; calcareous; pH 7.6.

Site 8

Classification: Udic Chromustert, fine, montmorillonitic (calcareous), Isohyperthermic.
Location: 1.5 km southwest Aybuutey, about 2 km south of the Shabelle River.
Physiographic location: Older alluvial flood plain about 76 m a.s.l.
Drainage: Moderately well drained.
Topography: Level portion of higher alluvial plain.
Vegetation: Sparse bush with thin grass cover.
Parent material: Silty clay loam alluvium.
Soil surface: Sink-holes, self-mulching.
Date: 24/7/85.

BRIEF DESCRIPTION OF PROFILE NO. 8

A deep, moderately well drained profile, with a moderately fine crumb surface horizon overlying, moderate medium prismatic breaking to moderate medium angular blocky structured subsoil with dark reddish brown to dark brown colours. A few large cracks appear in the subsoil from 10- 85 cm depth. Very compact in the subsoil with slickensides below the depth of 30 cm. Roots are well developed down to 85 cm. The profile is strongly calcareous throughout. The soil has been given a land class 3 sd rating, downgraded because of clay texture, low infiltration and slow hydraulic conductivity. Salinity class 1.

Profile 8

Ap	0-10	Dark reddish brown (5YR 3.5/3) clay; moderate fine crumb; firm (moist); many fine pores; medium coarse roots; calcareous; pH 8.7; clear smooth boundary.
A 11	10-32	Dark reddish brown (5YR 3.5/3) clay; moderate medium prismatic, breaking to moderate medium angular blocky; very firm (slightly moist); few large vertical cracks; fine pores common; many fine roots; strongly calcareous; clear wavy boundary; pH 8.3.
A 12	32-85	Dark brown (7.5YR 4/2.5) clay; strong medium to coarse prismatic breaking to moderate fine to medium angular blocky; hard (dry); few large vertical cracks; slickensides; few fine pores; few fine roots; strongly calcareous; pH 8.1; clear irregular boundary.
C 1	85-105	Dark reddish brown (5YR 3.5/3) clay; strong medium subangular blocky; slickensides; friable (slightly most); no visible pores; no roots; strongly calcareous; pH 7.9; clear smooth boundary.
IIC2	105-125	Reddish brown (5YR 5/3) silty clay loam; massive; friable (slightly moist); strongly calcareous; pH 8.1.

Site 9

Classification: Udic Chromustert, fine, montmorillonitic (calcareous) Isohyperthermic.
Location: 1.5 km west of Aybuutey, about 0.75 km southwest of the Shabelle River.
Physiographic location: Older alluvial flood plain, about 76 m a.s.l.
Drainage: Moderately well drained.
Topography: Level portion of higher alluvial plain.
Vegetation: Cereal crops, maize, sesame, tomatoes and onions.
Parent material: Alluvial clay.
Soil surface: Ploughed.
Date: 24/7/85.
Colours are for moist soil unless otherwise indicated.

BRIEF DESCRIPTION OF PROFILE NO. 9.

A deep moderately well drained, dark reddish brown colour with silty clay loam to clay texture and moderate fine crumb topsoil and moderate, medium to fine subangular blocky structured subsoil A few large to fine cracks occur in the subsoil The lower horizons are compact and present wedge-shaped structure and slickensides. The roots penetrate to 67 cm depth. The downward drainage is slowed due to the fine texture, so the land class is placed in Class 3 sd. The soil salinity is Class 1.

Profile 9

Ap	0-10 cm	Dark reddish brown (5YR 3/4) silty clay loam; moderate fine crumb; friable (slightly moist); many fine pores; medium to fine roots; strongly calcareous; pH 8.1; clear irregular boundary.
A 12	10-67 cm	Dark reddish brown (5YR 3/4) clay; moderate medium to fine subangular block, very firm (slightly moist); few large to fine vertical cracks; fine pores common; strongly calcareous; pH 8.4; clear irregular boundary.
C	67-120 cm	Reddish brown (5YR 4/3) clay; few fine mottles, red (2.5YR 4/6); moderate fine blocky and wedge shapes; friable moist; many medium to fine slickensides; few fine pores; strongly calcareous; pH 8.4.

Site 10

Classification: Aquollic Salorthids, fine-loamy, mixed (calcareous) Isohyperthermic.
Location: 1.5 km southwest of Jawhar-Awdheegle, 0.5 km south of the Shabelle River.
Physiographic location: Recent alluvial flood plain.
Drainage: Poorly to imperfectly drained.
Topography: Level.
Vegetation: Grass on abandoned farmland, due to salinity.
Parent material: Variable alluvial sandy clay.
Soil surface: Salinity efflorescence.
Date: 30/7/85.
Colours are for moist soil unless otherwise indicated.

BRIEF DESCRIPTION OF PROFILE NO. 10

A deep, poorly to imperfectly drained soil with reddish brown colour and clay loam texture. The whole profile is structureless with soft powdery salts in the subsoil and calcareous throughout. The roots penetrate to 53 cm depth. The soil has salinity hazard Class 3. The soil has been given a Class 4 sd/a rating, downgraded due to the poor drainage characteristics and Class 3 salinity and sodium hazards.

Profile 10

A 11 0.15 cm	Dark reddish brown (5YR 3/2) clay loam; massive; friable (moist); fine roots common; soft powdery carbonates; calcareous; pH 7.9; clear smooth boundary.
A 12 15-53 cm	Dark reddish brown (5YR 3.5/3) clay loam; massive; friable (moist); fine roots common; white soft powdery salts; calcareous; pH 7.9; abrupt smooth boundary.
IIA13 53-72 cm	Light brown (7.5YR 6/4) sandy loam; massive; very friable (moist); calcareous; pH 7.4 abrupt smooth boundary.
IIIC 72-150 cm	Dark brown (7,5YR 4/2) and (7.5YR 4/4) clay loam; massive; friable (very moist); soft powdery and medium to fine concretions of gypsum; calcareous; pH 8.1.

Site 11

Classification: Udic Chromustert, fine-loamy, montmorillonitic (calcareous) Isohyperthermic.
Location: 2.5 km eastsoutheast of Jawhar on the east side of Shabelle

River, on edge of swamp.
Physiographic location: Recent alluvial flood plain, surface flat. 71 m a.s.l.
Drainage: Very poorly drained.
Topography: Flat depression.
Vegetation: Dense grass with patches of bush.
Parent material: Alluvial clay.
Soil surface: Soft mulching with burnt grass ashes, sink-holes; microrelief gilgai.
Date: 31/7/85.
Colours are for moist soil unless otherwise indicated.

BRIEF DESCRIPTION OF PROFILE NO. 11

A deep, very poorly drained profile showing alternating layers of alluvial deposition. The upper horizon consists of moderate fine crumb and very dark gray loam, which overlies reddish brown to dark reddish brown clay loam. The structure of the subsoil is moderate medium to fine subangular blocky and underlying strong medium to coarse prismatic breaking to fine medium subangular blocky. At 40 cm depth there is more compact reddish brown clay with slickensides. The profile shows evidence of large vertical cracks below 5 cm depth. The soil is strongly calcareous throughout. Roots are well developed in the whole profile. The soil has a lowered potential for irrigation, due to the low infiltration and hydraulic conductivities in the lower clay textured horizons. The soil is subject to seasonal waterlogging during periods of river overflows. Thus the soil is placed in a land class 4 sd/f rating. Salinity hazard is Class 1.

Profile 11

A 11 0-5 cm Very dark gray (10YR 3/1) loam; moderate fine crumb; friable (slightly moist), filled cracks; many fine pores; medium to fine roots; slightly calcareous; pH 8.7; abrupt irregular boundary.

A 12 5-15 cm Reddish brown (5YR 4/3) clay loam moderate medium to fine subangular blocky; firm (slightly moist); large vertical cracks; few fine $CaCO_3$ nodules; fine pores common; common medium to fine roots; strongly calcareous; pH 8.3; clear irregular boundary.

A 13 15-40 cm Dark reddish brown (10YR 3.5/4) clay loam; strong medium to coarse prismatic breaking to fine medium subangular blocky; very firm (slightly moist), large vertical cracks; many fine pores; many medium to fine roots; strongly calcareous; pH 8.4; clear irregular boundary.

A 14 40-150 cm Reddish brown (5YR 4/3) clay; strong medium to fine subangular blocky; very firm (slightly moist); large vertical cracks; very common slickensides; fine roots common; strongly calcareous, pH 7.9.

Site 12

Classification: Udic Chromustart, fine, montmorillonitic (calcareous) Isohyperthermic.
Location: 2.5 km southeast of Jawhar.
Physiographic location: Recent alluvial plain, about 74.1 m a.s.l.
Drainage: Moderately well drained.
Topography: Level to very gently sloping.
Vegetation: Sparse bush.
Parent material: Clay loam alluvium.
Soil surface: Sink-holes, self-mulching, fine cracks, microrelief gilgai.

Date: 1/8/85.
Colours are for moist soil unless otherwise indicated.

BRIEF DESCRIPTION OF PROFILE NO. 12

A deep, moderately well drained with alternating dark reddish brown, reddish brown and dark brown to very dark gray colours. The upper horizon is silty clay loam with weak fine platy texture from 0 to 25 cm depth. The subsoil is clay with moderate fine to medium subangular blocky and few large cracks from 35 to 80 cm depth. The profile is compacted in the lower horizons below 80 cm depth by showing evidence of slickensides. Roots penetrate well to 100 cm. The whole profile is calcareous and gypsum crystals occur in the subsoil below 35 cm depth. The salinity hazard is Class 1. The soil is downgraded to land class 3sd/f due to possible drainage limitations such as low hydraulic conductivity.

