FOOD AND AGRICULTURAL ORGANIZATION OF THE UNITED NATIONS
ENVIRONMENTAL RESOURCE ASSESSMENT FOR RURAL LAND USE PLANNING
GCP/YEM/021/NET. 40 *Field Document 6*

THE SOILS OF EL-KOD RESEARCH FARM

AGRICULTURAL RESEARCH AND EXTENSION AUTHORITY
MINISTRY OF AGRICULTURE AND WATER RESOURCES
DHAMAR, REPUBLIC OF YEMEN

1997

FOOD AND AGRICULTURAL ORGANIZATION OF THE UNITED NATIONS
ENVIRONMENTAL RESOURCE ASSESSMENT FOR RURAL LAND USE PLANNING
GCP/YEM/021/NET *Field Document 6*

THE SOILS OF EL-KOD RESEARCH STATION

by

El-Abbas Doka Mohamed Ali
FAO Land Resource Expert

AGRICULTURAL RESEARCH AND EXTENSION AUTHORITY
MINISTRY OF AGRICULTURE AND IRRIGATION
DHAMAR, REPUBLIC OF YEMEN

1997

CONTENTS

INTRODUCTION

Soils can differ greatly in their morphological, physio-chemical and mineralogical properties. These differences affect crop responses to management operations. Improper use of soils may affect crop production and lead to soil degradation. It is therefore essential to understand the soils to ensure suitable sustained agriculture and proper conservation.

This study is part of the Environmental Resource Assessment for Rural Land Use Planning (GCP/YEM/021/NET) project's programme to conduct detailed soil surveys of AREA's seven agricultural research stations in Yemen. The objective of this programme is to make a comprehensive soil resource inventory of each station, advise on suitable management practices and indicate the extent to which the soils of the stations are representative for soils in Yemen, taking into account climatic criteria as well. This will assist in the transfer of soil-based agro-technology research findings to surrounding areas with similar soils.

This technical paper covers various aspects of the soils of El-Kod. It includes factors related to environmental development of the soils; methods of study and characterization of soils; suitability of the soils for different crops and the recommended management practices. The results obtained should be used in transferring the soil-based agro-technology research findings to other regional areas having similar soil characteristics.

It is hoped that the results and conclusions of this study will be used by agronomists and extension workers for linking their studies to agro-ecological criteria and, at a later stage, for determining locations for on-farm verification trials and to disseminate extension messages to farmers in areas for which new or improved technology packages are valid.

ACKNOWLEDGEMENTS

I wish to acknowledge with gratitude the following El-kod research station staff and project colleagues in the Environmental Resource Assessment project- Dhamar who all have kindly assisted in making this work possible.

From El-Kod research farm; Dr. Moalem, A.S. (Director) for welcoming the team and following up its activities; Dr. Azzari, A.S. and Dr. Faisal A. Ahmed (Soil and Irrigation Section) for providing basic information on the farm, making laborers available for field work and eventually following up the analysis of the soil samples; Soil and irrigation Section researchers and technicians for contributing in the detailed soil survey field work and laboratory analysis of the soil samples; other researchers who went all along to the field and contributed in the discussions about the objective of the soil survey and the performance of El-Kod farm soils under field conditions.

From the Environmental Resource Assessment project (GCP\YEM\021\NET) in Dhamar; Dr. Fadel, A.E. and laboratory staff for conducting the requested analysis for El-Kod soil samples; Ahmed Rizq and cartography staff for drawing the figures and producing this report; Ms.Bruggeman, H.Y. the database expert for providing updated climatic data; Mr. Frans Cortenbach for assisting in conducting the statistical analysis; project senior counterparts (Mr. Al-Hemiary, Mr. Al-Meshraki and Mr. Al-Borani) for contributing in the field work; Mr. Khalid Seif,A. (former NPD) and Mr. Bafadel, O. (NPD) for visiting the soil survey team in the El-Kod; Mr. Wen Ting-tiang, CTA for his contribution in the field work, revising and editing the final report; and Ms. Al-Khayat for typing the profile descriptions.

CHAPTER 1

GEOGRAPHIC SETTING

1.1 LOCATION

El-Kod Research Centre lies in Abyan Governorate, it is situated between latitudes 14 47500 m to 14 48500 m N and between longitudes 5 39100 m to 5 39800 m E. The Centre, covering an area of about 71 ha, is located about 50 km along the coastal road from Aden to Mukalah and is bordering El-Kod village (see location diagram on the Soil Map - Appendix 3). Both the Centre and the village are in the southwestern corner of Abyan delta.

1.2 PHYSIOGRAPHY, RELIEF AND DRAINAGE

Abyan delta, within which the Centre is situated, is a vast gently sloping alluvial pain which is seasonally affected by wadi floods. This deltaic plain is bounded in the 1north and north east by high mountains ranges with elevations from 700 to over 1000 m above mean sea level (asl). The plain in the north rises to about 200 m asl. while in the south its altitude is less than 50 m asl with some scattered very steep rock outcrops protruding 50-150 m above the surrounding plains. On both seaward corners the triangular plain is bordered by dunes fields, which include both stabilized and partially stabilized sand dunes. The alluvial deltaic plain is dissected by a number of wadis, all flowing towards the Gulf of Aden. Wadis Bana and Hassan are the main wadis which are debouching into this Gulf, while wadis Suhaybiah and Mahariah are minor wadis which do not reach the sea (see figure 1).

1.3 GEOLOGY

1.3.1 Regional Geology

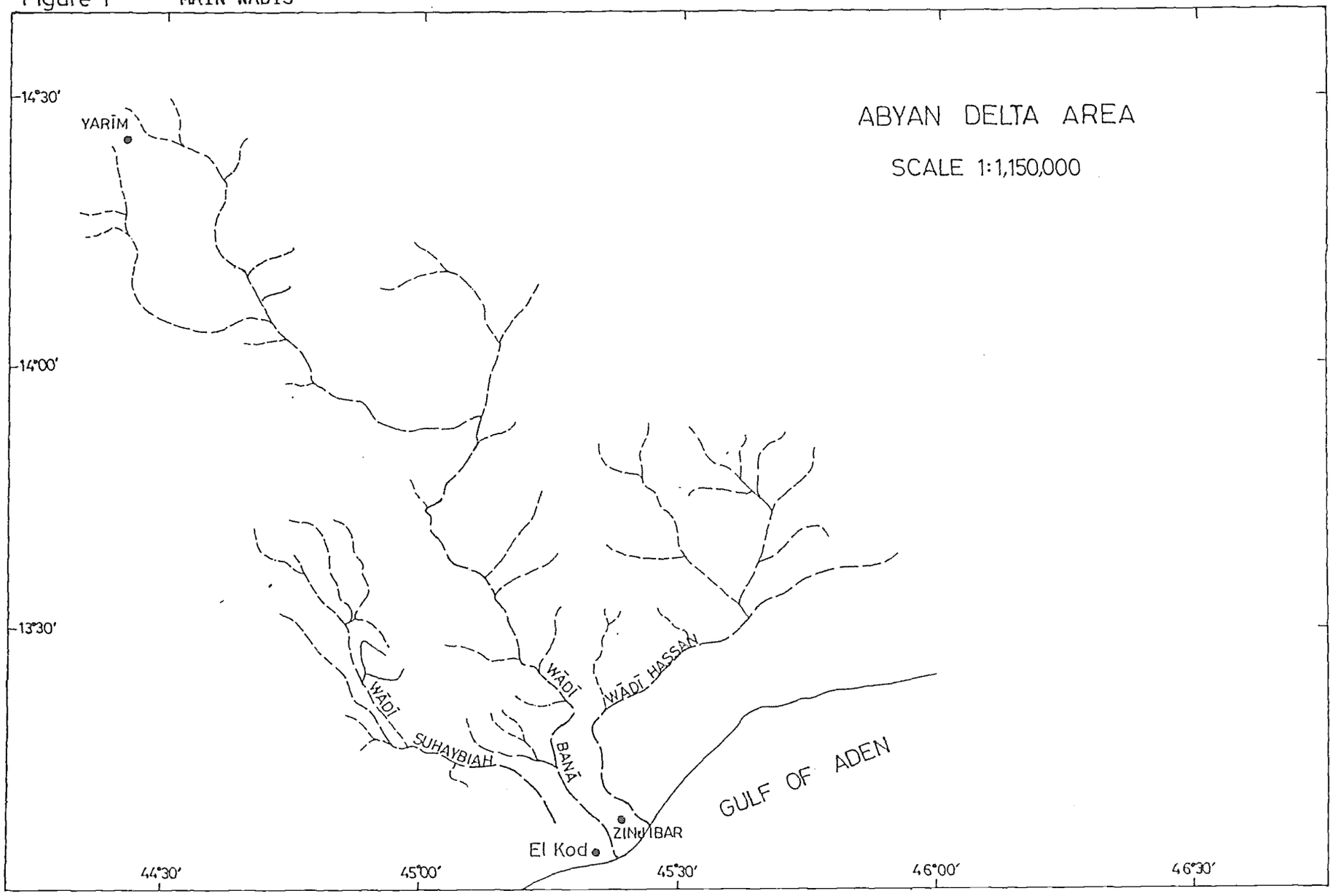
Abyan area lies in the tectonically uplifted main Basement block of Western Yemen. This block includes the confluence of three major tectonic features of the Ethiopian rifts, Red Sea and Gulf of Aden. These tectonic features are shown in the regional photogeological map prepared by Greenwood and Bleakley (1967, published in Dar Al-Handasah 1974). More detailed information and discussions on the geology of Delta Abyan are provided in the recent water resource studies (Report WRAY 34.1 and 34.2 1995). A brief summary is provided in the next section on geologic formations.

1.3.2 Geologic formations

Atkins (1984) reported that despite the apparent simplicity of the geological structure in the area, it is generally acknowledged that the underlying geology is very complex, having been subjected to much faulting and wrapping. The oldest formation to be found is the Basement Complex. These rocks are predominately schists and gneiss, often dissected by lighter colored pegmatite dykes and sills.

Lying uncomfortably over the Basement Complex are Jurassic formations. These vary considerably both in their thickness and extent, and are represented by a succession of limestone and marl deposits. Sandstone formations of cretaceous origin lie uncomfortably over the Jurassic limestone, or where this is absent directly over the Basement Complex. No outcrops of this formation were found to occur close to the study area. The gently sloping plain is composed of much more recent Quaternary formations. These can be divided into two main types : fluviatile formations and superficial marine and aeolian deposits. In some parts inside

Figure 1 MAIN WADIS



limestone and marl deposits. Sandstone formations of cretaceous origin lie uncomfortably over the Jurassic limestone, or where this is absent directly over the Basement Complex. No outcrops of this formation were found to occur close to the study area. The gently sloping plain is composed of much more recent Quaternary formations. These can be divided into two main types : fluviatile formations and superficial marine and aeolian deposits. In some parts inside the plain the aeolian deposits have been reworked by water, and mixed with recent and sub-recent alluvium to form very complicated and complex stratified soil deposits.

In WRAY 34.1 and 34.2 1995 it was reported that the Abyan Delta lies in the tectonically uplifted main basement block of the Western Yemen which is influenced by three major faulting systems: The Ethiopian Rift Valley, the Red Sea and the Gulf of Aden. Most of the delta is covered by Quaternary sediments (alluvium and aeolian deposits). Outcrops of volcanic, sedimentary and basement rocks are present in the northern part of the delta in a series of mountains and hills. The geologic formations in Abyan Delta (Table 1) consists of:

- Precambrian basement;
- Triassic sandstone;
- Jurassic and Cretaceous sedimentary formations;
- Alluvial sediments.

The Precambrian basement is mainly composed of crystalline and metamorphic rocks. The Triassic formation is a sandstone with little limestone ,fine grained with quartz sands. The Jurassic formation is a hard blocky limestone , whereas the Cretaceous formation is a sandstone. The Quaternary deposits consist of proluvial deposits (gravel, sands, conglomerate, sandstone, siltstone and fluvial deposits), aeolian sand beach deposits, and lagoonal and sabkha deposits towards the beach sea. The flat washplains of the Delta Abyan are covered by alluvial sand, silt, and clays. Some sand deposits are of aeolian origin. Near the mountains sands and gravels occur as well as in wadi beds. Sand dunes occur towards the beach, but also on the flanks of the Abyan Delta.

TABLE 1 Geological and hydrological setting of the Abyan Delta (WRAY 34.1 and WRAY 34.2 1995).

GEOCHRONOLOGY	LITHOSTRATIGRAPHY	LITHOLOGY	HYDROGEOLOGY
QUATERNARY TERTIARY	Recent unconsolidated formations, alluvial, aeolian and evaporitic sediments.	aeolian sands; alluvial boulders, pebbles, sands and gravel	good aquifer, permeability from low to high, thickness of the aquifer varies from west to east in the norther part of the delta.
	Archeozoic sandstone	angular to subangular grains of decomposed basement rocks	good aquifer
	Yemen volcanics (Trap series)	basalts, tuffs	poor aquifer
CRETACEOUS	Tawilah sandstone (Mukalla 2, Mukalla 1)	sandstone, shale, limestone	good aquifer, medium to high permeability
JURASSIC	Amran limestone (Nayfa, Mishal and Madbi)	limestone, dolomite with shale, marl, sandstone and clay.	poor aquifer, an aquifer in zones limited to fractured zones
TRIASSIC (Middle to Upper Jurassic)	Kohlan sandstone (Kohlan, Shuqrah)	sandstone with little limestone and fine grained sands	good aquifer if it is at shallow depth
PRECAMBRIAN	Basement Complex (Yaffa group)	schists, gneiss, granite, amphibolite	poor aquifer in general, may form an aquifer if fractured near the surface

1.4 CLIMATE

The El-Kod area, like the rest of the coastal regions of Yemen, experiences hot, dry and dusty weather during the period of the southwest monsoon from June to October. During this season frequent thunderstorms in upland areas are accompanied by torrential rainfall causing floods in the wadis. They might also cause serious dust and sand storms, which can inflict some damage to crops on the land. During the period between November and May the area is affected by northeast monsoon. It is usually a cool season characterized by milder easterly winds and clear sunny weather. It might be accompanied by rainfall resulting in minor floods during April and May. A warm climate prevails throughout the year. The lowest recorded mean monthly minimum temperature in 10 years (1981-91) is 19.2 °C, while the highest maximum is about 36 °C (Table 2.1 and Figure 2).