Profile 12

A 11	0-35 cm	Dark reddish brown (5YR 3.5/3) silty clay loam; weak fine platy; very friable moist, weakly cemented; common fine filled vertical cracks, fine pores; plentiful very fine to medium roots; strongly calcareous; pH 8.5; gradual wavy boundary.
A 12	35-80 cm	Reddish brown (5YR 4/3) clay; moderate fine to medium subangular blocky; friable moist; moderately cemented; few large cracks; fine and very fine pores common; fine and very fine roots common; gypsum concretions; calcareous; pH 8.4; gradual irregular boundary.
AC	80-100 cm	Dark brown (10YR 4/3) and very dark gray (10YR 3/1) clay; moderate fine to medium subangular blocky; firm, moist, weakly cemented; few medium slickensides; few very fine roots; gypsum concretions; calcareous; pH 8.3; clear smooth boundary.
C	100-150 cm	Reddish brown (5YR 4.5/3) loam; massive; firm moist; weakly cemented; calcareous; pH 7.9.

Site 13

Classification: Typic Ustifluvent, coarse, loamy, mixed (calcareous) Isohyperthermic.
Location: 1.0 km southeast of Jawhar-Awdheegle.
Physiographic location: Levee of older alluvial plain, about 77 m a.s.l.

Drainage: Well drained.
Topography: Level.
Vegetation: Sparse bush.
Parent material: Layers of variable textured (sandy loam, loam silty loam) alluvial materials.
Date: 1/8/85.
Colours are for moist soil unless otherwise indicated.

BRIEF DESCRIPTION OF PROFILE NO. 13

A deep well drained profile with alternating textural horizons. Reddish brown to brown of massive of recent alluvium of sandy loam, clay loam and sand textures deep to 80 cm. Roots are present down to 80 cm. The profile varies from slightly calcareous upper horizon to calcareous subsoil. The soil is downgraded to land class 2 d due to moderate subsoil drainage limitation such as low hydraulic conductivity.

Profile 13

A 11 0-27 cm Reddish brown (5YR 4/3) sandy loam; massive; friable (dry); many macro- and micropores; very weakly cemented; fine roots common; slightly calcareous; pH 8.5; gradual wavy bondary.

AC 27-64 cm Reddish brown (5YR 4/3) and strong brown (7.5YR 5/6) clay loam; massive; slightly hard (dry); weakly cemented; fine pores common; fine roots common; calcareous; pH 8.4; abrupt smooth boundary.

IIC1 64-80 cm Light brown (7.5YR 6/4) sand; structureless; loose (dry); few fine roots; slightly calcareous; pH 8.4; abrupt smooth boundary.

IIIC2 80-97 cm Dark reddish gray (5YR 4.2/5) clay loam; massive; friable (slightly moist); weakly cemented; slightly calcareous; pH 8.4; abrupt smooth boundary.

IIIC3 97-110 cm Brown (7.5YR 5/4) silt loam; massive; very friable (moist); calcareous; pH 8.4; clear smooth boundary.

IIIC4 110-150 cm Brown (5YR 5/3), light brown (7.5YR 6.5/4), reddish yellow (7.5YR 6/8) silt loam; massive; very friable (moist); calcareous; pH 8.3.

Site 14

Classification: Typic Ustifluvent, fine loamy, mixed (calcareous)

Isohyperthermic.
Location: 2.75 km south of Ayibuutey.
Physiographic location: Levee of older alluvial plain, about 75 m a.s.l.
Drainage: Moderately well drained.
Topography: Level.
Vegetation: Abandoned farmland with sparse trees.
Parent material: Alluvial clay.
Date: 5/8:,85.
Colours are for moist soil unless otherwise indicated.

BRIEF DESCRIPTION OF PROFILE NO. 14

A moderately well drained profile showing alluvial stratification in which clay loam horizons overlie silty clay horizon. The upper horizons have moderate fine to medium crumb and moderate medium to coarse prismatic breaking to moderate fine to medium subangular blocky structure. The whole profile is calcareous. Roots are present down to 100 cm. The soil is given a Class 2 sd rating due to low subsoil hydraulic conductivity. The salinity is Class 1.

Profile 14

A 11	0-20 cm	Dark reddish brown (5YR 3/4) clay loam; moderate fine to medium crumb; soft (dry); weakly cemented; many fine pores; fine roots common; calcareous; pH 8.2; abrupt smooth boundary.
A 12	20-60 cm	Dark brown (5YR 4/3) clay loam; moderate medium to coarse prismatic breaking to moderate fine to medium subangular blocky; hard (dry); weakly cemented; many fine pores; fine roots common; calcareous; pH 8.1; gradual irregular boundary.
AC	60-100 cm	Dark brown 5YR 4/3) silty clay; moderate fine to medium subangular blocky; firm (slightly most); weakly cemented; few fine pores; few fine roots; calcareous; pH 7.9; gradual irregular boundary.
C	100-150 cm	Dark brown (5YR 4/3) and red (7.5YR 5/8) mottled clay loam; massive; hard (slightly moist); weakly cemented; calcareous; pH 7.8.

Site 15

Classification: Typic Gysiorthid, fine, loamy, gypsic, Isohyperthermic.

Location: 1.0 km south of Aybuutey.
Physiographic location: Older alluvial flood plain, about 76 m a.s.l.
Drainage: Well drained.
Topography: Level.
Vegetation: Seasonal crops, maize and sesame.
Parent material: Alluvial clay containing gypsum in the subsoil.
Soil surface: Fallow.
Date: 5/8/85.
Colours are for moist soil unless otherwise indicated.

BRIEF DESCRIPTION OF PROFILE NO. 15

A deep well drained, two-layered alluvial soil with weak medium subangular blocky structured loam horizon overlying massive slightly hard clay loam subsoil. The upper layer has mixed reddish brown and dark reddish gray and the latter has brown colour. White soft powdery salts and concretions of carbonate and gypsum crystals are prevailing in the lower horizon. Roots are well developed throughout the horizon. The profile is calcareous to strongly calcareous. Salinity hazard is Class 1. The soil has moderate deficiencies in terms of subsoil structure and high content of carbonates and gypsum and thus the land is downgraded to a class 2 sd rating.

Profile 15

A 1	0-25 cm	Reddish brown to dark reddish gray (5YR 4/2.5) loam; weak medium subangular blocky; slightly hard (dry); weakly cemented; irregular fine cracks; white powdery salts; calcareous; pH 7.5; abrupt smooth boundary.
C ?	25-145 cm	Brown (7.5YR 5/4) clay loam; massive; slightly hard (dry); weakly cemented; many fine roots; soft powdery concretions of gypsum carbonates, strongly calcareous; pH 8.0.

Site 16

Classification: Typic Ustifluvent fine silty, mixed (calcareous) Isohyperthermic.
Location: 4.0 km southeast of Aybuuteey.
Physiographic location: Levee of older alluvial flood plain, about 77 m a.s.l.
Drainage: Well drained.

Topography: Level, raise levee.
Vegetation: Recently cleared of bush.
Parent material: Alluvial clay.
Soil surface: Surface crusting.
Date: 7/8/85.
Colours are for moist soil unless otherwise indicated.

BRIEF DESCRIPTION OF PROFILE NO. 16

A deep drained alluvial profile with alternating textural horizons in which silty clay loam and silty clay overlie a clay horizon. The upper horizon has a weak fine to medium crumb structure while the underlying horizons are moderate, coarse to medium subangular blocky. The subsoil is compacted and structureless. Roots are well developed and extend down to the lower layer. The soil is calcareous throughout. The salinity is Class 1. The profile has drainage limitations in the subsoil and thus is downgraded to a land class 3 std rating due to low infiltration and slow hydraulic conductivity.

Profile 16

A 11	0-15 cm	Dark reddish brown (5YR 3/4) silty clay loam; weak fine to medium crumb; soft (dry); fine pores common; medium to fine roots common; calcareous; pH 8.6; abrupt smooth boundary.
A 12	15-43 cm	Dark brown (5YR 4/3) silty clay; moderate; coarse to medium subangular blocky; firm (slightly moist); weakly cemented; fine cracks; fine pores common; fine roots common; calcareous; pH 8.1; abrupt smooth boundary.
C	43-150 cm	Dark brown (5YR 4/3) clay; massive; firm (slightly moist); weakly cemented; few fine pores; few fine roots; calcareous; pH 8.1.

Site 17

Classification: Entic Chromustert, fine loamy, montmorillonitic (calcareous) Isohyperthermic.
Location: 3.0 km southeast of Daarasalaam.
Physiographic location: Older alluvial flood plain, about 76 m a.s.l.
Drainage: Moderately well drained.
Topography: Level.
Vegetation: Ploughed land, prepared seasonal crops of maize and sesame.
Parent material: Alluvial clay.

Soil surface: Ploughed.
Date: 5/8/85.
Colours are for moist soil unless otherwise indicated.

BRIEF DESCRIPTION OF PROFILE NO. 17

A deep moderately drained clay loam textured soil with mainly reddish brown and dark reddish browh to reddish brown in the subsoil The upper horizon has a mixed moderate to fine crumb and is subangular blocky. Below there is strong very coarse to coarse prismatic breaking to strong, medium to coarse subangular blocky structure. Large vertical cracks occur below the ploughed upper layers from 15 to 63 cm depth. The lower layers are compacted, showing presence of slickensides and pressure faces. The profile is calcareous throughout. Salinity hazard is zero, but the soil is given a land class 3 sd, due to possible slow hydraulic conductivity in the subsoil.

Profile 17

Ap	0-15 cm	Reddish brown (5YR 4/3) clay loam; moderate medium to fine crumb and subangular blocky; hard (dry); weakly cemented; fine pores common; very common medium to fine roots; calcareous; pH 7.3; abrupt smooth boundary.
A 12	15-40 cm	Reddish brown (5YR 4/3) clay loam; strong very coarse to coarse prismatic breaking to strong, medium to coarse subangular blocky; very hard (dry); strongly cemented; many fine pores; few medium and many fine roots; large vertical cracks; few small pressure faces; calcareous; pH 7.5; clear smooth boundary.
AC	40-63 cm	Dark reddish brown to reddish brown (5YR 3.5/3) clay loam; strong medium to fine subangular blocky; very hard (dry); strongly cemented; few fine pores; few fine roots; few fine vertical cracks; small slickensides; calcareous; pH 7.8; abrupt smooth boundary.
C1	63-95 cm	Reddish brown (5YR 4.5/3) clay loam; massive; friable (slightly moist); weakly cemented; calcareous; pH 7.5; abrupt smooth boundary.
C2	95-145 cm	Dark reddish brown (5YR 4/2) silty clay; massive; friable (moist); weakly cemented; calcareous; pH 7.1.

Site 18

Classification: typic Ustifluvent, fine loamy, mixed (calcareous) Isohyperthermic.
Location: 1.0 km south of Daarsalaam.
Physiographic location: Recent alluvial flood plain, raised about 75 m a.s.l.
Drainage: Moderately well drained.
Topography: Very gently sloping.
Vegetation: Farmland growing maize and sesame.
Parent material: Alluvial clay.
Soil surface: Termites.
Date: 5/8/85.
Colours are for moist soil unless otherwise indicated.

BRIEF DESCRIPTION OF PROFILE NO. 18

A deep moderately alluvial profile with alternating deposition of loam and clay loam textured horizons with dark brown, dark reddish brown to reddish brown and reddish brown colours. The upper horizon is massive and overlies weak fine to medium subangular blocky subsoil. The profile evidences soft powdery and fine concretions of carbonates from 10 to 90 cm. The salinity hazard is Class 2 and thus the soil is downgraded to a class 2 sd rating due to imperfect drainage in the subsoil and the salinity hazard.

Profile 18

Ap 0-10 cm	Dark brown (10YR 4/3) loam; massive; soft (dry); weakly cemented; common medium to fine pores; many medium to fine roots; slightly calcareous; pH 8.3; clear smooth boundary.
A 12 10-45 cm	Dark reddish brown to reddish brown (5YR 3.5/3) clay loam; weak fine to medium subangular blocky; soft (dry); weakly cemented; many fine pores; common fine roots; soft white powdery carbonates; strongly calcareous; pH 7.9; clear smooth boundary.
AC 45-90 cm	Reddish brown (5YR 4/3) loam; massive; friable (moist); weakly cemented; few fine pores; few fine roots; soft fine carbonate concretions; calcareous; pH 7.9; diffuse irregular boundary.
C 90-135 cm	Reddish brown (5YR 4/5) clay with yellowish red (5YR 5/8) mottles; massive; friable (moist); weakly cemented; calcareous; pH 7.6.

Site 19

Classification: Typic Ustifluvent, fine loamy, mixed (calcareous) Isohyperthermic.
Location: 1.0 km east of Jawhar-Awdheegle.
Physiographic location: Levee of older alluvial flood plain, about 77 m a.s.l.
Drainage: Moderately well drained.
Topography: Level.
Vegetation: Sparse shrubs and grass.
Parent material: Alluvial clay.
Soil surface: Undisturbed under natural vegetation.
Date: 8/8/85.
Colours are for moist soil unless otherwise indicated.

BRIEF DESCRIPTION OF PROFILE NO. 19

A deep moderately well-drained profile with alternating textural horizons. Reddish brown alluvium of loam, clay loam clay, loam, sandy loam and clay loam textures extend down to 125 cm. The upper layer has a weak medium to fine medium granular structure overlying weak medium to fine subangular blocky and then massive. The soil is massive in the lower horizons with abrupt changes of texture which possibly affect the drainability of the profile. Roots are well-developed throughout the soil. The whole profile is calcareous or slightly calcareous. The soil is given a Class 2 sd/a rating and a Class 1 salinity hazard.

Profile 19

A 11	0-10 cm	Reddish brown (5YR 4/3.5) loam; weak medium to fine granular; soft (dry); common fine to medium pores; common medium to fine roots; slightly calcareous; pH 8.3; clear wavy boundary.
A 12	10-48 cm	Reddish brown (5YR 4/4.5) clay loam; weak medium to fine subangular blocky; slightly hard (dry); weakly cemented; common fine pores; few pressure faces; many fine roots; calcareous; pH 8.2; clear smooth boundary.
AC	48-70 cm	Reddish brown (5YR 4/3.5) clay; massive; firm (slightly moist); weakly cemented; few fine pores; few fine roots; calcareous; pH 8.4; clear wavy boundary.
C1	70-85 cm	Reddish brown (5YR 5/4) loam, massive; firm (slightly moist); weakly cemented; few fine pores; few fine roots; calcareous; pH 8.2; clear wavy boundary.
C2	85-100 cm	Reddish brown (5YR 4.5/4) sandy loam; structureless;

loose (slightly moist); few fine roots; slightly calcareous; pH 8.2; abrupt smooth boundary.

IIC3 100-110 cm Dark brown (7.5YR 4/4) clay loam; massive; firm (moist); very few roots; calcareous; pH 8.2; abrupt smooth boundary.

IIIC4 110-125 cm Brown (7.5YR 5/4.5) loam; massive; firm (moist); very fine roots; calcareous; pH 8.1.

Site 20

Classification: Udic Chromustent, fine loamy, mixed (calcareous) Isohyperthermic.
Location: 1.75 km east of Jawhar.
Physiographic location: Recent alluvial flood plain, 71 m a.s.l.
Drainage: Poorly drained.
Topography: Flat depression.
Vegetation: Bush.
Parent material: Alluvial clay.
Soil surface: Self-mulching, sink-holes, termites, shell fragments.
Date: 6/8/85.
Colours are for moist soil unless otherwise indicated.

BRIEF DESCRIPTION OF PROFILE NO. 20

A deep poorly drained profile with alternating textural horizons of clay loam and clay of dark reddish brown and reddish brown colours. The upper horizons are well structured and show evidence of vertical cracks. The subsoil is compacted with presence of slickensides. Roots penetrate to 105 cm. The whole profile is calcareous with many gypsum crystals present in the subsoil. The land has Class 4 sd/f rating, downgraded due to low subsoil hydraulic conductivity and on account of a flooding hazard. Salinity is Class 1.

Profile 20

A 11 0-10 cm Dark reddish brown (5YR 3/4) clay loam; moderately weak, fine to medium crumb; friable (slightly moist); weakly cemented; filled vertical cracks; common fine pores; plentiful medium to fine roots; slightly calcareous; pH 7.8; clear smooth boundary.

A 12 10-55 cm Dark reddish brown (5YR 3/4) or (3/) clay; strong very coarse to coarse prismatic breaking to medium to fine subangular blocky; very firm (moist); weakly cemented; large vertical cracks; many fine pores; common fine roots; very few fine carbonate concretions; calcareous; pH 7.6; clear smooth boundary.

AC 55-105 cm Reddish brown (5YR 4/3) clay; strong coarse to medium angular blocky; very firm (moist); weakly cemented; large to fine vertical cracks; few fine carbonate concretions; few fine roots; calcareous; pH 7.4; clear irregular boundary.

C 105-150 cm Mixed dark reddish gray (5YR 3.5/2) and reddish brown (5YR 4/3) clay; massive,; firm (moist); weakly cemented; slickensides intersecting to form wedge shapes; few fine carbonates concretions; many gypsum concretions; calcareous; pH 8.

Site 21

Classification: Udic Chromustert, fine, montmorillonitic (calcareous) Isohyperthermic.
Location: 2 km northeast of Jawhar on east side of the Shabelle River.
Physiographic location: Recent alluvial flood plain, about 71 m a.s.l.
Drainage: Very poorly drained.
Topography: Flat depression, slight gilgai.
Vegetation: Fallow crop land used to grow sesame.
Parent material: Alluvial clay.
Soil surface: Sink-holes, cracks, partially burned grasses.
Date: 8/8/85.

BRIEF DESCRIPTION OF PROFILE NO. 21

A deep very poorly drained profile with clay textured horizons of dark reddish brown and dark reddish gray colours. The structure is well developed with moderate, very fine to coarse crumb. Upper layer and moderate, very coarse prismatic breaking to strong, medium to coarse angular blocky in the subsoil. The profile shows evidence of vertical cracks and is compacted in the subsoil presenting slickensides and a few fine carbonate nodules. The whole profile is strongly calcareous. Roots are concentrated in the upper 50 cm. The soil has deficiencies in terms of slow infiltration, hydraulic conductivity due to high clay texture and possible flooding occurrence during river overflows. Salinity is Class 1 and the land is given a class 3 sd/f rating.

Profile 21

A 11 0-20 cm Dark reddish brown (7.5YR 3/2) clay; moderate very fine to coarse crumb; friable (slightly moist); few vertical cracks; many fine pores; common medium roots; strongly calcareous; pH 8.4; clear smooth boundary.

A 12 20-50 cm Dark reddish gray (5YR 3.5/2) clay with very dark gray to black mottles; moderate very coarse prismatic breaking to strong medium to coarse angular blocky; firm (slightly moist); few fine vertical cracks; few fine pores; common fine roots; few fine $CaCO_3$ nodules; strongly calcareous; pH 8.2; clear smooth boundary.

AC 50-150 cm Reddish brown (5YR 4/3) clay with very dark gray to black mottles; moderate coarse angular blocky, very firm moist; few fine vertical cracks; many large slickensides; very few fine pores; strongly calcareous; pH 8.0.

Site 22

Classification: Typic Ustifluvent, fine loamy, mixed (calcareous) Isohyperthermic.
Location: 0.75 km northeast of Jawhar.
Physiographic location: Recent alluvial flood plain, about 71 m a.s.l.
Drainage: Moderately well drained.
Topography: Flat depression.
Vegetation: Cereal crop, maize.
Parent material: Alluvial clay.
Soil surface: Furrowed, many shell fragments, termites.
Date: 13/8/85.
Colours are for moist soil unless otherwise indicated.

BRIEF DESCRIPTION OF PROFILE NO. 22

A deep, moderately well drained alluvial profile with alternating layers of sandy loam, clay, loam and clay texture and reddish brown, yellowish red and dark brown colours. The upper horizon is massively friable which overlies moderate medium to fine subangular blocky and is massively friable in the lower horizons. Roots are present down to 150 cm. The profile varies from slightly calcareous to calcareous. The soil has a high potential for irrigation but the lower horizons have limiting low hydraulic conductivities and thus the soil is downgraded to a land class 2 sd/a rating on account of the flooding hazard.