Rainfall is generally low to negligible, making Abyan Delta an arid region. Rare torrential rains in some years may occur, but these are often very short, followed by hot and dry weather. The area is mostly windy with dust storms during the peak of the monsoon season. Humidity does not vary much, but is slightly higher in El-Kod if compared with other areas such as Giar. In El-Kod also very little variation was also observed for the average daily number of sunshine hours. Soil temperature data have not been reported at any depth in El-Kod. A summary of climatic data obtained from El-Kod weather station is presented in table 2.1. Negeman 1995 reported that the reference evapotranspiration had been calculated from El Kod and Gi'ar meteorological stations data and amount 1,991 and 2,213 mm respectively. Other estimates of the ETo from El Kod station data are: 1,960 mm (W.S. Atkins), 1,902 mm (Dar Al Handasah), and 1,980 mm (GDC, 1980).

1.5 VEGETATION

At El-Kod farm almost all natural vegetation was cleared completely for cultivation. In some localized areas either trees were planted along the roads or scattered bushes have regenerated at the edges of canals and/or abandoned fields. As for the surrounding area Dar Al-Handasah (1974) reported that the distribution of various species is related to a number of factors, including topography, soils, salinity, natural water supply and irrigation. Along, the banks of the main wadis and forming large clusters within it, is dense Tamarix. Mixed in with the Tamarix are a few Salvadora Persica bushes and Pluchea dioscondis trees. Calotropis Procera is common in wadis and on the margins of the Tamarix scrub. Along the lower wadi and its tributaries, where less water reaches, Tamarix remains common but not always dominant. A low shrub called 'Shahir' is often the dominant species, as it has very strong roots able to penetrate deep into quite coarse sands to find more moisture. Shahir scrub seems to be the natural vegetation on sandy soils.

Irrigated areas similar to El-Kod farm have much less natural vegetation. Both Tamarix and Salvadora species occur sporadically, forming groups of bushes on elevated ground surrounded by fields. In less irrigated tracts with light soils Salvadora is also very common on scattered wind hummocks. Acacia tortilis (somar) is also found on the higher hummocks. On the land between the hummocks Tamarix and Dipterium species are typical of the lighter soils, but where soils are heavier, a variety of shrubs appears, most common are 'Digir' and 'Hisar'. A common grass is 'Suda', a Boeyhavia species, covers areas never cultivated or abandoned for a long time. A dense tall dark green grass 'Khu' appears in areas with a high water table. These two types are also evidence of salinity in the area.

Table 2.1 Climatic data (1981 - 91) El-Kod weather station
(Coordinates: 45° 22′ E and 13° 03′ N; Altitude: < 20m)

Climatic parameter		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Temperature °C	Max.	28.7	29.3	30.5	31.7	34.7	35.7	35.3	34.8	35.1	32.9	30.9	29.4
	Min.	21.2	21.8	22.9	23.7	24.7	26.6	27.2	26.7	26.0	21.8	19.2	20.2
	Mean	25.0	25.6	26.7	25.7	29.7	31.2	31.3	30.8	30.6	27.4	25.1	24.8
Relative Humidity (%)		79.8	81.4	81.5	80.4	80.5	77.5	76.2	76.5	81.3	78.6	78.0	79.9
Windrun (Km/day)		113	123	126	113	104	115	132	129	107	101	91	104
Sunshine (Hours/day)		8.1	8.4	8.3	9.0	10.1	9.0	7.7	8.3	8.6	9.6	10.3	8.7
Precipitation (mm/month)		6.5	15.4	16.3	5.2	5.5	0.3	1.3	2.2	5.5	0.6	0.0	1.2
ETO (mm/month)		94	105	117	129	140	140	138	135	131	119	103	91
0.5 ETO (mm/month)		47	53	59	64	70	70	69	68	66	60	52	46

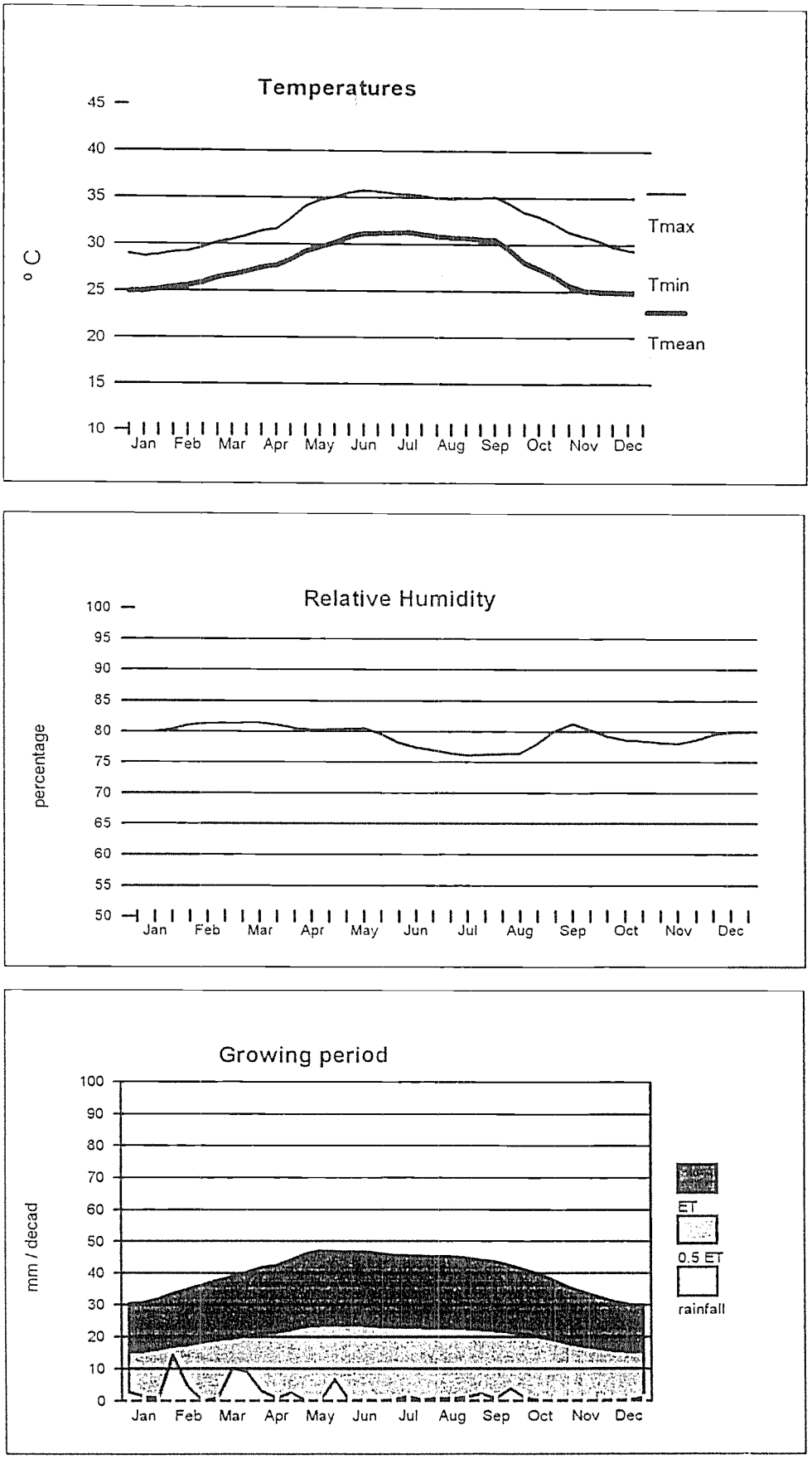


Figure 2: Temperature, relative humidity and growing period in El-Kod

1.6 WATER RESOURCES

The Abyan Delta is one of the important irrigation areas in the southern governorates with surface and groundwater irrigation. The gross servable command area of the Abyan Delta surface water irrigation system is 28,453 ha. The groundwater irrigated area is almost 4,000 ha. The rainfall over the Abyan Delta can be neglected. The rainfall in the Wadi Bana catchment varies from 200-300 mm in the lower and middle reaches to 500 mm in the higher reaches (Negeman 1995). The consecutive presence of the two convergence zones over the Wadi Bana catchment area, creates two separate flood seasons which results in two irrigation seasons. The seif (March-May) and Kharif (July-October) irrigation seasons accounted for 90% of the annual runoff in the period 1951-65. 66% runoff was accounted for the Kharif season alone (Negeman 1995).

A comprehensive surface irrigation system is operational in Abyan Delta. It is based on diverting the flood waters from the Wadis Bana and Hassan through surface water intake structures. Then primary and secondary irrigation canals convey the surface water to the command areas. Irrigation department of the Ministry of Agriculture operate and maintain the system through its branch office at Gi'ar and Zinjibar. The spate irrigation which is practiced in the Abyan Delta is basically basin irrigation, where an entire plot is surrounded by bunds and around 50-60 cm of water is impounded. The overall efficiency for surface water irrigation was estimated to be between 36 and 45%.

1.6.1 Surface water

Wadi Suhaybiah, wadi Hassan and wadi Bana are the main three streams draining Abyan delta. Regarding Al-Kod farm, of these three streams wadi Bana is by far the most important and flows more or less perennially through the Delta. The mean annual Wadi Bana runoff for 1951-1965 period is 162 Mm^3. The estimates of the baseflow in the Wadi Bana vary between 50 and 1,500 l/sec. The mean annual runoff estimates for the Wadis Hassan and Suhaybiah are 40 and 2 Mm^3 respectively. Mean annual floods peaks of 980 m3/sec in the Wadi Bana can be expected. High floods in the Wadi Bana in the past have created considerable damage in El-Kod farm and the rest of Abyan Delta.

Water quality based on different samples collected from several locations in wadi Bana was reported by Dar Al-Handasah (1972). It was concluded that the quality of surface water from wadi Bana is favourable for irrigation on all soils in Abyan delta. However, it was noted that the ratio of sodium to other cations is relatively high. The high permeability of the soils and the flooding method of irrigation practiced in the area might reduce the hazard of salt accumulation. Negeman 1995 stated that the electric conductivity of the baseflow reached a value higher than 1,700 uS/cm in October 1993 with a yield of around 300 l/sec, while EC values of flood flows are much lower.

The flows of wadi Bana have been observed to be highly charged with suspended sediment. This has resulted in many cases in silting of certain water control structures in the delta. Ten water samples were analyzed by Dar Al-Handasah (1972) for suspended sediments. The analysis showed that 100% of the suspended sediments was of a size less than 0.1 mm, thus ranging from fine sand to clay. Clay percentages were generally low, however, in relation to the total suspended sediment. Dar Al-Handasah (1972) estimated these sediments would add an average of 1 cm of soil to the land annually. As for the fertility of the river sediments, Dar Al-Handasah concluded that reliance on the water transported sediments for soil fertility is not warranted.

The General Department of Hydrology in its report WRAY 34.4 (1995) concluded that electrical conductivities of the baseflow reached more than 1700 uS/m at the end of Kharif

season in 1993. The minimum value measured was 416 uS/m in May 1993, one day after an estimated discharge at Bateis of more than 320 m_3/sec. The maximum value measured was 1788 uS/m in October 1993, at which moment the floods had subsided and only a only a baseflow of less than 8 m^3/sec remained.

Groundwater

The aquifers of the Abyan delta consist of two permeable formations (Zones A & B) superimposed on top of each other and separated by middle clays. The subsurface data of the sedimentary rocks forming the delta, were collected from the lithology of the drilled wells in the area. The constructed cross-sections of the area (Dar Al-Handasah 1972) show that the subsurface section from top to bottom consists of the following units :

- Clays
- Fine to coarse sand with clay streaks (Zone A)
- Clay
- Coarse sand, pebbles and boulders (Zone B)
- Claystone, with sand streaks.

The Abyan delta aquifers (Zone A & B) have been tapped for groundwater for both irrigation and domestic purposes. Previous survey of wells did not reveal any pattern for development, but rather indicated that wells were or drilled on basis of convenience and need for water supply.

Deep tubewells (15-35m) are tapping water from deep aquifer (Zone B) whereas shallow wells (2-10m) extract water from the upper aquifer (Zone A). Deep wells are mainly used for irrigation characterized by high extraction rates (>40 million m^3 in 1971). Shallow wells are used for limited irrigation of some individual farms. The majority of the other wells have been dug for domestic purposes. The upper sands of zone A which are tapped by shallow wells are fed mainly by canal and river bed percolation as well as from excess irrigation. The permeability of this zone is much lower than that of zone B. The small pumps installed for shallow wells are usually operated for a few hours at a time, then stopped to allow drawdown recovery before the pumps can be run again. These wells have large diameters and hence act as collecting and storage basins. Discharge of shallow wells amounts to about 4-5 million cubic meters a year (1971 survey).