Profile 22

Ap 0-15 cm Reddish brown (5YR 4/6) sandy loam; massive; friable (moist); weakly cemented; many medium to fine pores; common medium to fine roots; slightly calcareous; pH 8.1; abrupt smooth boundary.

A 11 15-37 cm Yellowish red (5YR 4/6) clay; moderate medium to fine subangular blocky; firm (moist); weakly cemented; many fine pores; many fine roots; calcareous; pH 8; abrupt smooth boundary.

A 12 37-45 cm Dark brown (5YR 4/2.5) loam; massive; friable (moist); weakly cemented; few fine pores; few fine roots; slightly calcareous; pH 8.0; clear irregular boundary.

C 45-150 cm Dark brown (5YR 3.5/3) clay; massive; firm (moist); weakly cemented; few fine roots; calcareous; pH 8.0.

Site 23

Classification: Udic Chromustert, fine loamy, montmorillonitic (calcareous) Isohyperthermic.

Location: 20 km south of Awdheegle, about 1.0 km east of the Shabelle River.

Physiographic location: Recent alluvial flood plain, about 71 m a.s.l.

Drainage: Moderately well drained.

Topography: Level, raised level of flood plain with slight gilgai microrelief.

Vegetation: Dense grass with sparse shrubs 2-2.5 m in height.

Parent material: Alluvial clay, with a thin surface cover of loamy material.

Soil surface: Self-mulching, shell fragments.

Date: 13/8/85.

Colours are for moist soil unless otherwise indicated.

BRIEF DESCRIPTION OF PROFILE NO. 23

A deep moderately well-drained alluvial profile showing prominent stratification in which clay loam with dark reddish brown colour and moderate medium to fine crumb structure overlies loam which is reddish brown, and weak fine platy, and clay, which is dark reddish brown and has coarse to fine subangular blockly structure in lower horizons. No cracking visible at the surface, but prominent vertical cracks extend from down 10 cm to 145 cm. Very compact below a depth of 52 cm with slickensides. The profile ranges from slightly calcareous to strongly calcareous. The soil has poor textural characteristics in the subsoil resulting in slow infiltration and hydraulic conductivity which downgrade it to Class 4 sd/f, but there is no salinity hazard.

Profile 23

A 11	0-10 cm	Dark reddish brown (5YR 3/2) clay loam; moderate medium to fine crumb; soft (dry); weakly cemented; common fine pores; medium to fine roots; very fine filled cracks; slightly calcareous; pH 8.5; abrupt wavy boundary.
A 12	10-22 cm	Reddish brown (5YR 4/4) loam; weak fine platy; soft (dry); weakly cemented; common medium to fine pores; fine filled vertical cracks; many medium to fine roots; calcareous; pH 8.3; abrupt wavy boundary.
IIA13	22-52 cm	Dark reddish brown (5YR 3/2) clay; coarse to fine subangular blocky; very firm (moist); weakly cemented; large vertical cracks; many fine roots; slightly calcareous; pH 8.0; abrupt wavy boundary.
IIC	52-145 cm	Dark reddish brown (5YR 3/4) to reddish brown (5YR 4/4) clay; strong very coarse prismatic; very firm (moist); weakly cemented; large vertical cracks; wedge shaped slickensides; strongly calcareous; pH 7.9.

Site 24

Classification: Entic Chromustert, fine loamy, montmorillonitic (calcareous) Isohyperthermic.
Location: 2 km north of Jawhar, about 0.5 km east of the Shabelle River.
Physiographic location: Recent alluvial flood plain about 75 m a.s.l.
Drainage: Moderately well drained.
Topography: Level with slight gilgai microrelief.
Vegetation: Dense grass, abandoned farmland.
Parent material: Alluvial clay.
Soil surface: Self-mulching, sink-holes, shell fragments.
Date: 13/8/85.
Colours are for moist soil unless otherwise indicated.

BRIEF DESCRIPTION OF PROFILE NO. 24

A deep reddish brown moderately well-drained profile with loam, moderate fine crumb structure, overlying clay texture with moderate very coarse prismatic breaking to strong medium to coarse subangular blocky structure. Filled cracking visible in the surface, but prominent vertical cracks appear in the subsoil. Roots penetrate deep to 75 cm. Soft powdery and few fine carbonate nodules occur in the subsoil and the profile is strongly calcareous throughout. The soil, being subject to frequent flooding, has high clay texture which downgrades its potential irrigability to land class 3 sd/f, but has no salinity hazard.

Profile 24

A 11	0-8 cm	Reddish brown (5YR 4/3 dry) loam; moderate fine crumb; very friable (slightly moist); filled cracks visible; many fine pores; strongly calcareous; pH 7.6; gradual smooth boundary.
A 12	8-75 cm	Reddish brown (5YR 5/4) clay; moderate very coarse prismatic breaking to strong medium to coarse subangular blocky; few large cracks; few fine pores; common fine roots; few fine $CaCO_3$ nodules; Strongly calcareous; pH 8.6; gradual smooth boundary.
C	75-150 cm	Reddish brown (5YR 4/3) clay; massive; very firm (moist); no visible pores; no roots; strongly calcareous; pH 7.4; clear smooth boundary.

Site 25

Classification: Udic Chromustert, fine loamy montmorillonitic (calcareous) Isohyperthermic.
Location: 1.25 km north of Jawhar, about 0.75 km northeast of Shabelle River.
Physiographic location: Recent alluvial flood plain, about 75 m a.s.l.
Drainage: Moderately well drained.
Topography: Level with slight gilgai microrelief.
Vegetation: Dense grass, abandoned farmland.
Parent material: Alluvial clay.
Soil surface: Sink-holes, shell fragments.
Date: 13/8/85
Colours are for moist soil unless otherwise indicated.

BRIEF DESCRIPTION OF PROFILE NO. 25

A deep moderately well-drained profile with moderate fine crumb structure and consists of dark brown clay loam texture overlying moderate, medium to coarse subangular blocky of mixed dark brown, dark reddish brown and dark reddish gray clay textured subsoil. Fine filled cracks visible in the upper horizon but pronounced large cracks show in the subsoil. Roots are well developed down to 84 cm. The soil is subject to frequent flooding and has moderate limitations of drainage deficiencies in terms of clay textures in the lower horizons which result in too slow infiltration and hydraulic conductivity. Consequently, the soil is given a class 4 sd/f rating. Salinity Class 1.

Profile 25

A 11	0-20 cm	Dark brown (7.5YR 3.5/2) clay loam; moderate fine crumb; very friable (slightly moist); fine filled cracks visible; many fine pores; common fine roots; strongly calcareous; pH 8.7; abrupt wavy boundary.
A 12	20-84 cm	Mixed dark brown (7.5YR 4/4), dark reddish brown (5YR 3/4) and dark reddish gray (5YR 4/4) clay; moderate medium to coarse subangular blocky; hard (dry); larges vertical cracks; few fine pores; few fine roots; strongly calcareous; PH 8.2; abrupt irregular boundary.
AC	84-150 cm	Reddish brown (5YR 4/3) clay; moderate very coarse prismatic breaking to strong medium to coarse angular blocky; slightly hard (dry); fine vertical cracks; few fine pores; strongly calcareous; pH 8.2.

Site 26

Classification: Entic Chromustert fine loamy, montmorillonitic (calcareous) Isohyperthermic.
Location: 1 km south of Awdheegle, 0.5 km east of Shabelle River.
Physiographic location: Flat depression; in alluvial flood plain, about 75 m a.s.l.
Drainage: Poorly drained.
Topography: Flat depression.
Vegetation: Bush with dense grass.
Parent material: Alluvial clay.
Soil surface: Self-mulching, sink-holes, shell fragments.
Date: 15/8/85.
Colours are for moist soil unless otherwise indicated.

BRIEF DESCRIPTION OF PROFILE NO. 26

A deep poorly drained alluvial profile with alternating textural stratification of sandy loam, clay and silty clay with reddish brown to dark brown colours. The upper layer has moderate fine crumb overlying moderate medium prismatic and structureless subsoil. Vertical large cracks are visible in the lower horizons where they are not filled. A few fine carbonate nodules occur from 5 to 63 cm depth. The profile is calcareous to strongly calcareous. Roots penetrate well to 140 cm. Salinity is Class 1. The soil has possibly drainage limitation due to high clay texture subsoil and is subject to seasonal flooding, thus is given a class 4 sd/f rating.

Profile 26

A 11	0-5 cm	Reddish brown (5YR 4/3) sandy loam; moderate fine crumb; very friable (slightly moist); filled cracks visible; many fine pores; plentiful medium to fine roots; calcareous; pH 7.5; clear smooth boundary.
A 12	5-63 cm	Reddish brown (5YR 4/3.5) clay; moderate medium prismatic; very firm (slightly moist); large vertical cracks; common fine pores; common fine roots; few fine $CaCO_3$ nodules; strongly calcareous; pH 7.9; gradual irregular boundary.
AC	63-140 cm	Dark brown (7.5YR 4/4) silty clay; massive; firm (slightly moist); few fine vertical cracks; very few fine pores; few fine roots; strongly calcareous; pH 7.7.

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20. REFERENCES

Beaty et al., 1979. Planning the uses and management of land. Agronomy No. 21.

Black, C.A. et al., 1965. Methods of soil analysis. Part 1 and Part 2. Agronomy No. 9, American Society of Agronomy, Inc., Publisher.

Bolletino della societa italiana della scieza del suolo. 1976. No. 10, Firenze. Italy.

Boul, S.W., 1983. Soil Genesis and Classification. S.W. Boul, F.D. Hole, R.J. Mc Cracken, 2nd edition.

Buringh, P., 1979. Introduction to the study of soils in tropical and subtropical regions. Centre for Agricultural Publishing and Documentation, Wageningen.

Central Agricultural Station, Afgoi 1967, Shabelle river water quality: 1965-66. USAID/SOMALI Republic. University of Wyoming Team. Mogadishu, June 1967, 29 pp, tables.

Central Agricultural Station, Afgoi. Shabelle Water Salinity Measurements: Electrical conductivity in micromhos/cm. 1965-1970.

Central Agricultural Research Station, Afgoi. Rainfall and temperatures at Afgoi, Somali Republic. 1965/66/USAID/Somali Republic. University of Wyoming Team. Mogadishu, June 1967. 19 pp.

Cottenie, A. 1980. Soil and plant testing as a basis of fertilizer recommendations. FAO Soils Bulletin 38/2, FAO, Rome, 112 pp.

Credito Somalo. 1967. Chart of seasons in Somalia.

Dent, D. & Young, A., 1981. Soil Survey and Land Evaluation. London, George Allen/Unwin.

Dewis, J. & Freitas, F.C.R., 1970. Physical and Chemical Methods of Soils and Water Analyses. FAO Soils Bulletin No. 10, Rome.

Dregne, H.E., 1976. Soils of Arid Regions. Elsevier Scientific Publishing Company.

Dudal, R., 1965. Dark clay soils of tropical and subtropical regions. FAO Agricultural Development paper No. 83, Rome.

Eck, H.V. & Unger, P.W., 1985. Advances in Soil Science, Volume 1, pp. 66-95.

EL-Swaify et al., 1985. Advances in Soil Science, Volume I, p. 157.

Fantoli, A., 1964. Carte pluviometriche atmospheriche della Somalia. Ministero Africa Italiana. Ufficio Studi. Roma 1953. Contributo alle climatologia della Somalia. Ministero Affari Esteri. O.P.L. Roma. 487 pp.

FAO & UNSF, 1966. Agricultural and Water Survey. Somali Republic. Vol. 1 (General Report).

FAO, 1968. Agricultural Water Survey, Somalia. Final Report.
Vol. I (General)
Vol. II (Water Resources)
Vol III (Landforms and Soils). FAO SF/36/SOM, Rome.

FAO/UNESCO, 1973. Irrigation, Drainage and Salinity. An international source book. Paris/UNESCO.

FAO (1973). Reclamation and management of calcareous soil. Soils Bull. No. 21. FAO, Rome.

FAO/UNESCO, 1974. Soil Map of the World, 1:5 000 000. Vol. 1. Legend. Dudal, R. et al., UNESCO, Paris.

Field Extract of Soil Taxonomy, 1980. International Soil Museum, Wageningen. 95 pp. Reprinted 1982.

Gerard, A.J., 1981. Soils and landforms. An integration of Geomorphology and Pedology. London.

Giovanni Merla et al., 1979. A geological map of Ethiopia and Somalia. Firenze, Italy.

Goosen, D., 1967. Aerial photointerpretation in soil survey. FAO Soils Bulletin No. 6, FAO, Rome.

Heinonen, R., 1985. Soil Management and Crop Water Supply. 4th ed. Swedish University of Agricultural Sciences, Uppsala, Sweden.

Hesse, P.R., 1971. A textbook of soil chemical analysis. London: John Murray.

Hunting Technical Services Ltd. 1977. Inter-riverine Agriculture Development Study. Settlement Development Agency, Somalia.

International Service for National Agricultural Research (ISNAR), 1983 Development of an Agricultural Research System. Report to the Government of the Democratic Republic of Somalia. The Hague, Netherlands.

Kifle, H., 1983. The Role of State Farms in Agrarian Transformation in Centrally Planned Economics in Africa. In paper for Workshop on Transformation of Agrarian Systems in Centrally Planned Economics in Africa. Arusha, Tanzania, 17-22 October 1983.

Landon, J.R., 1984. Booker Tropical Soil Manual. Booker International Limited.

Leuder, D.R., 1959. Aerial photography interpretation, Mc Graw-Hill Book Company, INC.

Ministry of Agriculture & Ministry of Public Works and Communication. 1964. Surface and Underground Water Resources of the Shabelli Valley. Mogadishu.

Mokma, D.L. et al., 1984. Geoderma, 33, pp. 219-226.

Olson, G.W., 1984. Field guide to soils and the environment. Dowden & Culver, Inc.

Pons, L.J. & Zonneveld, I.S., 1965. Soil ripening and soil classification, International Institute for Land Reclamation and Improvement, Wageningen, Netherlands.

Richards, L.A., 1954. Diagnosis and improvement of saline and alkali soils. U.S. Salinity Laboratory Staff. Agriculture Handbook no. 60. United States Department of Agriculture.

Ruthenberg, H., 1980. Farming systems in the tropics. Oxford Science Publications. Oxford University Press.

Shainberg, J.D. Oster., 1978. Quality of irrigation water, III C Publication No. 2. International Irrigation Information Center, Israel.

United Nations Development Program (Special Fund). Project for the water control and managament of the Shebelli River, Somalia, FAO. Hunting Technical Services Ltd. and Sir Macdonald & Partners (London). November 1969, 141 pp, tables, maps, diagrams.

Vol. I	(General Report)
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USDA, 1951. Soil Survey Manual, Handbook No. 18, 503 pp.

USDA, 1975. Soil Taxonomy, Agricultural Handbook No. 436, 754 pp.

Verstappen, H. Th., 1983. Applied Geomorphology. Geomorphological Surveys for Environmental Development, International Institute for Aerial Survey and Earth Science (I.T.C.), Enschede, The Netherlands. Elsevier.

Virgo, K.J., 1981. Observations of Cracking in Somali Vertisols, Soil Sci., 131:60-61.

Western, S., 1978. Soil Survey Contracts and Quality Control. Oxford University Press.

White, L.P. Aerial Photography and Remote Sensing for Soil Survey. Oxford University Press.

Worthington, E.B., 1976. Arid Land Irrigation in Developing Countries. Environmental problems and effects. Pergamon Press.

Young, A., 1976. Tropical soils and soil survey.

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PHYSICAL AND CHEMICAL ANALYSIS OF ALL PROFILES SAMPLED (Table 8, Appendix)

Profile No.	Depth (cm)	Sand % (2-0.5 mm)	Silt % mm (0.5-0.002)	Clay % <0.002 mm	Texture class	s.p. %	pHe (H_2O)	ECe mS/cm	Soluble cations m.e./l: $Ca^{+2}+Mg^{+2}$	Na^+	K^+	Soluble anions m.e./l: Cl^-	SO_4^{-2}	HCO_3^-	CO_3^{-2}
1	0- 20	33	26	41	C	52	8.4	0.5	5.6	1.1	0.4	2.0	1.9	3.5	-
	20- 35	30	30	40	C	50	8.4	0.6	5.6	0.9	0.1	2.5	5.4	2.5	-
	35- 50	28	15	57	C	56	8.2	0.9	7.8	2.5	0.1	-	9.7	2.5	-
	50- 85	25	20	55	C	56	8.3	0.6	4.4	1.5	0.1	2.5	20.7	2.5	-
	85-125	29	21	50	C	59	8.2	1.0	7.8	2.1	0.1	3.0	16.1	1.0	-
	125-150	35	18	47	C	50	8.0	3.9	67.7	6.0	0.2	3.5	1212.	1.0	-
2	0- 50	27	37	36	CL	50	8.4	1.0	10.0	1.8	0.3	3.0	19.0	2.5	-
	50-100	78	9	13	SL	38	8.2	0.8	10.0	1.2	0.3	2.5	12.5	1.5	-
	100-140	52	20	28	ScL	48	8.0	1.0	11.1	1.6	0.2	3.0	19.4*	1.6	-
3	0- 30	47	33	20	L	42	8.3	1.1	7.8	3.6	0.5	12.5	5.7	1.8	-
	30- 70	34	33	33	CL	45	8.1	5.4	40.0	45.0	0.4	-	11.2	1.0	-
	70-100	57	23	20	SL	43	8.5	9.5	35.5	87.0	0.4	-	31.7	1.0	-
	100-135	27	39	34	CL	50	8.1	9.5	89.9	89.0	-	-	112.7*	-	-
4	0- 60	39	30	31	C	43	8.4	1.0	10.0	3.5	0.9	5	7.4	2.0	-
	60-100	19	33	48	CL	57	8.2	3.0	18.9	15.7	0.2	20	3.1*	2.0	-
	100-125	25	29	46	SiC	57	8.2	3.1	24.4	25.0	0.2	20	72*	1.4	-
	125-140	52	26	22	CL	46	8.1	4.0	37.7	17.5	0.1	20	90.1*	1.4	-
5	0- 40	27	36	37	CL	50	7.7	1.4	12.2	2.7	1.0	5	11.7	1.4	-
	40- 70	25	34	41	CL	46	8.2	1.8	21.1	4.0	0.5	3	41.7	5.0	-
	70- 90	22	34	44	C	55	7.5	1.2	11.1	3.1	0.3	3	44.9	1.2	-
	90-120	71	17	12	SL	42	8.3	1.0	10.0	3.1	0.3	2	21.3	1.0	-
	120-150	17	25	58	C	59	8.2	2.0	18.9	7.0	0.4	4	94.7	1.6	-
6	0- 55	23	39	38	CL	50	7.8	25.5	113.2	20.0	0.1	-	313	2.0	-
	55- 90	28	-	-	CL	62	8.0	11.3	6.7	112.5	8.3	65	1850*	2.5	-
	90-150	-	-	-	C	65	7.7	12.5	2.2	10.5	3.0	51	2610*	3.0	-
7	0- 25	47	25	28	Sc	50	7.7	1.3	14.4	3.6	1.0	5	23.8	2.0	-
	25- 45	32	26	42	C	52	7.2	1.7	21.1	4.9	6.6	7.5	52.3	1.4	-
	45- 50	52	24	51	Sc	42	7.1	2.2	20.0	6.0	-	7.5	44.2	2.3	-
	50-100	31	34	35	CL	50	7.8	3.3	51.1	9.1	0.8	11.5	130.4	1.6	
	100-150	76	15	9	SL	42	7.6	3.0	39.9	9.5	0.8	6.0	440*	2.0	-
8	0- 10	31	34	35	C	50	8.7	1	7.8	3.7	0.5	5.0	9.5	1.3	-
	10- 32	25	32	43	C	51	8.3	1.6	13.3	2.5	0.2	11.0	12.5	2.2	0.4
	32- 85	30	26	44	C	60	8.1	1.2	11.1	3.7	0.2	3.5	38.4	2.3	-
	85-105	17	32	51	C	61	7.9	5.5	61.1	25.0	0.4	4.5	395	0.8	-
	105-125	17	47	36	SiCL	50	8.1	4.8	38.9	8.7	0.2	6.0	16.2*	2.0	-
9	0- 10	18	44	38	SiCL	56	8.1	0.8	7.8	1.8	0.4	6.0	6.8	1.6	1.6
	10- 67	22	30	47	C	58	8.4	1.0	10.0	2.0	-	3.5	17.0	1.8	-
	67-120	16	29	55	C	62	8.4	2.1	18.9	3.0	-	4.5	44.3	2.4	-
10	0- 15	37	30	33	CL	54	7.9	7.8	67.7	40.0	-	-	108	2.4	-
	15- 53	28	35	37	CL	56	7.9	23.0	124.3	136.0	5.0	-	308*	5.0	4.0
	53- 72	74	13	13	SL	32	8.0	19.2	115.4	144.5	3.5	-	2138*	7.5	-
	72-150	-	-	-	CL	72	8.1	17.2	99.9	165.0	1.0	-	486*	7.5	-
11	0- 5	36	37	27	L	47	8.7	1.2	10.0	3.5	1.6	4.5	29.2*	3.6	-
	5- 15	31	33	36	CL	50	8.3	1.3	12.2	14.8	0.8	3.5	23.7*	2.4	0.4
	15- 40	25	40	35	CL	50	8.4	1.2	11.1	3.9	0.6	5.0	525*	2.0	-
	40-150	17	27	56	C	59	7.9	3.9	48.8	9.0	0.2	6.0	530*	1.2	-