A decline of groundwater level was reported in many places around delta Abyan. Between 1964 and 1971 Dar Al-Hanadasah surveys indicated a drop of 6 m in some places. It was concluded that the present conditions of groundwater and recharge in the coastal region of Abyan delta are at critical stage. Increased pumping coupled with decreased recharge may invite seawater intrusion into the aquifer, which will cause serious deterioration of the groundwater quality. If, on the other hand, the fresh water gradient is maintained seawater intrusion could be checked at its present acceptable level (Dar Al-Handasah 1972).

Dar Al-Handasah (1974) reported two groundwater surveys carried in 1964 and 1971 in relation to water quality all over Abyan delta. It was mentioned that the 1971 surveys showed very little change in the electrical conductivity of groundwater in Abyan delta since 1964. Conductivities still range from 1.0 to 2.0 mmhos/cm in the north as well as in the area between Musaymir and El-Kod in the south. Dar Al-Handasah survey of 1971 indicated a deterioration in water quality in the central and south-eastern parts of the delta. Electrical conductivities of up to 10 mmhos/cm were reported in these localities. This was attributed to the meager flows of wadi Hassan in recent years. Dar Al-Handasah (1974) argued that reduced recharge may result in water quality deterioration because subsurface formations of the Abyan delta are of marine origin. It is very likely that brackish waters are trapped in some aquifer bottoms.

bottoms. Increased recharge in this case would improve water quality. Chemical analysis for eighteen samples was also provided by Dar Al-Handasah to evaluate the quality of groundwater supplies for irrigation. These results showed that analyzed water samples ranged from moderately to highly saline and in all samples sodium is high. As well effective salinity is high also.

During this survey four water samples were collected for analysis to determine the quality of irrigation water. Two of the samples were collected from wells inside El-Kod farm and the other two from wells within its vicinity. Table 3 shows the results of the chemical analysis of these four water samples. It clearly shows that since the Dar-Al-Handasah surveys water quality has further deteriorated. According to USDA (1964) water salinity classes, Al-Kod samples were classified as C4-C3 and C3-S3. This indicates very high to high salinity and high sodium water. Such water is generally unsuitable for irrigation except for very tolerant crops under very specific conditions of good internal drainage and excessive leaching. Harmful levels of sodium may build up unless the soil under irrigation is rich in gypsum. Irrigation water with a RSC of more than 2.5 are strictly considered unsuitable for irrigation. As for the other two samples outside the farm, characterized by very high salinity and sodium, they were both classified C4-S4. They are generally unsuitable for irrigation except for reclamation of sodic soils with higher values of SAR and RSC than the figures for this water.

A recommendation from Dar Al-Handasah stated that only waters that have EC values of less than 2.0 mmhos/cm and a Sodium Adsorption Ratio (SAR) of less than 10.0, should be used for irrigation. El-Kod water salinity figures are more than the mentioned limits. However, the relatively high permeabilities of soils coupled with a leaching program and occasional applying wadi water to leach accumulated salts, would ensure feasible cultivation of soils having low EC levels.

Table 3 Chemical analysis of groundwater samples from four wells at El-Kod farm and in its vicinity.

WELL	pH	EC	Na^+	K^+	Ca^{2+}	Mg^{2+}	CO^-	HCO^{3-}	Cl^-	SO_4^{2-}	SAR	RSC	USDA Class
El-Kod farm Deep well (1)	8.3	2.4	16.0	0.7	3.8	1.8	1.2	10.5	8.0	2.6	9.0	6.1	C4 S3
El-Kod farm Deep well (2)	8.2	2.2	17.0	0.7	2.6	3.9	1.2	10.0	6.0	7.0	9.0	4.7	C3 S3
Shallow well (3) Intersection of Abr Osman/ Giar road	8.1	3.1	23.5	0.8	2.6	4.3	1.3	7.0	12.0	10.9	13	12	C4 S4
Shallow well (4) Along Giar road	8.0	5.5	49.5	1.2	3.8	6.7	0.6	0.8	22.0	30.6	23	19	C4 S4

The General Department of Hydrology, Ministry of Oil and Mineral Resources, supported by the Dutch TNO Institute of Applied Geoscience, conducted water resources investigations for Abyan Delta (van der Gun and Abdul Aziz Ahmed, 1995). The findings were published in four reports:

Report WRAY 34.1 Well inventory
Report WRAY 34.2 Geophysical investigations and exploratory drilling
Report WRAY 34.3 Pumping tests
Report WRAY 34.4 Surface water

The results of these studies revealed that the groundwater levels are between half a meter and a little more than 30 meters below surface. The piezometric surface shows a southward oriented groundwater flow, from Bateis to the Gulf of Aden, following the course of wadis Bana, Hassan and Suhaybiyah. These wadis, together with irrigation canals are the main source of groundwater recharge. The EC values range between 1,000 and more than 10,000 uS/m. More than 50% of the measured values are above 2,700 uS/m, which is a rather high value. Lower values are found in the recharge zones near the wadi beds and irrigation channels. The observed conductivities, when compared with measurements from the years 1980 and 1993, show a clear deterioration of groundwater quality in most areas, apart from those areas where there is refreshment of groundwater recharge. Infiltrating surface water from the wadis has EC-values between 500 and 1700 uS/m, depending on the discharge volumes.

It was also mentioned that for 1993 the total abstraction was estimated at 86.4 Mm^3, from the main pumped aquifer in Abyan Delta (11.5 Mm^3 for public and domestic use and 75 Mm^3 for irrigation purposes). This means an increase in abstraction rates over the last ten years of 10 Mm^3. Areas with concentrated abstraction seem to induce groundwater recharge and have fresher water than other areas. In the well inventory no evidence has been found of salt water conning up or rapid advancing saltwater intrusion in the coastal zone of the delta. Results on field observations regarding water use at the farm level indicated that most is used for the irrigation of vegetables and bananas, and to a lesser extent for tobacco, cotton and maize. It was also stated that quality restrictions of groundwater for irrigation purposes are less than for human consumption (i.e. exceeding WHO standards for sodium-chloride, sulphate, fluor, nitrate, and nitrite in drinking water). Destruction of soil structure and decrease in crop production are the main problems. Irrigation with water containing high sodium concentration will destroy the soil in an irreversible way. As well, high sodium-chloride concentrations in irrigation water will diminish crop production to less than 50% of the potential (Report WRAY 34.1, March 1995) .

CHAPTER 2

METHODS OF SOIL SURVEY

2.1 SURVEY AREA

The existing El-Kod farm is now composed of two adjacent experimental blocks (II & III), kept after other blocks were claimed back by their original owners immediately after unification of the country (Figure 3). The total area of the two blocks is about 170 feddans (about 70 ha), block II occupying about 90 feddans and the rest 80 feddans for block III. A fair sketch map showing the layout of these two blocks with some other details was provided by the Soil and irrigation section of the Centre. Each block is divided into eight symmetrical plots, plus a ninth different extra plot extending from block II and making it larger than block III. The irrigation water from three wells is conveyed to the different plots by two cemented narrow canals, one lying along the western border of block III and the other on the eastern border of block II. The farm is accessed through a motor track separating the two blocks with two branches at the bottom of the blocks one leading to the HQ office and the other to the main asphalt road to Aden.

2.2 METHODS AND PROCEDURES

2.2.1 Survey methods

2.2.1.1 Level of survey

The soil survey was carried on a detailed scale of 1:2500 and the observation sites were determined on grid survey, with the observations spaced every 50 meters to provide a rectangular grid over the survey area. This method was adopted since recent, large-scale aerial photographs were not available, and also no surface expression (such as levees, sand bars, depressions, hummocks etc.) related to possible soil distribution could be observed. Original surface features have disappeared through the different agricultural operations since early fifties. The soil were tested by auger holes and profile pits at an overall intensity of two observations per hectare.

2.2.1.2 Soil mapping and description

The soil mapping and the location of observations was done on a layout sketch map of 1:2500 scale, showing all plots and other features. The cemented canal along the western border line of block III was taken as a baseline (figure 1). From this baseline, traverses spaced at 50 m intervals were demarcated parallel to the east-west borders of the experimental plots. Auger observations were made every 50 m along the traverses to describe some selected soil properties (texture, colour, depth, $CaCO_3$ content). An initial legend was prepared from a brief reconnaissance and the relevant available information. During the course of the survey the legend was further corrected and refined. Eventually, and based on the soil information collected, the tentative soil unit demarcations were drawn and then profile pits were located within each map unit. Profile and auger descriptions were noted on coded description sheets

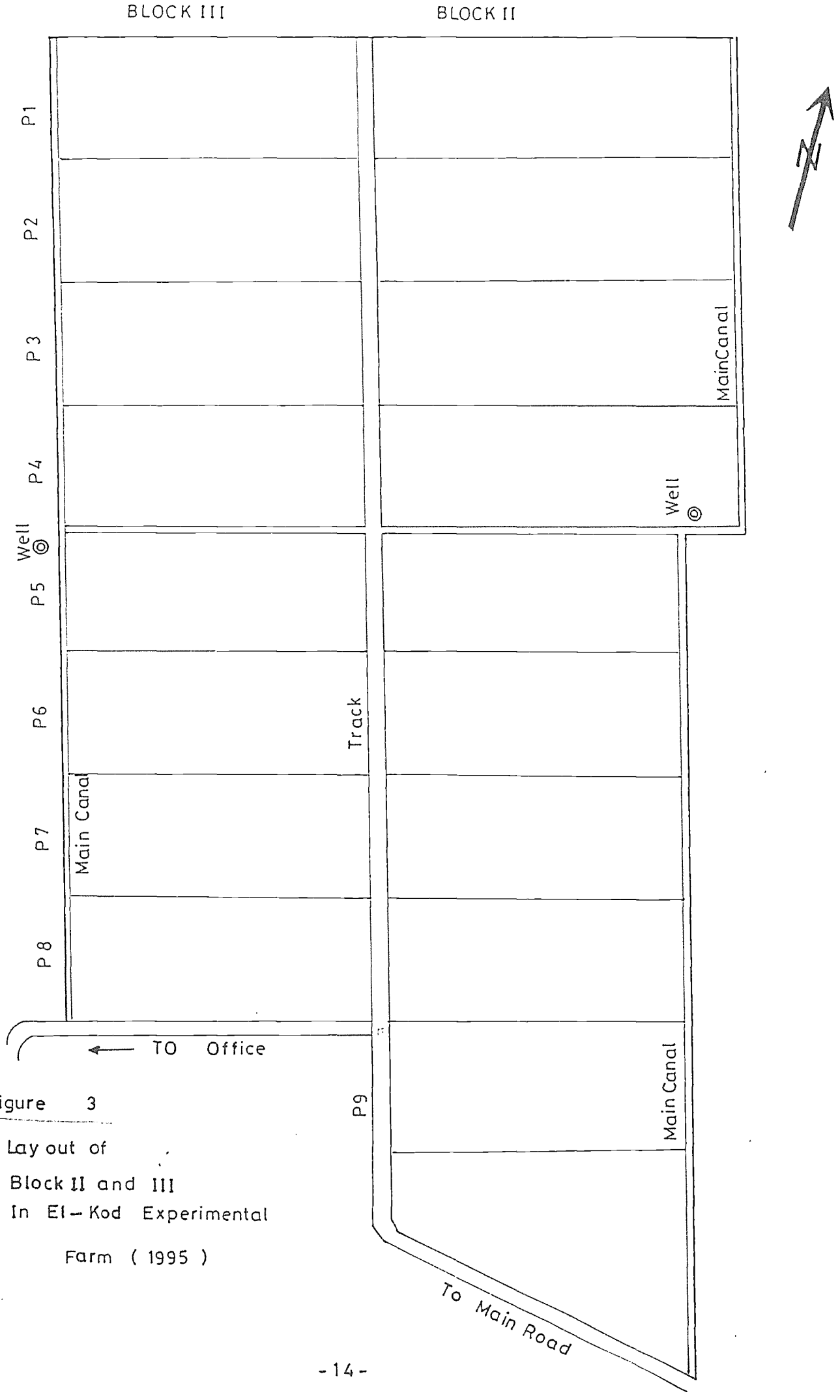


Figure 3

Lay out of Block II and III In El-Kod Experimental Farm (1995)

compatible to the computer-based soil information system. A total of 140 observations (fifteen profile pits and 125 auger observations) were described at the farm. The augers were normally drilled down to 1 metre and the soil profiles were dug to about 1.5 metre depth.

2.2.1.3 Soil classification

The soils of El-Kod research farm were classified according to the Soil Taxonomy of the United States Department of Agriculture (1994), and correlated with the FAO/Unesco Soil Map of the World classification (1988). At national level, the soils were classified to the family level and lately correlated with the existing soil series already established in previous soil surveys (El-Abbas Doka M. Ali and Wen Ting-tiang 1996).

2.2.1.4 Soil sampling and laboratory analysis

Doublicate soil samples were collected from all identified horizons in the fifteen profiles described at the farm. One set of samples was handed to the El-Kod laboratory, and one set to the Dhamar laboratory. The intention was to have some samples analyzed in both laboratories, so as to be able to compare results. However, this did not materialize. In total, about 90 soil samples were analyzed at El-Kod for the following parameters:

Total nitrogen*	Soil reaction (pH)*
Organic carbon*	Extractable phosphorus*
Mechanical analysis	Cation exchange capacity
Electrical conductivity	Exchangeable sodium
Soluble salts	Total Carbonates

* topsoil only

2.2.2 Field staff

The three soil surveyors and expert coming from Dhamar, were joined by four assistant researchers and a number of technicians from the Soil and irrigation section for training and assistance purposes. The whole staff was divided into three working groups under the supervision of the soil survey expert. The following staff members contributed in soil survey field work:

From Dhamar	From El-Kod
Dr. El Abbas Doka M. Ali	Ms. Zahra Ahmed Musa
Mr. A. Maged Abdul Raqip	Mr. Ahmed Mohamed Abdo
Mr. M. H. Al-Meshraki	Ms. Baraka Mohamed Saleh
Mr. A. A. K. Al-Borani	Mr. Fadl Haidrah Mohamed

Some of El-Kod staff members contributed also in the soil analysis carried out at El-Kod laboratory for the farm samples. Mr. Wen Ting-tiang, the project's Chief Technical Adviser (CTA), visited the survey area for soil correlation purposes accompanied by Mr. Abdul Alim Khalid Saif, the former National Project Director together with the present NPD, Mr. Omar Bafadel.