Profile No.	Depth (cm)	SAR	% $CaCO_3$ equivalent: $CaCO_3$	AmAc extractable Ca and Mg, m.e./100 g: Ca	Mg	Exchangeable K and Na, m.e./100 g: K	Na	CEC m.e.100g	ESP	Org.m. (%)	C (%)	Tot. N (%)	C/N	NO_3^--N (ppm)	Available P, ppm
1	0- 20	0.7	18.9	48.4	6.3	1.1	0.1	36.1	0.3	0.93	0.54	0.02	23	<1	1.6
	20- 35	0.5	19.4	68.8	6.8	0.8	0.2	28.1	0.7	0.76	0.44			"	0.4
	35- 50	1.3	22.0	55.8	9.5	0.7	0.2	34.8	0.6	0.76	0.44			"	1.0
	50- 85	1.0	19.5	51.8	9.8	0.8	0.4	34.9	1.1	0.96	0.56			"	0.7
	85-125	1.3	16.6	53.5	9.8	0.7	0.3	33.9	0.9	1.22	0.71			"	0.5
	125-150	1.0	22.8	94.4	6.5	0.7	0.2	21.3	0.9	0.87	0.51			"	0.6
2	0- 50	0.8	24.1	53.5	5.7	1.1	0.1	24.3	0.4	1.07	0.62	0.05	13	"	0.9
	50-100	0.5	16.7	29.5	3.3	0.4	0.1	15.2	0.6	0.59	0.35			"	0.3
	100-140	0.7	22.3	46.7	5.8	0.6	0.1	28.0	0.4	0.55	0.32			"	1.3
3	0- 30	1.8	18.6	60.3	5.8	1.3	0.2	5.8	3.4	2.04	1.18			<1	1.1
	30- 70	10.1	19.95	43.2	9.8	0.5	0.7	33.8	2.1	1.37	0.80			5.1	0.6
	70-100	20.7	24.1	34.7	7.2	0.5	0.2	21.1	0.9	0.42	0.24			<1	0.5
	100-135	13.2	23.0	39.8	12.7	0.4	0.5	31.3	1.5	0.66	0.38			"	0.1
4	0- 60	1.6	19.5	51.8	5.8	0.8	0.5	28.3	1.8	1.29	0.75	0.06	13	"	1.4
	60-100	5.1	22.1	51.8	5.0	1.3	0.4	27.6	1.4	1.32	0.76				2.0
	100-125	7.2	21.2	101.3	6.8	0.7	0.3	43.7	0.7	1.60	0.93			7.6	2.5
	125-140	4.0	20.4	45.0	4.8	0.4	0.2	22.2	0.9	0.44	0.26			<1	0.1
5	0- 40	1.1	21.2	31.0	5.0	2.6	0.2	32.7	0.5	1.39	0.81	0.03	28	13.3	2.1
	40- 70	1.2	23.2	31.3	6.0	1.5	0.2	29.2	0.7	0.65	0.38			<1	1.6
	70- 90	1.3	24.9	50.3	6.7	1.3	0.5	28.1	1.8	0.80	0.47			"	0.8
	90-120	1.4	17.9	42.0	3.7	0.7	0.2	16.4	1.2	0.43	0.25			"	0.6
	120-150	2.3	22.1	54.8	8.6	1.5	1.0	43.7	2.3	0.73	0.42			"	0.7
6	0- 55	2.7	21.3	48.1	7.3	19.7	11.2	30.3	37.0	1.59	0.46	0.08	6	59.4	5.4
	55- 90	66.9	21.3	85.9	13.1	16.6	3.6	11.8	30.5	1.06	0.61			<1	2.7
	90-150	10.0	24.0	72.0	15.9	9.7	13.9	11.7	118.8	0.89	0.52			"	1.6
7	0- 25	1.3	19.5	46	5.6	1.8	0.3	43.3	0.7	1.95	1.13	0.03	38	7.1	3.6
	25- 45	1.5	18.5	48.1	7.9	1.5	0.3	25.3	1.2	0.89	0.52			2.3	1.0
	45- 50	1.9	21.3	47.9	2.3	1.1	0.1	12.1	0.8	0.61	0.35			1.8	0.1
	50-100	1.8	24.9	49.8	4.2	1.4	9.2	24.6	0.6	0.47	0.27			1.9	1.0
	100-150	2.1	15.7	48.1	0.9	0.7	0.3	10.6	2.8	0.46	0.27			<1	0.1
8	0- 10	1.9	15.7	53.1	4.6	1.6	0.2	31.6	0.5	0.98	0.57	0.02	29	3.8	1.6
	10- 32	1.0	21.2	52.5	9.5	1.3	0.3	33.8	0.9	1.25	0.73			4.2	1.0
	32- 85	1.6	9.2	54.2	6.1	1.0	0.6	18.9	3.2	0.99	1.09			1.8	1.2
	85-105	4.5	22.9	57.5	5.0	1.0	0.4	33.9	1.2	0.75	0.43			<1	1.5
	105-125	2.0	28.3	63.2	7.5	1.2	?-	23.7	-	0.67	0.39			1.6	0.6
9	0- 10	0.9	25.1	54.8	2.9	1.7	0.2	35.0	0.6	1.39	0.81	0.07	12	2.9	0.8
	10- 67	0.9	23.0	54.2	5.8	1.4	0.3	36.2	0.8	1.85	0.72			2.4	0.7
	67-120	1.0	22.1	52.5	6.1	0.9	-	40.9	-	1.29	0.50			<1	1.0
10	0- 15	6.9	20.4	49.8	7.0	4.2	4.5	34.9	12.9	4.09	2.38	0.36	7	17.8	7.2
	15- 53	17.3	22.1	55.9	8.2	4.2	13.6	16.6	81.9	1.61	0.94			<1	2.2
	53- 72	19.0	12.0	40.9	7.2	1.1	8.4	23.5	35.7	0.85	0.50			"	0.7
	72-150	23.3	8.3	92.9	7.5	1.3	18.7	21.9	85.3	0.70	1.02			"	1.2
11	0- 5	1.6	12.0	48.7	7.5	1.7	0.3	34.2	0.9	7.93	4.65	0.15	30	<1	0.8
	5- 15	6.0	31.5	47.6	8.2	1.5	-	28.1	-	1.62	0.94			"	1.4
	15- 40	1.7	24.9	58.6	9.0	0.9	0.5	26.5	1.9	1.84	1.07			"	0.8
	40-150	1.8	25.8	-	-	1.1	7.2	31.3	-	0.88	0.51			"	-