3.1 PREVIOUS WORK

El-Kod Research farm was established during colonial times in 1955, five years after the introduction of cotton in Abyan Delta. Although it was intended to serve the whole country, it had to pay special attention to local cotton growers, who started to face some problems, particularly in relation to soils (e.g. salinity, root rot, overwatering etc.). At this stage no soil survey was carried out to characterize soils of the farm.

In 1972 a land and water resource inventory was carried for Abyan Delta region by Dar Al-Handasah to provide an inventory of these resources. In 1984 W.S. Atkins & Partners revised the work of Dar Al-Handasah and published another report. These investigations provided valuable information for agricultural development in the region, but the studies did not provide detailed information on soil variations within small areas such as the El-Kod research farm.

When plant growth at some localities in the farm started to deteriorate the need was felt for more detailed soil studies. Two surveys were carried out on the farm by Abdul Rahman in 1972 and M.A. Abdel Salam in 1975. Both surveys provided valuable information and comments on the nature of the farm's soils, but unfortunately the standard of these detailed soil survey is not completely satisfactory, as the intensity of observations is rather low and the soil map units are not well characterized. It is not also possible to correlate soil classification to some previous studies or new systems due to very brief profile descriptions and different categorical levels of classification being used. Abdel Salem (1975) provided detailed methods and results for calculating irrigation and leaching requirement for a number of crops being grown on the farm.

After reviewing previous soil survey investigations it was decided to carry out a standard detailed soil survey on Block II and III which make the existing farm with an area of about 170 feddans (approx.71 ha). Other blocks were already being released to former local owners.

3.2 Morphological and physical characteristics

3.2.1 Parent material and genesis

The parent material of the soils of El-Kod research farm are part of the recent alluvial deposits laid down by three wadis (Bana, Hassan and Suhaibiya) in the Abyan delta. The alluvium is mainly composed of stratified silt loams, clay loams and very fine sands with variable thickness. The low duneland along the southwestern margin of Abyan delta lies close to the El-Kod research farm, and the whole area including the farm is affected by wind blowing. Aeolian deposits are seasonally reworked by wadi flood waters and mixed with other alluvium or deposited as thin sandy layers.

Absence of pedogenetic features in Abyan soils as already reported by Dar Al-Handasah (1974), is also confirmed through field observations at the El-Kod research farm. These immature soils are not expected to develop under the present arid climatic conditions. Evidence of calcium carbonate movement within the profile was not reported. Soil texture and degree of stratification are the main criteria used to differentiate the soils of the farm due to the absence of clear pedogenetic features. Some more characteristics, closely related to texture

and stratification, were also used to differentiate soils (e.g. salinity, structure, permeability). Most of the natural deposits in Abyan Delta seem to have been affected by intermittent anthropic deposition and wind action (Dar Al-Handasah, 1974). In the El-Kod farm although there are some deep, homogenous, relatively thick stratifications (dark layers) in block II which might probably indicate anthropic deposition (spate irrigation), it is believed that most soil were developed in natural deposits.

3.2.2 Stratifications and textures

All soils have clear stratifications with different textures throughout their profiles. Most profiles are strongly stratified with 6 - 9 layers and the rest are moderately stratified with 4 -5 layers. Thickness of layers range from 20 to 40 cm, but few have layers of more than 40 cm thickness. Textures are dominantly silt loam, silty clay loam with very few layers of loam, clay loam and sandy loam (Figure 4 and 5). Clayey stratified textures of clay and sandy clay loam are localized in one site in block II. Fine to medium silt is the dominant particle size, mixed with variable amounts of clay, coarse silt and very fine and fine sand. It was assumed that the slightly lower parts of block II were mostly flood-irrigated and hence characterized by deep silty clay loams and silt loams with little stratifications. It is here that anthropic deposition is suggested.

3.2.3 Soil colour

Under the prevailing arid conditions, the organic matter content of the soil is negligible and no translocation of clay and carbonates would occur. Therefore, the soil colour reflects the colour of the textural particles only. Very little variation in colour exists among most textures, but generally heavy textured soils have darker colours than lighter ones. All hues were reported as 10YR, with values ranging between 7 and 4 while the chroma is between 4 and 2. In some profile dark mottles were reported.

3.2.4 Structure and porosity

Since these alluvial soils are silty and stratified, common platy structures with limited porosity are dominant under these arid conditions . Soil structure refers to the nature and degree of aggregation of soil particles and porosity refers to the amount of voids between and within these aggegrates. Stratified soils with dense or contrasting layers at different depths will definitely affect water infiltration, and a perched water table might develop and which could lead to reduction in soil aeration for crops.

3.2.5 Soil-water relationships

i) Infiltration rate and permeability field

The least pervious layer in a profile regulates the vertical permeability, and thus controls the infiltration rate (FAO 1986). Optimum infiltration rates for gravity irrigation are between 0.7 and 3.5 cm/hr. Structure, sodicity and bulk density all influence the infiltration rate through their relation to pore size and cleavage plane. The average hydraulic conductivity of a soil profile is used to determine subsurface drainage and to evaluate the possibility of perched water table developing. In strongly stratified soils such as found at El-Kod, the minimum hydraulic conductivity values depend on the depth of the slowly permeable layer. The development of a perched water table is also influenced by the frequency of irrigation and/or heavy rainfall during the cropping season. To obtain high yields, the upper rooting zone should in general not be saturated for more than 48 hours during most of the crop growth period, although this depends to some extent also on the crop being grown, with some crops (such as sesame) being more sensitive to water logging than others (such as sorghum after seedling

stage). Field determinations for both parameters were not done and it was suggested to be carried as part of the research for the soil and irrigation section in the future. The following data was selected from Dar Al-Handasah(1974) previous work in Abyan Delta.

The data shown in table 4 indicate that contrasting layers, fine textures (silt + clay) and total carbonates have a significant effect on the infiltration rate and permeability. These soils from Abyan delta fairly represent El-Kod soils despite their lower silt %, and the relatively low $CaCO_3$ and ESP figures in two of the pits. Pits 695/1 and 210/4 represent the very few homogenous fine and coarse texture soils respectively. Pits 674/5 and 706/3 represent dominantly stratified soils with different textures and/or contrasting layers. It can be assumed that such soils with higher figures of ESP and fine silt or clay would have infiltration rate values even lower than in table 4.

Table 4 Terminal infiltration rate for soils similar to those at El-Kod, selected from Dar Al-Handasah (1974)

Pit No.and Depth cm	Texture Class	Silt %	Clay %	Total CaCo3 %	ESP	Terminal Infiltration Rate (cm/hr)
695/1						
0 -15	Cl	30	38	11.8	11.0	
15-35	Cl	24	38	11.4	10.9	
35-90	Cl	20	34	13.9	6.4	
90-150	L	38	18	14.3	13.5	1.6
674/5						
0 -50	L	42	14	28.4	8.0	
50 -100	Sl	44	4	23.4	15.7	
100-150	Sil	52	4	21.6	12.5	5.7
706/3						
0 -20	L	36	26	8.7	0.5	
20 -50	Ls	8	10	3.4	0,8	
50 -85	Cl	34	30	9.7	0.3	
85 -95	Sl	8	18	5.4	0.4	
95 -150	Sl	16	12	6.2	0.8	4.6
210/4						
0 -15	L	46	16	6.7	14.5	
15 -65	L	46	22	7.0	8.0	
65 -75	Sl	36	14	8.1	11.0	
75 -125	L	38	16	7.6	12.0	
125-150	Sl	22	12	7.8	22.0	10.8

Figure 4 Dominent coarse textures

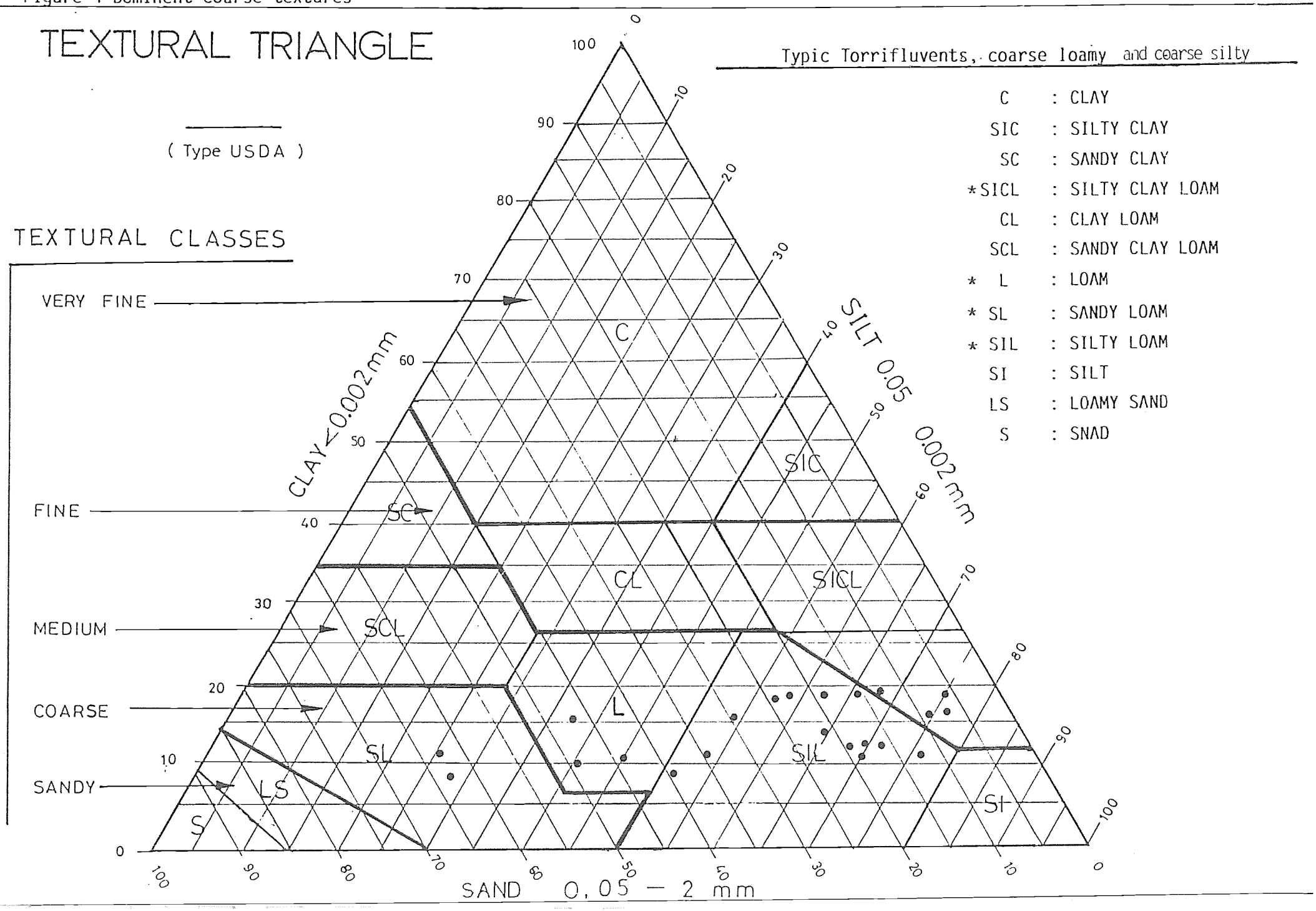
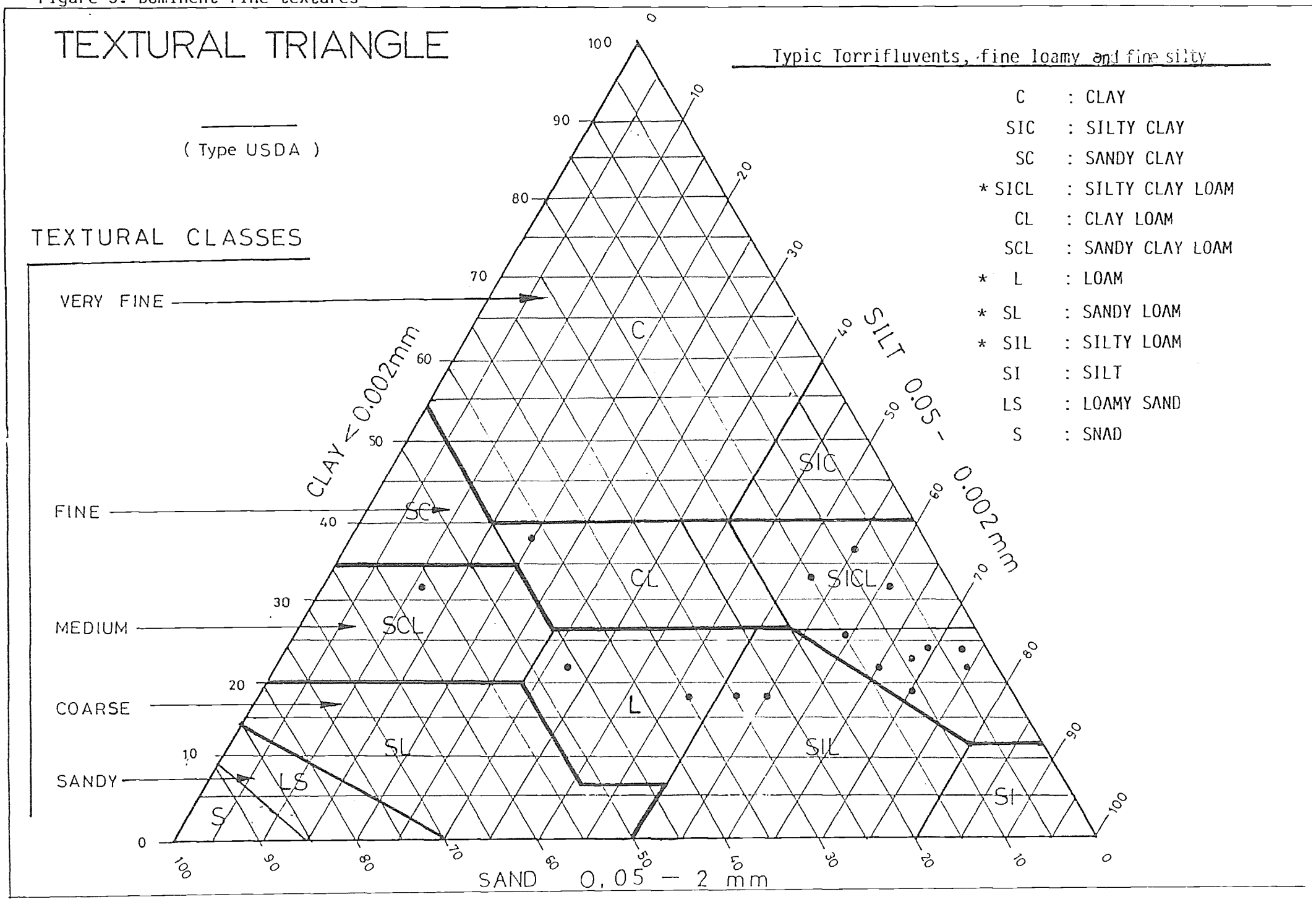


Figure 5. Dominent fine textures



ii) Available water

Since it is debatable whether the water holding capacity at 1/10 or 1/3 atmosphere tension represents the Field Capacity, particularly for coarse textured soils (Hansen et al, 1979), Dar Al-Handasah (1974) decided to take the average of these values. As the stratified El-Kod soils have both fine and coarse textures within most profiles, it seems that average values represent these soils fairly well. Table 5 shows the average minimum (water at 1/3 atm. minus water at 15 atm.) and the average maximum (water at 1/10 atm. minus water at 15 atm.) available water for dominant textures in El-Kod farm, as adapted from Dar Al-Handasah (1974).

Table 5 Available water for some selected textures in Abyan delta and relevant to El-Kod farm, as adapted from (Dar Al-Handasah 1974)

Textural Class	Available Water (cm water per 100 cm soil)	
	Range (minimum - maximum)	Average
Loamy Sand	3.9 - 7.9	5.9
Loam	13.8 - 26.3	20.1
Sandy loam	14.3 - 27.7	21.0
Silt Loam	16.3 - 28.2	22.3
Clay Loam	17.0 - 29.6	23.3
Silty Clay Loam	22.8 - 28.0	25.4

Table 6 shows the calculated available water capacities for some profiles representing the soil series in El-Kod farm. The data show clear differences between the slightly stratified, dominantly fine or coarse textured soils (e.g Tarim and Nuqub) and the strongly stratified soils (Zinjibar and AL-Nash).

Table 6 Available water in profiles representing the soil series of El-Kod farm

Soil Series (representative profile)		Available Water Holding Capacity (cm water per 100 cm soil)
Zinjibar	(ABI001)	22.4
Zinjibar variant	(ABI013)	22.2
Nuqub	(ABI002)	23.3
Nuqub variant 1	(ABI005)	21.8
Nuqub variant 2	(ABI014)	22.3
Tarim	(ABI007)	26.3
Al-Nash	(ABI008)	22.9

3.3 Chemical characteristics

3.3.1 Salinity and alkalinity

The results of the chemical analysis shows that most soils are slightly saline and few are moderately saline and alkaline (see Annex 2). Dar Al-Handasah (1974) reported that 75 % of its sites are non to slightly saline, 20 % moderately saline and alkaline and 5 % are strongly saline. This corresponds very well with the situation in El-Kod despite the absence of strongly saline soils in E l-Kod (Figure 6). Vertical distribution of salinity within the profile seems to be controlled by texture and stratifications. Homogenous fine or coarse textured soils have regular distribution of slight salinity within the profile with some increase of salts in the topsoil (e.g. pits ABI010 and ABI013). In stratified soils the heavy textured layers in the topsoil, substratum or inside the profile always have high concentration of salts (e.g pit ABI001). Strongly stratified layers with contrasting textures or high clay contents have high levels of salts (e.g. pits ABI008 and ABI009). Land use is an important influence in controlling salts as it was reported that abandoned fields tend to become slightly to moderately saline through time. Intensive cropping and elimination of long fallows results in increased water use in the recharge area, decreased seepage flow and therefore a reduced salinity problem (FAO 1988).

The degree of alkalinity is reflected in the percentage of exchangeable sodium (ESP), which at El-Kod shows a wide range of values (20 - 75). The pH is relatively high, which can also be an indication of high Na levels, although its range is less wide (8.0 - 8.4). Most soils are moderately to severely alkaline, which might have been caused by using the farm irrigation water with its high levels of sodium (Figure 4). In this respect El-Kod farm does not represent surrounding soils in Abyan with their low levels of ESP as reported by Dar Al-Handasah in 1974.

3.3.2 Total carbonates

Despite the high content of carbonates in the soils of El-Kod farm in the form of $CaCO_3$ they are not visible in the soil profile. Soft aggregates, streaks and hard concretions were not observed in soil profiles. The chemical analysis showed that almost all horizons have between 100 and 150 g/kg $CaCO_3$, and very few with less than 100g/kg. Dar Al-Handasah (1974) reported that generally between 5 and 30 % of the carbonate in Abyan delta soils occur in the silt and clay fractions where they have direct effect on soil texture and related properties. This seems to apply to El-Kod soils as well.

3.3.3 Fertility status

Organic carbon, Nitrogen, phosphorus and potassium have been analyzed in the topsoils. In all previous work as well as in this report, the organic matter percentage was calculated from organic carbon figures (Organic carbon g/kg X 0.174). An average from all previous topsoil results showed that they are extremely low with less than 1.5 % organic matter. Recent Organic carbon data from El Kod (Appendix 3) showed relatively high figures than the normal which require further investigation and checking. Nitrogen is also extremely low (0.01 - to 0.05 %), and on average even less than what was reported in Dar Al-Handasah (1974), which ranged from 0.01 % to 0.13 % (average 0.05 %). Available phosphorus levels (dominantly between 4 - 8 ppm) are fairly adequate for some crops like cereals, but moderately deficient for cotton and highly deficient for vegetables (Table 7). This is most probably attributed to the strongly calcareous soils of El-Kod , which can fix high amounts of phosphorus. Previous data from Dar Al-Handasah (1974) indicated an average of about 5000 ppm total extractable potassium for Abyan delta soils, which seems adequate. Soil parent

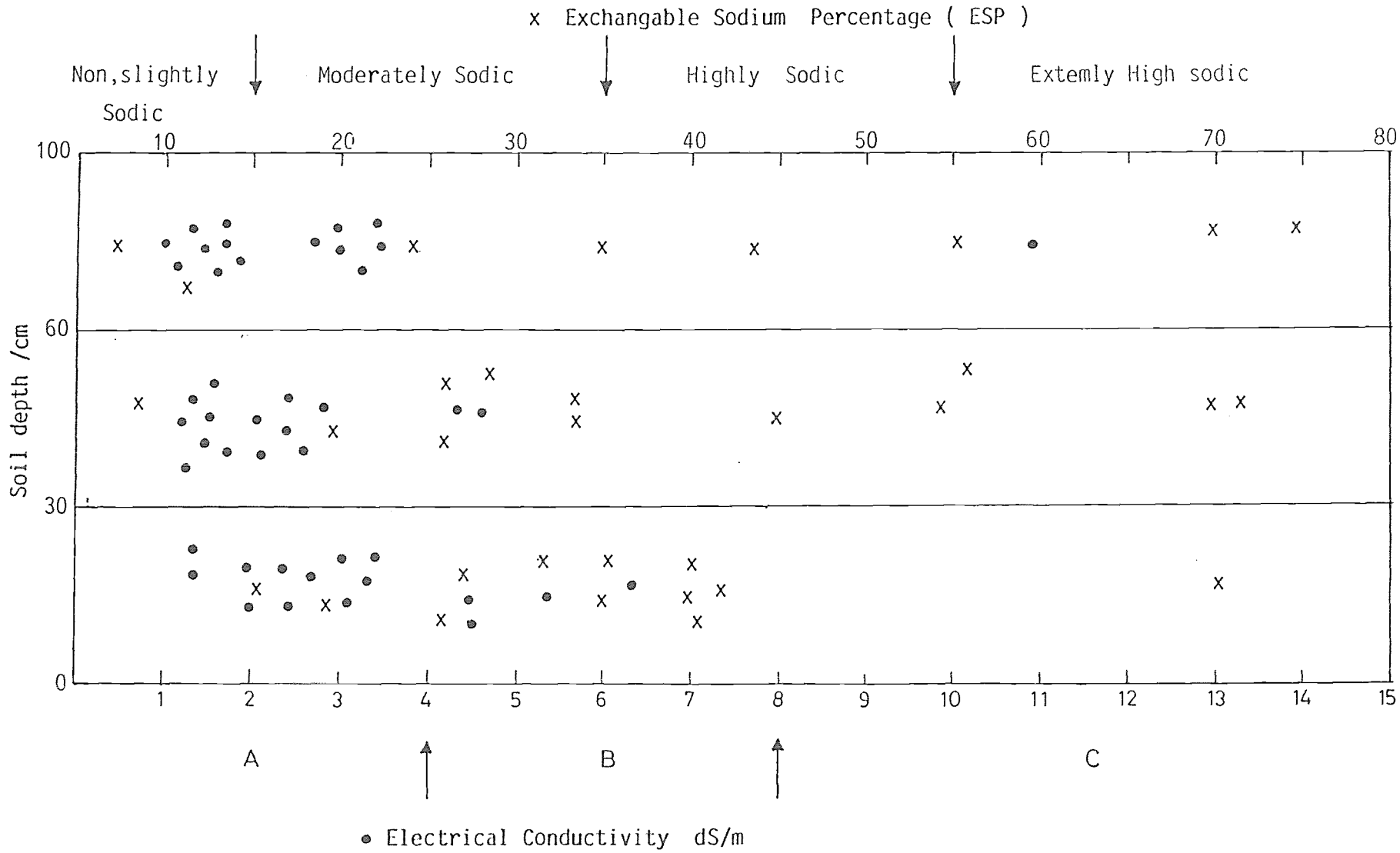


Figure 6. ESP and EC in El Kod Research farm

materials rich in potassium (e.g. muscovite, biotite etc..) are abundant in Abyan Delta. Glittering mica particles were already noticed in all locations within the farm. Previous data on boron revealed that the figures obtained are below toxicity levels.

Table: 7 General interpretation of available phosphorus determined by Olsen's method (Landon 1991)

Characteristic crop demand	Examples	Indicative available P Values (ppm)		
		Deficient	Questionable	Adequate
Low P	Grass, cereals, soybeans, maize	< 4	5 - 7	> 8
Moderate P	Lucerne, cotton, sweetcorn, tomatoes	< 7	8 - 13	> 14
High P	Sugarbeet, potatoes, celery, onions	< 11	12 - 20	> 21

3.4 SOIL CLASSIFICATION

Four **soil series** and three **soil variants** were identified in El-Kod farm. Some of these *taxonomic units* were named in previous surveys carried out in Abyan, Ahwar and Nuqub (Mohamed Ali and Wen, 1996) and characterized as "depositional" series due to their mode of formation. The definition of a soil series is " a group of soils having soil horizons similar in differentiating characteristics and arrangement in the soil profile, except for the texture of the surface soil, and developed from a particular type of parent material. The soils within a series are essentially homogenous in all soil profile characteristics except texture, principally of the surface horizon, and slope, stoniness, degree of erosion, topographic position and depth to bedrock where these features do not modify greatly the kind and arrangement of soil horizons". However, since 'soil series' is traditionally restricted to soils in which profiles are differentiated by a sequence of morphological features resulting from a pedogenetic process, it was preferred to modify the term for soils which are pedogenetically inactive. Hence the term 'depositional series' was used (Nuqub Area, Hunting Technical Services Ltd 1967). They are mainly stratified alluvium deposits laid down by wadis. A soil variant is defined as a soil unit closely related to a soil series but departing from it in at least one differentiating characteristic at series level. It is used to avoid establishing a separate series. The variant was used in El-Kod research farm to allow mapping areas of limited extent and slightly different than one of the defined soil series.

All soil series were classified as Typic Torrifluvents with coarse or fine silty and or with coarse or fine loamy textural class families according to the USDA Soil Taxonomy (1994). Based on the available three years soil temperature data in El Kod, the mean soil temperature is 30.5°C in winter, 36.0°C in summer and the mean annual is 32°C. Accordingly the soil temperature regime in El Kod farm is classified as hyperthermic in which the mean annual soil temperatures are of 22°C or higher with a difference of more than 5°C between mean summer and mean winter soil temperatures. The soils are assumed to have a mixed clay mineralogy as they were washed by water from different locations having variable parent materials. Since all soils are calcareous, calcareousness was not indicated in the family name. Physiographic position, stratifications and irregular decrease of organic carbon with depth are the main criteria to identify these taxonomic units. Although the first two conditions are evident, all organic carbon analyses were unfortunately done for topsoils only. Therefore, organic carbon analysis for the whole soil profile depth need to be made for all soil series to complete their identification. According to the FAO soil classification (1988) and the World Reference Base (WRB) for Soil Resources (1994) all taxonomic units were classified as Calcaric Fluvisols.