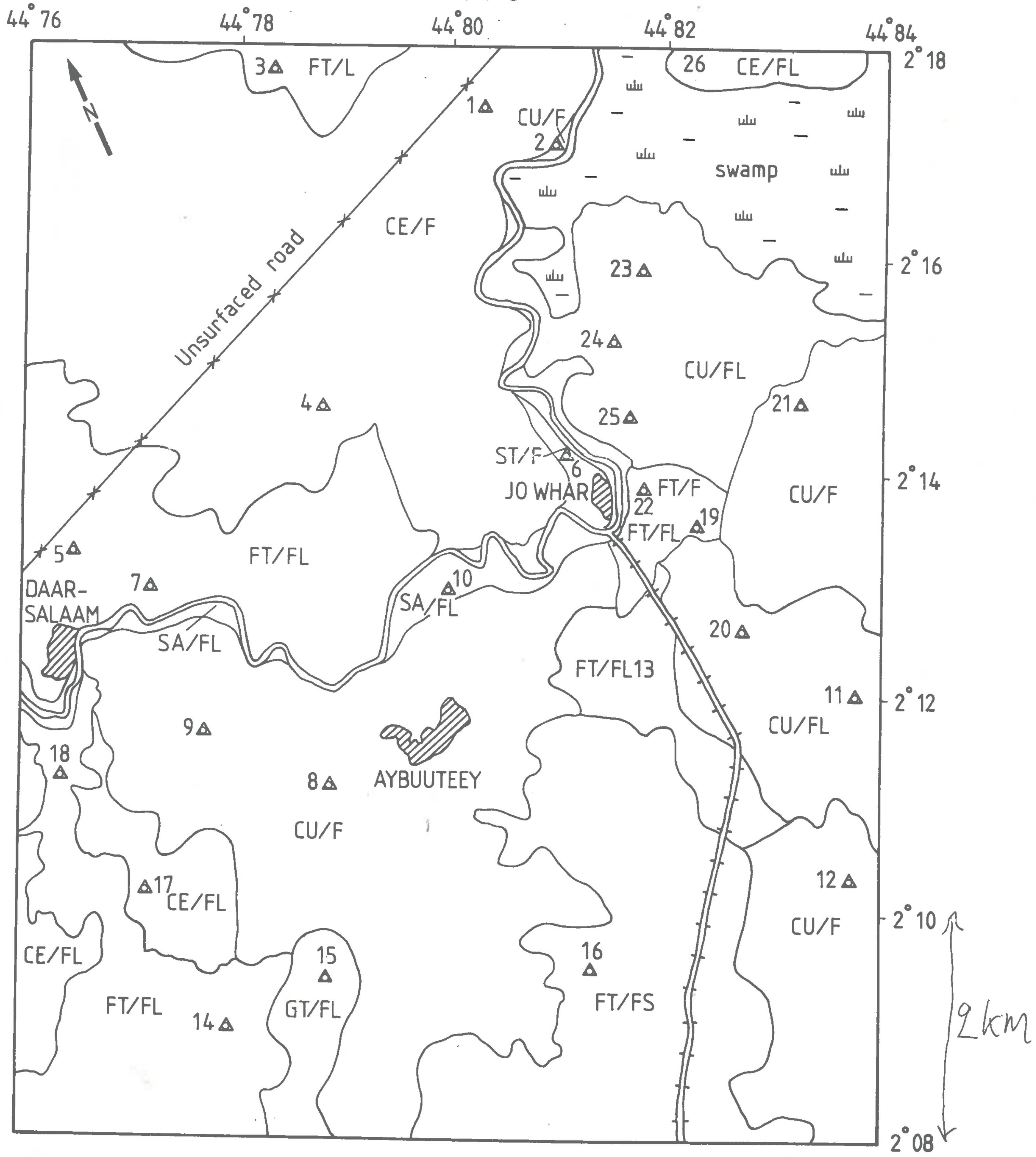
PHYSICAL AND CHEMICAL ANALYSIS OF ALL PROFILES SAMPLED (Table 8, Appendix)

Profile No.	Depth (cm)	Sand % (2-0.5 mm)	Silt % (0.5-0.002 mm)	Clay % <0.002 mm	Texture class	S.P. %	pHe (H_2O)	ECe mS/cm	Soluble cations m.e./l			Soluble anions m.e./l				SAR	% $CaCO_3$ equivalent	AmAc extractable Ca and Mg, m.e./100 g		Exchangeable K and Na, m.e./100 g		CEC m.e.100g	ESP	Org.m. (%)	C (%)	Tot. N (%)	C/N	NO_3-N (ppm)	Available P, ppm
									$Ca^{+2}+Mg^{+2}$	Na^+	K^+	Cl^-	SO_4^{-2}	HCO_3^-	CO_3^{-2}		$CaCO_3$	Ca	Mg	K	Na								
12	0- 35	19	46	35	SiCL	55	8.5	1.0	8.9	5.0	0.3	5.0	8.7	2.8	-	2.4	23.0	52.5	12.1	1.1	-	34.6	-	1.87	1.09	0.05	21	5.8	0.8
	35- 80	16	26	58	C	57	8.4	2.8	10.0	20.3	0.4	5.5	11.3	-	-	9.1	22.1	52.5	8.5	1.0	1.0	33.3	3.0	1.89	1.10			3.4	0.8
	80-100	-	-	-	C	59	8.3	4.0	36.6	21.4	0.3	6.0	141.7*	2.5	-	5.0	19.4	76.4	19.2	0.8	1.5	12.8	11.7	2.03	1.18			<1	1.6
	100-150	40	33	27		48	7.9	5.5	49.8	28.0	0.4	7.5	1244*	2.0	-	5.6	23.0	67.0	5.9	0.7	6.6	46.8	14.1	0.71	0.41			"	0.2
13	0- 27	70	15	15	SL	40	8.5	0.8	6.7	-	-	4.0	7.4	3.6	3.6	-	14.7	39.8	6.7	1.4	-	8.4	-	1.24	0.72	0.05	16	3.6	3.4
	27- 64	45	23	32	CL	50	8.4	0.5	89.9	-	-	3.0	3.2	2.0	-	-	20.3	43.1	12.4	1.5	-	22.2		0.79	0.46			2.2	6.0
	64- 80	96	2	2	S	36	8.4	0.5	6.7	-	-	2.5	4.7	1.0	-		12.0	32.0	9.3	0.4	-	9.3	-	0.53	0.31			<1	2.0
	80- 97	38	30	32	CL	46	8.4	1.0	8.9	3.2	1.0	5.0	18.0	1.8	-	1.5	19.4	45.3	10.0	2.1	0.8	41.5	1.9	1.13	0.44			1.9	8.5
	97-110	20	56	24	SiL	47	8.4	1.7	11.1	1.2	0.7	5.0	36.9	1.8	-	0.5	34.1	45.3	3.9	1.2	0.8	30.4	2.6	0.43	0.25			1	1.5
	110-150	24	62	14	SiL	50	8.3	2.4	20.0	1.6	0.3	5.0	39.3	2.0	-	0.5	24.9	48.1	5.0	0.9	0.6	9.4	6.4	0.54	0.31			1	1.4
14	0- 20	32	39	29	CL	47	8.2	1.2	7.8	8.0	1.1	7.5	7.8	3.2	0.4	4.1	20.3	48.1	4.5	6.9	0.8	30.3	2.6	1.72	1.00	0.10	10	10.6	1.0
	20- 60	22	39	39	CL	46	8.1	3.2	21.1	13.2	-	24.5	6.6	1.8	-	4.1	22.8	48.7	6.0	1.7	0.4	31.6	1.3	1.42	0.83			11.0	1.0
	60-100	18	41	41	SiC	50	7.9	3.1	22.2	16.5	0.3	30.0	23.1	1.0	-	5.0	24.0	51.4	6.5	1.0	0.1	32.4	0.3	1.26	0.73			5.0	0.5
	100-145	39	35	26	C	46	7.8	7.5	69.9	40.0	0.7	52	360.0*	1.4	-	6.8	15.7	54.8	5.8	0.8	3.1	25.7	12.0	0.82	0.48			18.7	1.0
15	0- 25	34	44	22	L	50	7.5	1.8	22.2	2.8	0.8	5.0	72.0	1.4	-	0.8	20.3	51.4	4.0	1.6	0.1	19.5	0.5	1.32	0.77	0.06	14	12.3	1.0
	25-145	-	-	-	CL	44	8.0	3.9	6.7	5.2	0.6	3.5	1500*	2.2	-	2.8	22.8	103.4	7.1	0.7	0.1	11.4	0.9	0.43	0.25			<1	2.5
16	0- 15	15	48	37	SiCL	50	8.6	0.7	6.7	2.8	0.2	3.0	13.0	2.1	-	1.5	24.0	51.4	4.4	1.2	0.6	12.8	4.7	1.06	0.62	0.07	9	4.4	1.5
	15- 43	19	38	43	SiC	50	8.1	1.4	15.5	5.0	0.3	8.5	27.0	2.0	-	1.8	15.7	52.0	5.9	1.2	0.1	38.1	0.3	1.30	0.76			3.0	1.0
	43-150	19	31	50	C	50	8.1	8.0	68.8	39.6	0.6	47.5	538.0*	5.0	-	6.8	28.6	58.6	8.4	1.1	-	35.6	-	1.09	0.63			<1	1.0
17	0- 15	36	36	28	CL	50	7.3	3.4	32.2	1.5	0.6	25.0	27.9	5	-	0.4	25.5	49.8	6.0	10.0	0.2	30.4	0.7	2.13	1.24	0.12	10	27.1	0.5
	15- 40	30	29	41	CL	50	7.5	0.8	10.0	1.9	0.8	-	8.5	1.5	-	0.8	23.0	49.8	5.8	2.0	0.3	31.6	0.9	1.24	0.72			5.3	1.0
	40- 63	31	29	40	CL	50	7.8	0.6	7.8	1.5	0.1	3.0	17.5	1.7	-	0.8	25.0	51.4	6.3	1.0	0.3	31.5	1.0	0.98	0.57			2.0	1.0
	63- 95	38	29	33	CL	50	7.5	1.2	12.2	2.5	0.1	2.5	27.2	2.0	-	1.0	22.2	49.8	5.6	0.6	0.6	32.7	1.8	0.48	0.28			1.7	1.0
	95-145	16	41	43	SiC	59	7.1	1.9	18.9	7.5	0.2	3.5	67.0	2.0		2.4	22.1	51.2	6.0	0.6	0.5	33.9	1.5	0.60	0.35			1.0	1.0
18	0- 10	31	22	27	L	47	8.3	2.3	20.0	7.1	2.4	10	41.8	1.9	-	2.2	-	47.0	6.4	6.9	-	27.7	-	1.72	1.32	0.10	13	12.6	1.5
	10- 45	26	39	35	CL	50	7.9	4.2	67.7	11.0	2.3	10	400.0	5	0.2	1.9	23.2	48.2	9.9	2.1	1.9	33.9	5.6	1.42	0.61			5.0	1.0
	45- 90	43	33	24	L	50	7.9	4.8	51.1	17.0	0.3	20	1250.0*	2.4	0.4	3.4	22.1	42.3	7.7	0.6	0.5	21.0	2.4	1.26	0.25			1.2	1.0
	90-135	24	29	47	C	50	7.6	7.5	64.4	32.5	0.2	50	233	2.0	-	5.7	22.55	48.2	8.4	0.6	0.6	28.1	2.1	0.82	0.35			2.2	1.0
19	0- 10	41	44	15	L	50	8.3	1.3	13.3	2.5	2.0	4.0	9.8	3.0	-	1.0	20.30	53.2	7.2	0.7	1.9	28.1	6.8	2.45	1.42	0.37	4	11.8	1.0
	10- 48	29	33	38	CL	50	8.2	0.7	4.4	1.4	0.2	3.0	6.7	2.0	-	1.0	24.90	42.3	5.9	0.6	1.0	27.7	3.6	1.18	0.69			3.6	0.5
	48- 70	33	36	31	C	47	8.4	1.1	5.6	5.7	0.2	2.5	17.0	2.6	-	3.4	22.10	42.3	5.5	8.9	0.8	26.7	3.1	1.69	0.98			2.0	3.0
	70- 85	42	34	24	L	46	8.2	1.3	8.9	6.5	0.1	3.5	24.3	2.0	-	3.1	23.30	44.1	6.6	1.1	0.5	22.2	2.3	0.79	0.41			<1	1.0
	85-100	74	12	14	SL	37	8.2	1.1	7.8	8.0	0.1	2.0	16.4	2.6	0.4	4.1	19.40	43.2	6.7	0.8	0.4	12.1	3.3	0.49	0.28			1.6	1.0
	100-110	29	35	36	CL	50	8.2	2.2	20.0	13.0	0.3	11.0	37.7*	1.6		4.1	22.75	40.4	5.6	0.6	-	31.4	-	0.82	0.48			1.0	1.0
	110-120	35	44	21	L	44	8.1	1.2	11.1	1.9	0.1	2.5	-	1.4	-	0.8	24.90	36.8	4.2	0.5	-	23.4	-	0.36	0.21			1.0	1.0
20	0- 10	26	43	31	CL	55	7.8	1.2	11.1	2.3	1.0	2.5	8.8	2.0	-	1.0	21.20	41.8	5.9	5.9	0.1	32.7	0.3	2.28	1.33	0.13	10	16.8	1.2
	10- 55	25	27	48	C	50	7.6	1.0	10.0	2.5	0.1	5.0	21.9	7.5	-	1.1	20.40	45.9	9.0	1.0	0.4	33.9	1.2	1.06	0.61			2.0	1.0
	55-105	17	32	51	C	50	7.4	3.2	51.1	15.0	0.3	4.5	319.0*	1.6	-	3.0	23.20	50.4	9.3	0.9	0.1	30.4	0.3	0.97	0.56			1.8	0.5
	105-150	18	25	57	C	57	8.0	4.4	42.2	8.8	0.2	3.0	945.0*	1.6	-	1.9	21.30	59.1	11.4	0.9	2.8	26.4	10.6	0.94	0.55			1.0	0.5
21	0- 20	21	29	50	C	59	8.4	1.2	7.8	3.0	1.0	6.0	14.7	2.4	0.4	1.5	11.10	53.6	6.8	6.9	0.3	47.5	0.6	4.27	2.49	0.15	16	3.9	1.0
	20- 50	19	27	54	C	59	8.2	1.0	13.3	1.6	0.2	2.0	40.6	-	-	0.6	20.70	49.1	8.3	1.1	0.2	40.3	0.5	1.48	0.86			1.9	1.0
	50-145	23	19	58	C	56	8.0	3.0	42.2	5.0	0.2	4.5	161*	2.0	-	1.1	21.80	48.2	12.1	1.1	0.6	35.0	1.7	1.29	0.75			<1	0.5
22	0- 15	56	30	14	C	43	8.1	1.7	18.9	3.7	1.0	3.0	36.1*	2.4	0.4	1.2	19.4	40.0	4.6	1.4	0.1	25.9	0.4	1.09	0.63	0.08	8	7.8	1.5
	15- 37	21	37	42	C	57	8.0	3.4	51.1	7.0	0.3	5.0	169	2.6	-	1.4	23.0	48.2	6.6	0.9	0.2	34.5	0.6	1.43	0.83			2.2	1.0
	37- 45	44	29	26	L	50	8.0	2.6	41.1	4.9	0.3	2.0	39.8*	3.0	-	1.1	15.7	46.3	7.2	0.7	2.0	25.3	7.9	1.00	0.58			9.3	0.5
	45-145	25	28	47	C	50	8.0	3.0	38.9	5.2	0.3	7.5	129*	1.4	-	1.2	22.1	47.3	8.4	0.9	0.2	7.0	3.0	1.16	0.67			3.8	1.0
23	0- 10	22	42	36	CL	50	8.5	0.5	4.4	1.5	0.8	2.5	2.0	3.0	-	1.0	17.1	48.6	5.6	8.4	0.2	38.4	0.5	4.36	3.09	0.12	26	6.1	4.0
	10- 22	42	37	21	L	50	8.3	0.7	5.6	2.1	0.1	3.5	24	2.0	0.2	1.3	22.1	52.7	6.6	0.9	0.6	22.2	2.7	0.96	0.56			2.4	1.0
	22- 52	18	29	53	C	57	8.0	1.3	14.5	2.9	0.1	5.0	6.2	1.8	-	1.1	18.6	47.3	3.5	0.4	0.2	47.0	0.4	3.76	2.08			5.0	0.5
	52-150	17	34	49	C	50	7.9	1.7	16.7	1.9	0.1	2.5	6.9	1.0	-	0.7	25.0	46.3	9.7	1.0	0.3	32.7	0.9	0.93	0.54			<1	0.5
24	0- 8	32	42	26	L	58	7.6	0.8	6.7	1.8	0.7	3.5	9.4	3.5	0.6	1.0	20.3	45.4	4.4	1.8	0.3	31.3	1.0	1.47	0.85	0.09	9	11.8	1.0
	8-75	29	14	57	C	60	8.6	1.4	14.5	1.3	0.2	4.0	34	2.0	-	0.5	17.6	52.7	7.4	1.1	0.5	33.8	1.5	2.37	1.36			<1	0.5
	75-150	16	34	50	C	63	7.4	2.9	44.1	5.4	0.2	3.5	101	2.0	-	1.2	21.2	48.6	9.5	1.1	0.3	29.1	1.0	0.97	0.56			<1	0.5
25	0- 20	27	42	31	CL	54	8.7	0.8	7.8	1.8	0.5	2.5	-	4.0	1.0	0.9	17.5	44.1	5.1	0.7	0.5	24.4	2.0	1.96	1.14	0.11	10	2.2	-
	20- 65	17	30	53	C	58	8.2	0.9	9.8	1.6	0.3	5.0	143	2.0	-	0.7	20.4	44.1	5.3	0.7	0.5	35.7	1.4	1.67	0.97			2.3	0.5
	65-150	-	-	-	C	48	8.2	0.9	9.8	2.5	0.3	3.0	21.1	2.5	-	1.1	19.6	48.2	6.8	1.2	0.2	35.0	0.5	1.75	1.02			<1	0.5
26	0- 5	78	9	13	SL	47	7.5	0.9	8.9	1.6	-	3.5	11.7	2.7	-	0.8	12.1	53.6	7.2	0.7	0.2	34.7	0.6	7.14	4.15	0.31	28	5.8	0.6
	5- 63	22	36	42	C	48	7.9	1.2	13.3	2.6	0.5	2.5	33.4	1.7	-	1.0	21.3	45.0	7.8	1.5	0.3	34.4	0.9	0.81	0.47			3.3	0.6
	63-150	17	42	41	SiC	50	7.7	3.2	38.9	2.7	0.2	-	208*	1.4	-	0.6	25.0	47.3	8.5	0.8	1.2	32.0	3.8	0.91	0.53			2.0	1.9