Series should be defined in the same way everywhere, regardless of the immediate purpose of the survey. Where detailed interpretations are required, the series can be subdivided into phases according to any characteristics significant to land use, for example depth, surface texture, stoniness, slope or salinity. The phase is not a unit of taxonomic classification. It can be used at any categoric level to draw attention to differences of practical significance.

All soil series (Zinjibar, Nuqub, Tarim and Al-Nash) and soil variants (Zinjibar variant-1, Nuqub variant-1 and variant-2) were described below and the differentiating characteristics were summarized in Table 8. Al-Nash series is a new addition to the national soil series list (Doka M. Ali and Wen Ting-tiang 1996). It was initiationally excluded when selecting soil series due to the abscence of chemical data with the original description. Now a similar profile to Al-Nash was identified in El-Kod research farm and supported by recent analytical data will be taken to represent Al-Nash series.

3.4.1 Zinjibar series

This is a very deep, well drained, very pale brown and brown moderately stratified alluvial soil. Textures are coarse loamy (dominantly silt loam, loamy very fine sand and loam). They are non-saline and sodic, developed in sub-recent alluvium. The EC of the topsoil ranges between 2 to 4 mS/cm, and in the subsoil 1 to 4 mS/cm. Exchangeable sodium percentage (ESP) figures vary between 35 and 85. Total carbonates figures have a wide range of 50 - 140 g/kg. Cation Exchange Capacity (CEC) values are low, ranging between 14 to 24 cmol/kg.

Typical profile: **ABI001** [other profiles: ABI003, ABI004 and ABI011]

3.4.2 Zinjibar variant-1

Zinjibar variant-1 is a very deep, well drained, brown and dark yellowish brown, moderately stratified alluvial soil. Textures are coarse loamy (dominantly silt loam). Topsoils are non-saline (< 2.0 mS/cm) and subsoils are slightly saline (2.0 - 4.0 mS/cm). They are non sodic with ESP values generally less than 15 %. Total carbonate figures are generally above 100 and up to 140 g/kg. The CEC figures are slightly lower than in the Zinjibar series (15 - 20 cmol/kg).

Typical profile : **ABI013** [other profile: ABI006]

3.4.3 Nuqub Series

This is a very deep, moderately well drained, pale brown and brown to dark brown strongly stratified alluvial soil. Their texture is fine silty (dominantly silt loam, silty clay loam and loam). The EC of topsoil and subsoil is generally below 2.0 mS/cm. Organic Carbon figures are generally high (> 8.0 g/kg). The soils are slightly to moderately alkaline with ESP values ranging from 21 to about 60. Although total carbonates range from about 60 to 140 g/kg, dominant figure consistently stay above 100. These soils are quite homogenous in the distribution of their chemical and physical properties within the profile.

Typical profile : **ABI002** [other profiles: ABI010, ABI015]

3.4.4 Nuqub variant-1

Nuqub variant-1 soils are very deep, moderately well drained, yellowish brown and dark yellowish brown, slightly to moderately stratified alluvial soils. The texture is coarse silty (dominantly silt loam and loam). The topsoil is slightly saline (about 3.0 mS/cm) and the subsoil normally non saline (< 2.0 mS/cm). Organic Carbon is very high if compared with other soils on the farm. Total carbonate values are dominantly between 110 to 150 g/kg and some levels as low as 90 were also noticed. Available phosphorus is relatively high (about 10 mg/kg) considering the calcareousness of the soils.

Typical profile : **ABI014**

3.3.5 Nuqub variant-2

Nuqub variant-1 soils are very deep, moderately well drained, yellowish brown and dark yellowish brown, slightly to moderately stratified alluvial soils. The texture is fine loamy

(dominantly silt loam and loam). The topsoil is slightly saline (about 3.0 mS/cm) and the subsoil normally non saline (< 2.0 mS/cm). Organic Carbon is very high if compared with other soils on the farm. Total carbonate values are dominantly between 110 to 150 g/kg and some levels as low as 90 were also noticed. Available phosphorus is relatively high (about 10 mg/kg) considering the calcareousness of the soils.

Typical profile : **ABI005**

3.4.6 Tarim Series

This is a very deep, moderately to poorly drained, grayish brown and dark brown, slightly stratified alluvial soils. Their texture is clayey (dominantly clay loam, sandy clay loam and clay). The soils are non-saline, but a slight salinity in the topsoil can be expected. CEC is relatively high in top and substratum clayey textures. Total carbonates show a strong relation with the high clay content in top and bottom layers, indicating that a considerable amount of the fine material is in carbonate form. These soils are moderately to strongly sodic (ESP values range from 25 to 75 %).

Typical profile : **ABI007**

3.4.7 Al-Nash Series

This is a very deep, moderately well drained, yellowish brown and pale brown moderately to strongly stratified alluvial soil. Its texture is coarse loamy (dominantly silt loam and loam). It is a moderately saline (dominantly between 4 and 12 mS/cm) and strongly sodic soil (ESP about 30 to 80). Al-Nash series is characterized by its high silt content with silt and clay making up more than 85 % of the particle size distribution. In the subsoil, which becomes fine loamy, this figure increase to 95 %. If the dominant figures of carbonates (120 - 150 g/kg) were added to the silt and clay, permeability should be highly affected.

Typical profile : **ABI008** [other profiles: ABI009, ABI012]

Table 8 : Differentiating soil characteristics for Soil Taxonomic units (soil series and soil variants) in El-Kod research farm

Soil Taxonomic Units	Particle size distribution			Texture	Family Textural Class	Stratification	Sodium Adsorption Ratio (SAR)	EC	Available Water Capacity cm/100cm	Representative profile
	Sand	Silt	Clay							
1. Zinjibar series	> 15	≃ 50	< 18	Silt loam	Coarse loamy	Moderately stratified	>15	2 - 4	22.4	ABI001
2. Zinjibar variant-1	> 15	≃ 50	< 18	Silt loam	Coarse loamy	"	<15	≃ 2	21.5	ABI013
3. Nuqub series	< 15	> 50	> 18	Silt loam	Fine silty	Strongly stratified	>15	< 2	23.3	ABI002
4. Nuqub variant-1	< 15	> 50	< 18	Silt loam	Coarse silty	"	>15	< 2	21.8	ABI014
5. Nuqub variant-2	< 15	≃ 50	> 18	Silt loam	Fine loamy	"	>15	< 2	22.3	ABI005
6. Tarim series	< 15	< 25	> 30	Silty clay loam	Clayey	Slightly stratified	<15	< 2	26.3	ABI007
7. Al-Nash series	> 15	> 50	< 18	Silt loam	Coarse loamy	Strongly stratified	>15	> 4	22.9	ABI008

3.5 MAPPING UNITS

3.5.1 Main concepts

Depending on the purpose of a survey, a number of soil and land characteristics need to be determined. For surveys for irrigation projects, these include topography, texture, drainage, texture, reaction, maximum tolerance of salinity for different crops and ESP. Soils can then be grouped in delineations (map units) according to similarities and differences in key characteristics in relation to irrigation , and accordingly a soil map is be produced.

The main purpose of the El-Kod soil survey is :

1. Test the representation of El-Kod soils to the regional soils,
2. Define the main soil and water constraint s in relation to crop production and
3. Recommend suitable management and agricultural practices in relation to soil and water.

Two types of mapping units were identified at the El-Kod farm:

A. Soil consociations

In a consociation, delineated areas are dominated by a single soil, and soils very similar to it (Van Wambeke and Forbes, 1986). As a rule, at least one half of the soils in each delineation of a soil consociation are of the same taxonomic unit and provide the name for the map unit. Most of the remainder of the delineation consists of taxonomic units so similar to the named soil that major interpretations are not affected significantly. The total amount of dissimilar inclusions of other components in a map unit generally does not exceed about 15 % if can not be cultivated (e.g rocky), and 25 % if they can be cultivated.

Example: Nuqub silt loam; and Al-Nash silt loam

B. Soil complexes

A complex is a group of associated soils which can not be separated at the scale of mapping due to the complexity of the soil pattern. The total amount of inclusions that are dissimilar to all of the major components does not exceed about 15 % if limiting and 25 % if nonlimiting.

Examples: Nuqub - Zinjibar Complex; and Nuqub - Nuqub variant-1 Complex

3.5.2 Description of map units

The map units symbol, name, percentages of soil components, main characteristics, constraints and extent were described for the eight map units within Al-Kod farm as shown in Table 8a and 8b. Some representative pits within each map unit were also indicated. Minor soils within map units were indicated as inclusions.

Table 8a: Main characteristics of map units in El-Kod research farm

MAP UNIT		COMPONENTS (%)	MAIN CHARACTERISTICS	CONSTRAINTS	EXTENT ha	Profile(s) within the unit
Symbol	Name					
ZB	*Zinjibar silt loam, silty clay substratum*	Zinjibar(ZB) 70 % Nuqub variant-1 20 % Inclusions (NQ) 10 %	Stratified, dominantly silt loam and loamy very fine sand soils with silt loam top-soil and silty clay loam substratum, slightly saline, moderately sodic.	Moisture, alkalinity and fertility	3.0	ABI001
ZB - NQv2	*Zinjibar-Nuqub variant-2 Complex*	Zinjibar(ZB) 40 % Nuqub variant-2 40 % Inclusions (NQv1, NS) 20 %	Stratified, dominantly silt loam and silty clay loam soils with silt loam topsoil and silty clay loam substratum, non to slightly saline and moderately sodic.	Moisture and alkalinity.	8.7	ABI003 ABI005
NQ - ZB	*Nuqub-Zinjibar Complex*	Nuqub(NQ) 50 % Zinjibar(ZB) 25 % Inclusions (NQ, NQv1, TR) 25 %	A complex of stratified dominantly silty clay loam soils , with silt loam topsoil and silty clay loam substratum and soils similar to Zinjibar , non- saline and non-sodic.	Permeability and alkalinity.	15.8	ABI002 ABI004 ABI010 ABI011
TR - ZB	*Tarim-Zinjibar Complex*	Tarim(TR) 65 % Zinjibar(ZB) 25 % Inclusions (NQ, NQv2) 20 %	A complex of moderately drained, dominantly silty clay and clay loam soils with silt loam and silty clay loam topsoil and soils similar to Zinjibar with silt loam and silty clay loam topsoils. They are slightly saline, moderately sodic.	Permeability, alkalinity and moisture.	5.1	ABI006 ABI007

Table 8b: Main characteristics of map units in El-Kod research farm

MAP UNIT		COMPONENTS %	MAIN CHARACTERISTICS	CONSTRAINTS	EXTENT Ha	PROFILE(S) WITHIN THE UNIT
Symbol	Name					
NS	*Al-Nash silt loam*	Al-Nash(NS) 75 % Inclusions 25 % (NQv1, NQv2)	Stratified, dominantly silt loam and loam soils, with silt loam topsoil and silty clay loam substratum. Minor inclusions of strongly stratified silty clay loam and silty loam soils with silt loam and silty clay loam topsoil are available.The soils are saline and sodic	Salinity, Alkalinity and fertility	8.9	ABI008 ABI009
NS - ZBv1	*Al-Nash - Zinjibar variant-1 Complex*	Al-Nash(NS) 50 % Zinjibar variant-1 35 % Inclusions 15 % (NQ, NQv1)	A complex of soils similar to Al-Nash and stratified dominantly silt loam and loamy very fine sand soils with silt loam topsoil and silty clay loam substratum, slightly saline and sodic.	Alkalinity, salinity and Fertility	6.7	ABI012 ABI013
NQ - NQv1	*Nuqub - Nuqub variant-1 Complex*	Nuqub(NQ) 45 % Nuqub variant-1 35 % Inclusions 20 % (ZB, ZBv1)	A complex of soils similar to Nuqub and moderately stratified, dominantly silt loam soils with silty clay loam topsoil and substratum. They are non-saline and sodic. They occupy slightly higher position.	Permeability and Alkalinity	10.2	ABI014 ABI015

3.5.3 Predictive accuracy of soil map units

The purpose of the boundaries on a soil map is to enable the user to predict the soil properties of the individual mapping units more precisely than those of the area as a whole, and to be in a position to manage each unit differently. A map is only worth making if each of the units shown both (i) differ significantly from each of the other units in respect of soil properties, and (ii) respond differently to at least some kinds of management. That is, the difference between mapping units must be both statistically significant and relevant to land use or management. The method for measuring the degree of difference between mapping units is based on the relative variance (RV) defined as:

$$RV = \frac{\text{Variance within mapping units}}{\text{Total variance over mapped area}}$$

The predictive accuracy of a map is given by 1 - RV. A 'perfect' map, one in which the mapping units are all completely homogenous internally, but differ from each other , gives a value for 1 - RV of 1. A useless map, in which variance within mapping units is just as large as over the area as a whole, gives 1 - RV as 0 (Dent and Young 1982). Similar statistical analysis were carried for El-Kod soil map units. A summary for analysis of variance is given in Tables 9 and 10 shown below, but detailed data was provided in Appendix 1.

Table 9 Values of significance for three particle sizes and some of their combinations among the mapping units in El-Kod research farm.