C = clay
L = loam
Si = silty or silt
S = sand or sandy
e = extract
* = samples contained gypsum

Soil Classification and Land Suitability Studies in the lower Shabelle Region, Somalia

SOIL MAP 3



Legend

Mapped symbol	Landform	Topography	Soil classification at family level (USDA)	Soil drainage
CU/FL	Recent Shabelle alluvium	Flat depression	Fine-loamy, montmorillonitic (calcareous), Isohyperthermic, Udic Chromusterts	Poor to very poor
CU/F		Flat depression	Fine, montmorillonitic (calcareous), Isohyperthermic, Udic Chromusterts	Very poor
CE/F	Recent Shabelle alluvium	Level, slight gilgai	Fine, montmorillonitic (calcareous), Isohyperthermic, Entic Chromusterts	Moderate
CE/FL		Level, slight gilgai	Fine-loamy, montmorillonitic (calcareous), Isohyperthermic, Entic Chromusterts	Moderate
CU/F		Flat depression	Fine, montmorillonitic (calcareous), Isohyperthermic, Udic Chromusterts	Moderate
CU/FL		Level, slight gilgai	Fine-loamy, montmorillonitic (calcareous), Isohyperthermic, Udic Chromusterts	Moderate
FT/FL		Level to flat depression	Fine-loamy, mixed (calcareous), Isohyperthermic, Typic Ustifluvents	Moderate
ST/F		Gently sloping	Fine, mixed (calcareous), Isohyperthermic, Typic Salorthids	Poor to imperfect
SA/FL		Level	Fine-loamy, mixed (calcareous), Aquollic Salorthids	Poor to imperfect
CE/FL	Older alluvial lower cover floodplain	Level	Fine-loamy, montmorillonitic (calcareous), Isohyperthermic, Entic Chromusterts	Moderate
CU/LF		Level to gently sloping	Fine, montmorillonitic (calcareous), Isohyperthermic, Udic Chromusterts	Moderate
GT/FL		Level	Fine-loamy, gypsic (calcareous), Isohyperthermic, Typic Gypsiorthids	Moderate
FT/L	Older alluvial upper cover floodplain	Level	Loam, mixed (calcareous), Isohyperthermic, Typic Ustifluvents	Well drained
FT/CL			Coarse-loamy, mixed (calcareous), Isohyperthermic, Typic Ustifluvents	Well drained
FT/FL		Level to gently sloping	Fine-loamy, mixed (calcareous), Isohyperthermic, Typic Ustifluvents	Moderate
FT/FS		Level	Fine-silty, mixed (calcareous), Isohyperthermic, Typic Ustifluvents	Moderate

- Settlement
- Road Unsurfaced
- River
- Canal
- Swamp
- Representative profile
- Study area boundary