Descriptive item	Observed F	Indication
Variance among mapping units		
Clay content	4.67	**
Silt content	2.85	
Silt plus clay content	16.65	***
silt plus very fine sand content	2.70	

Criteria

Probability level	10%	5%	1%
F-value	3.05	4.28	8.47
Indication	*	**	***

Table 10 Values of significance for three particle size stratifications and some of their combinations within the mapping units in El-Kod research farm.

Descriptive item	Observed F	Indication
Variance among mapping units		
Clay content	2.46	
Silt content	2.66	
Silt plus clay content	4.32	**
silt plus very fine sand content	1.37	

Criteria

Probability level	10%	5%	1%
F-value	3.05	4.28	8.47
Indication	*	**	***

Based on the above summary of results, the relative Variance (RV) was calculated for the different particle sizes and their combinations as follows:

$$\text{RV for clay} = \frac{2.46}{4.67} = 0.53$$

$$\text{RV for silt} = \frac{2.66}{2.85} = 0.93$$

$$\text{Rv for silt + clay} = \frac{4.32}{16.65} = 0.25$$

$$\text{RV for VFS + silt} = \frac{1.37}{2.70} = 0.51$$

According to the above results of Relative Variance, the calculations for 1 - RV for the different selected particle sizes for Al-Kod soil map units will be as follows:

For clay (1-RV) = 1 - 0.53 = 0.47
For silt (1-RV) = 1 - 0.93 = 0.07
For silt + clay (1-RV) = 1 - 0.25 = 0.75
For VFS + silt (1-RV) = 1 - 0.51 = 0.49

It is now clear that silt plus clay which are the most important two particle size components of the textural classes in El-Kod farm, are statistically significantly different in the mapping units. As the differences in texture affect the use and management of these depositional soils, the mapping units delineations in El-Kod farm should be considered adequately by farm managers and researchers when designing trials related to these properties.

4.1 LAND SUITABILITY CLASSIFICATION

Land suitability evaluation is the process of assessing the suitability of land for specific kinds of use. These may be major kinds of land use, such as rainfed agriculture, irrigated agriculture, livestock production, etc.; or land utilization types described in more detail, for example irrigated arable farming based on banana and papaya, or rainfed arable farming based on sorghum and groundnuts. There are four categories or levels of classification: Land suitability orders, classes, subclasses and units (Table 11). These suitability classes are assessed separately for each kind of land use under consideration, with respect to each land mapping unit in the survey area. *Suitability orders* separate land assessed as 'suitable' (S) from that which is 'not suitable' (N) for the use under consideration. The three main reasons why

Table 11: Categories of land suitability classification

Category			
Order	*Class*	*Subclass*	*Unit*
S, suitable	S1 S2 S3	S2m S2e* S2me	S2e-1* S2e-2*
phase; Sc, conditionally suitable	Sc2	Sc2m	
N, not suitable	N1 N2	N1m N1e	

land may be classed as not suitable are that the proposed use is either technically impracticable (cultivating very thin or rocky soils); environmentally undesirable (would lead to severe soil erosion) or economically unprofitable. *Suitability classes* indicate degrees of suitability. S1, 'highly'; S2 'moderately' and S3 'marginally' suitable. Of the two classes within the order 'not suitable', N1, indicating 'currently not suitable',refer to the land on which the use under consideration is technically possible but not economic; at present prices the cost of inputs needed to overcome the limitations would exceed the cost of production. Changes in the relative prices of the product and inputs , or advances in technology, e.g. new drought resistant crop varieties, can result in upgrading of N1 land. N2, indicating 'permanently not suitable', is applied to land on which it is unlikely that any foreseeable change in technical or economic conditions would render it viable for the use. *Suitability subclasses* indicate kinds of limitations, e.g. moisture deficiency, erosion hazard. They are indicated by lower case letters placed after the class symbol, e.g. S2m, S2e. *Suitability units* are divisions of subclasses that differ from each other in detailed aspects of their production characteristics or management requirements (Dent,D. and Young, A. 1981).

4.2 IRRIGATION AND LEACHING REQUIREMENTS

Leaching requirements is always considered when it is necessary to avoid accumulation of high levels of salts from irrigation water, which are harmful to the crops. Abdel Salam (1975) have discussed in detail leaching and irrigation requirements for different crops grown in El-Kod farm. Due to the lack of drainage system in El-Kod farm, he based his calculation on a leaching index (**LI**) defined as follows:

LI = Crop salinity tolerance / (crop salinity tolerance - water salinity).

The average salinity of the irrigation water calculated from data of seven wells in 1975 was about 1.20 mmhos/cm. Abdel Salam (1975) stated that according to Handbook 60 (1954), crop tolerance in mmhos is 16 for cotton, 10 for grains crops and vegetables and 4 for fruit trees. Accordingly he calculated the leaching indices ; 1.1 for cotton, 1.14 for grain crops and vegetables and 1.5 for fruit trees. The recent laboratory analysis carried for this study showed that the average salinity of irrigation water collected from two wells in El-Kod, is about 2.3 dS/m (equals 2.3 mmhos/cm). This data is summarized in Table 12. When Leaching Index is recalculated based on the new figures of water salinity, a considerable difference is apparent, particularly for fruit trees as shown in Table 13.

Table 12 : Leaching Index (LI) for irrigation water in 1975 & 1996

CROPS	Cotton	Grain crops	Fruit trees
Crop tolerance *	16	10	4
EC of irrigation water 1975 *	1.2		
Leaching Index 1975	1.1	1.14	1.5
EC of irrigation water 1996 *	2.3		
Leaching Index 1996	1.2	1.3	2.4

* All salinity figures are dS/m = mmhos/cm

Table 13 Irrigation and leaching requirements for some crops in El-Kod farm for 1975 and 1996

CROP	Irrigation requirements	Irrigation plus leaching requirements in 1975	Irrigation plus Leaching requirements in 1996
	M^3/feddan		
Cotton	4670	5137	5604
Corn	2813	3206	3657
Sesame	3333	3500	4333
Sorghum	2831	3227	3680
Millet	2710	3089	3523
Wheat	3262	3719	4241
Potato	2530	2884	3289
Tomato	3590	4079	4667
Other vegetables	3600	4104	4680
Melons	3669	4132	4770
Banana	12900	19350	30960
Mango	4520	6780	10848
Papaya	5567	8350	13361
Citrus	8316	12474	19958
Alfalfa	3516	3516	3516

The consumptive use requirements for crops were calculated according to Blaney-Criddle and Penman formulas (Abdel Salam, M.A.1975). The irrigation requirements were estimated assuming 30% conveyance losses. According to the data showed in Table 13 , it seems that the fruit trees need large quantities of irrigation water to meet their leaching requirements. It is also evident that grain crops need the least, if compared with fruit trees and vegetables. With the present quality of water it might be concluded that it is economically feasible and environmentally desirable to grow cereals and grain crops than intensive crops. If it is possible and as well feasible to find alternative sources of better irrigation water outside the farm, other selected crops might be considered. These kinds of situations might be existing in some other places and applies to most of the farming systems. Updating resource information is highly needed for regional agricultural planning, especially in relation to water, crops, climate and soil.

4.3 SOIL SUITABILITY FOR CROPS

Climate and soil requirements for some adapted crops were listed in Tables 14, 15 and 16 . This information was adapted from international established records(Dent and Young 1982; FAO 1995), since regional research findings in Yemen does not cover all aspects of crop requirements. However, beside the soil fertility trials in El-Kod, some effort has to go to soil permeability, salinity and water requirements trials for different crops to have a complete list of crop requirements for the locally adapted crops. Monitoring of water and soil salinity is also vital for all management practices and trials.

The soil suitability of the different map units within El-Kod farm for some selected crops is shown in Table 17. Most crops were grouped together since their soil requirements are similar.

Table 14 Climatic, soil and water requirements for some selected crops

Crop	Total Growing period (days)	Temperature requirements for growth(0C) optimum(range)	Day length requirements for growing	Specific climatic constraints and/or requirements	Soil requirements	Sensitivity to salinity	Water requirements (mm)in growing period	Sensitivity to water supply (ky)
alfalfa	100 - 365	24-26(10-30)	day neutral	sensitive to frost;cutting related to temp.;requires low humidity in warm climates.	deep, medium textured, well drained, pH = 6.5-7.5	moderately sensitive	800 - 1600	low to medium-high (0.7 1.1)
pea	fresh: 65-100; dry 85-120	15-18(10-23)	day neutral	slight frost tolerance when young	well drained and aerated soils; pH = 5.5-6.5	sensitive	350 - 500	medium to high(1.15)
sorghum	100 - 140+	24-30(15-35)	long day	sensitive to frost; for germination temp. > 10oC;cool temp. causes head sterility	light to medium/heavy soils relatively tolerant to periodic waterlogging,pH = 6-8	moderately tolerant	450 - 650	medium-low (0.9)
maize	100 - 140+	24-30(15-35)	day neutral/short day	sensitive to frost; for germination temp. > 10oC; cool temp. causes problem for ripening.	well drained and aerated soils with deep water table and without waterlogging; optimum pH = 5.0 - 7.0	moderately sensitive	500 - 800	high(1.25)
barley	100 - 130	15-20(10-15)	day neutral/long day	sensitive to frost; dry period required for ripening	medium textured is preferred;relatively tolerant to high water table;pH = 6-8	moderately tolerant	450 - 650	medium-high (1.15)
wheat	100 - 140	15-20(10-15)	day neutral/long day	spring wheat: sensitive to frost;dry period required for ripening.	medium textured is preferred; relatively tolerant to high water table;pH = 6-8	moderately tolerant	450 - 650	medium-high (1.15)
cotton	150 - 180	20-30(16-35)	short day/day neutral	sensitive to frost; strong or cold winds; required for boll development 27-32oC(18-38); dry ripening period required	deep,medium to heavy textured soils; pH = 5.5-8.0 with optimum pH = 7.0-8.0	tolerant	700 - 1300	medium-low (0.85)
groundnut	90 - 140	22-28(18-33)	day neutral	sensitive to frost; for germination temp. > 20oC	well drained,friable,medium textured soil with loose topsoil; pH = 5.5-7.0	moderately sensitive	500 - 700	low(0.7)
soybean	100 - 130	20-25(18-30)	short day/day neutral	sensitive to frost; for some varieties temp. > 24oC required for flowering	wide range of soils except sandy; well drained; pH = 6-6.5	moderately tolerant	450 - 700	medium-low (0.85)
sunflower	90 - 130	18-25(15-30)	short day/day neutral	sensitive to frost	fairly deep soils; pH = 6-7.5	moderately tolerant	600 - 1000	medium-low (0.95)

Table 15 Climatic, soil and water requirements for some selected crops

Crop	Total Growing period (days)	Temperature requirements for growth(OC) optimum(range)	Day length requirements for growing	Specific climatic constraints and/or requirements	Soil requirements	Sensitivity to salinity	Water requirements (MM) in growing period	Sensitivity to water supply (ky)
tobacco	90-120 (+40-60 in nursery)	20-30(15-35)	short day/day neutral	sensitive to frost	quality of leaf depends on soil texture; pH=6-7.5	sensitive	400 - 600	medium-low (0.9)
rice	90-150	22-30(18-35)	short day/day neutral	sensitive to frost;cool temp. causes head sterility;	heavy soils preferred for low percolation loses; pH=5.5-6.0	moderately sensitive	450 - 700	high
potato	100-150	15-20(10-25)	long day/day neutral	sensitive to frost; night temp.<15oC required for good tuber initiation	well drained ; aerated and porous soils; pH=5.5-6.0	moderately sensitive	500 - 700	medium-high (1.1)
onion	100-140	15-20(10-25)	long day/day neutral	tolerant to frost; low temp,(<14-16oC) required for flower initiation; no extreme temp. or excessive rain	medium textured soils; pH=6.0-7.0	sensitive	350 - 550	medium-high (1.1)
pepper	120-150	18-23(15-27)	short day/neutral day	sensitive to frost	light to medium textured soils; pH=5.5 -7.0	moderately sensitive	600-900	medium-high (1.1)
bean, common	fresh 60-90; dry 90-120	15-20(10-27)	short day/day neutral	sensitive to frost, excessive rain,hot weather	deep friable soil,well drained and aerated ; opt.pH=5-8	sensitive	300-500	medium-high (1.15)
tomato	100-140	15-20(10-25)	long day/day neutral	sensitive to frost	medium textured soils; pH=5.0-7.0	moderately sensitive	400-600	medium-high (1.15)
cucumber	90-120	18-32(10-35)	long day/day neutral	sensitive to frost	medium textured soils; pH=6-8	sensitive	400-1000	medium-high (1.1)
carrot	90-120	15-25(10-30)	long day/day neutral	tolerant to frost	medium textured soils;pH=6-8	sensitive	400-600	medium-high (1.15)
broad bean	90-120	18-28(10-30)	long day/day neutral	sensitive to frost; excessive rain and hot weather	medium textured soils; pH=6-8	sensitive	300-650	medium-high (1.15)
citrus	240-365	23-30(13-35)	day neutral	sensitive to frost (dormant trees less); strong wind,high humidity; cool winter or short dry period preferred	medium textured, well drained soils;pH=6-8	moderately sensitive	400-1500	medium-low(0.85)
banana	300-365	25-30(15-35)	day neutral	sensitive to frost; temp.<8oC for long periods causes serious damage; requires high RH, wind <4 ms-1	deep, well drained loam without stagnant water; pH=5-7	sensitive	1200-2200	high (1.2-1.35)

Table 16 Climatic, soil and water requirements for some selected crops

Crop	Total Growing period (days)	Temperature requirements for growth(0C) optimum(range)	Day length requirements for growing	Specific climatic constraints and/or requirements	Soil requirements	Sensitivity to salinity	Water requirements (MM) in growing period	Sensitivity to water supply (ky)
grapefruit	180-270	2 0-25(15-30)	short day/day neutral	resistant to frost during dormancy(down to -18oC) but sensitive during growth;long,warm to hot,dry summer and cool winter preferred/required	well drained, light soils are preferred;pH=6-8	moderately sensitive	500-1200	medium-low(0.85)
lemon	180-270	21-28(12-35)	short day/day neutral	resistant to frost during dormancy(down to -18oC) but sensitive during growth; long hot,dry summer and cool winter preferred/required	light, well drained soils are preferred;pH=6-8	moderately sensitive	300-1500	medium-low(0.85)
papaya	300-365	25-30(15-35)	day neutral	sensitive to frost, temp. <8oC for long periods causes damage; require high RH, wind < 4ms-1	deep, well drained soils without stagnant water;pH=5-7.5	sensitive	700-1500	high(1.2-1.35)
qat	300-365	15-25(10-30)	short day/day neutral	sensitive to frost	moderately deep and deep,well drained medium textured soils;pH=6-8	sensitive	400-1200	medium-low(0.85)
mango	300-365	25-30(15-45)	day neutral	sensitive to frost; long hot,dry summer and mild winters preferred	very deep and deep, fine and medium textured soils;pH=5-8	moderately sensitive	800-1700	low(1.2-1.35)
guava	300-365	25-30(15-35)	short day/day neutral	resistant to frost during dormancy(down to -15oC)but sensitive during growth;long hot, dry summers and cool winters preferred	very deep and deep medium and light textured soils preferred;pH=6-8	moderately sensitive	400-1100	medium-low(1.2-1.35)
water mellon	90-120	18-32(10-35)	day neutral	sensitive to frost	light to medium textured soils	sensitive	400-1000	medium-high(1.1)
coffee arabica	300-365	15-30(10-35)	short day/day neutral	sensitive to frost	deep, well drained medium textured soils; well aerated;pH=5-7.5	sensitive	750-1400	high(1.2-1.35)
fenugreek	90-120	13-28(5-30)	short day/day neutral	resistant to frost	deep, medium textured soils;pH=6-8	sensitive	300-600	medium-low(1.2-1.35)

CHAPTER 5

RESPONSES TO MANAGEMENT

5.1 Field experiments

Since the start of El-Kod research farm in 1955 with limited experimental trials till the recent broad ongoing programmes, numerous experimental studies have been conducted in various aspects related to crop production. In relation to soils properties, the trials generally cover the following subjects:

- Response to fertilizers (rate, kind and placement) particularly N,P,K; micronutrients trials are limited.
- Irrigation trials; mainly water requirements, time and amounts of applications and different types of methods e.g. sprinklers and flood irrigation similar to spate method.
- Testing the performance of new imported crop and tree varieties under local environmental conditions so as to be introduced to improve different yield qualities(e.g. yield per feddan, resistant to diseases, tolerance to drought etc...).

The experimental crops covered by the above subjects of trials have been grouped into the following categories:

1) Industrial crops.

   Cotton, tobacco, sunflower and sesame.

2) Fruit crops.

   Papaya, banana, mango and citrus.

3) Legumes

   Broad beans, soybean and groundnuts.

4) Vegetables

   Tomato, onions, sweet pepper and water mellons.

5) Field crops

   Sorghum, millet and maize.

In El-Kod research centre, the seasonal research programmes are supervised and conducted by small groups of specialized researchers(Research Group). Each research group is assigned for a specific category of crops as listed above. At the end of a particular research season each research group will publish the findings from the different field trials carried which include one or some crops of the group. The information on the generalized response to fertilizers and packages of management for some selected crops, provided below, was summarized from the seasonal technical reports prepared by the different research groups in El-Kod research centre (1986/87 - 1991/92). These are the only technical reports from El-Kod research groups found in the library of AREA HQ in Dhamar. A recent very brief summaries on research conducted nation wide for different crops was prepared to serve as a background

when formulating the new research strategic plan. Tables 18, 19 and 20 provide a brief summary of some field trials conducted in a El-Kod farm during seasons 1986/87 - 1991/92, by specialized researchers. Documents showing detailed information and the results of the past different field trials and research activities could be accessed in EL-Kod station or AREA HQ library.

5.2 Generalized response to fertilizers

Trials on the effect of Nitrogen(N) and Phosphorus(P) fertilization on yield was carried out for most of the adapted crops (i.e. cotton, sesame, tobacco, sorghum, maize, papaya, banana, citrus fruits, legumes nd some vegetables). Limited trials on micronutrients were also carried in particular for some fruits. Water requirements and yield of new varieties have also being studied for some of these crops. In almost all fertilization trials soil maps or spatial variations of soils within the trial plots were not mentioned. Soil properties for certain plots are rather considered when designing these trials. It is now evident from the soil map that there are considerable variations in salinity and texture within the farm. Experimental and commercial management practices based on the soil map would lead to better results.

Table 18 : Brief summary of some field trials in El-Kod research farm

Main adapted crop	Field trials			
	Yield of selected new varieties (ton per ha)	Responses to fertilizers (NPK mainly with few micronutrients)	Irrigation requirements (similar to spate irrigation)	Consideration of soil factor in relevant trials
1) Industrial crops				
- Cotton	Adaptation to local conditions and yield (long and short stable varieties).	Effect of Nitrogen and Potassium fertilization on yield.	Irrigation requirements and cost of production.	In some fertility trials, generalized soil description provided for one soil type. Spatial variation not considered.
- Sesame	Yield of different imported varieties under local cropping practices.	Optimum fertilization on yield (mainly Nitrogen).	Irrigation requirements.	Same as above but general conclusions on yield of different textural classes was made.
-Tobacco	Same as above.	Addition of gypsum and phosphorus on quality. Effect of Nitrogen plus potassium on Virginia tobacco.	Effect of soil moisture content and irrigation requirements on Nicotine and other tobacco qualities.	NA

Table: 19 Brief summary of some field trials in El-Kod research farm

Main adapted crop	Field trials			
	Yield of selected new varieties (ton per ha)	Responses to fertilizers (Mainly NPK with few micronutrients trials)	Irrigation requirements (similar to spate irrigation)	Consideration of the soil factor in relevant trials
2) Field crops				
-Sorghum	Yield and adaptation trials for Coastal, Middle Highlands and Highlands varieties.	NPK fertilization trials to recommend optimum dose in relation to yield. Depth, method and rate of application of phosphorus.	Amount, time, depth and rate of irrigation water in relation to fertilizers uptake and yield.	Some important soil characteristics were reported, but no clear comments on soil variability.
-Maize	NA	Available miconutrients in the soil (low for Fe & Zn but moderate for Mn and Cu).	NA	Same as above
3) Vegetables				
-Tomato	Performance of some varieties under coastal cropping systems.	Available micronutrients in the soil. Similar levels reported in Maize soil above.	Testing sprinkle irrigation in relation to soil moisture characteristics, salinity and yield	Soil salinity was examined before and after sprinkle irrigation. Soil variations were not mentioned.
-Onion	Yield, optimum season and storage capacity.	NA	NA	NA

Table: 20 Brief summary of some field trials in El-Kod research farm

Main adapted crop	Field trials			
	Yield of selected new varieties (ton per ha)	Responses to fertilizers (Mainly NPK with few micronutrients)	Irrigation requirements (similar to spate irrigation)	Consideration of the soil factor in relevant trials
4) FRUITS				
-Papaya	Comparing the yield of different local and imported varities.	NA	NA	NA
-Banana	Determing plant spacing in relation to yield.	NA	NA	NA
-Citrus	NA	Response to micronutrients.	NA	In fertility trials chemical properties and variations were reported for the site.
-Mango	Comparing the yield of local and new hybrids under local conditions.	NA	NA	NA
5) LEGUMES -Groundnuts -Lubia -P. vulgaris -Green gram -Soybeans	Yield and % of oil for groungnuts (local & imported varities); but yield and management trials for others.	NPK for some legumes; effective nedulation (Nitrogen fixation) for Greengram and micronutrients for groundnuts.	Soil moisture during growing season; comparing spate and pump irrigation; and irrigation rate versus soil moisture depth.	In fertility trials chemical properties and variations were reported for the site.

CHAPTER 6

CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

Does El-Kod Farm represent Abyan region ?

It is now more than twenty years since the last regional and detailed soil surveys were conducted in Abyan and El-Kod farm (Dar Al-Handasah 1974, Abdel Salam 1975, Rahman 1987 and Atkins 1984). Although almost in all reports of these soil surveys the attention was drawn to the adverse effects of salinity and alkalinity on the soils and crop production, but these factors were not included properly in the differentiating criteria to separate the soils. Increasing levels of soil salinity and alkalinity should be expected, due to the deteriorating quality of irrigation water and continuous abandonment of large tracts of land. The revision of the regional soil survey already done by W.S.Atkins (1984) revealed high levels of soil salinity and alkalinity.

W.S.Atkins (1984) argued that the previous detailed soil surveys in El-Kod have provided only information of limited applicability to the area as a whole. This might be true only in relation to the management and agricultural practices and to some extent for limited situations in water and soil. The soils of the whole region were reported as stratified coarse and fine loamy materials developed in mixed alluvium with complex distribution and variability. These physical parameters are well represented in Al-Kod farm. The high levels of salinity and alkalinity in the soils and water of the region are also evident in some parts of El-Kod farm. Therefore, developing of methodologies to use and manage such soils, can well be done in El-Kod. For the rare completely different kinds of soils and water, farmers' field trials is the best answer.

6.2 Recommendations

1) Monitoring the chemical characteristics of the groundwater used for irrigation in El-Kod research station and as well in some selected regional sites every year. The existing relatively high levels of EC figures in irrigation waters and in some soils in the farm and elsewhere make this routine highly essential.

2) A detailed salinity and sodicity maps for block II & III, based on three soil depths (0 - 30; 30 - 60; 60 - 100) would help researchers to consider these effective factors when designing yield trials. Samples should be taken every 50m. This could also help in developing methodology for treating similar soils.

3) Since all soils in El-Kod farm are developed on moderately to highly stratified alluvium, permeability measurements and research in the field is needed to determine their behavior under irrigation conditions. Realistic irrigation and leaching requirements would be based on these findings.

4) Trials on farmers' fields planned for the whole region are highly essential to cover areas which might have significant environmental differences, particularly in soils and water.

5) Economic analysis for different land utilization types is essential to recommend on economic feasibility of fruit trees and vegetables which need large amounts of irrigation water for sustainable production.

6) Since there are significant variations in texture and other soil properties in Al-Kod farm, which affect their use and management, the soil map drawn on these bases must have special value to farm managers and researchers. The soil map should be utilized in different farm management activities related to soils, particularly in selection of plots and designing trials for different crops.

7) Special management practices should be designed and tested for the plots with relatively high salinity levels. These technical results, could then be transferred to similar soils which are expected to be widely distributed in the region.

REFERENCES

Abdel Salam, M.A. 1975. The national program of tomato production for processing. Part 1: Study of soils and water in selected areas. Part 2: Soil survey of Al-Kod Experimental Farm. 81 pp. UNDP/FAO project PDY/71/516.FAO, Aden

Acres, B.D. 1982. Soil classification and correlation in the Montane Plains. YAR Montane Plains and wadi Rima' Project. Project record 72. 124 pp. LRDC, Surbiton. England

Atkins, W.S. & Partners, 1984. Feasibility study for Wadi Bana and Abyan Delta development project . Vol. IV, Annex C: Soils. 117 pp. Min. of Agriculture and Agrarian reform. Aden

Dar Al-Handasah Eng. & Arch. 1974. Abyan Delta Project. Definite plan report. Annex IV, soil and Land Classification. 94 pp. Min. of Agriculture and Agrarian Reform. Aden.

David, D. and A. Young. 1982. Soil Survey and Land Evaluation. 278 pp. George Allen and Unwin. London.

Doka M. Ali, El Abbas. and Wen Ting-tiang. 1996. A Framework for National Soil Series in Yemen. Project Document NO.2 (First Part). Environmental Resource Assessment for Rural Land Use Planning (FAO-GCP/YEM/021/NET). AREA, DHAMAR. YEMEN.

FAO. 1979. Soil Survey Investigations for Irrigation. Soils Bulletin 42. Rome.

FAO - UNESCO. 1988. Soil Map of the World. Vol.1: Legend (Revised Legend). 119 pp. FAO. ROME.

FAO and ISRIC. 1990. Guidelines for Soil description (3rd Edition, Revised). Soil Resources, Management and Conservation service, Land and Water Development Division. 70 pp. Rome.

FAO. 1970. Physical and chemical methods of soil and water analysis. FAO soils Bulletin 10. FAO. Rome

FAO. 1988. Salt-affected soils and their management. FAO Soils Bulletin 39. FAO. Rome

Hunting Technical Services Ltd. 1967. Report on Soil Survey and Land Classification of Nuqub (Beihan) Area. South Arabia Department of Agriculture and Irrigation. Herts. England .

Hunting Technical Services Ltd. 1967. Report on Soil Survey and Land Classification of Ahwar Area. South Arabia Department of Agriculture and Irrigation. Herts. England.

ISSS, ISRIC and FAO 1994. World Reference Base for Soil Resources (Draft). Compiled and edited by O.C. Spaargaren. 161 pp. Wageningen.

Mcbeth Division of Kollmorgan Instruments corporation. 1994. Munsell Soil Color Charts (Revised Edition). 405 Little Britain Road, New Windsor, NY 12553.

Rahman, M.R. 1978. Detailed soil survey of El-Kod agricultural demonstration and research farm. 54 pp.UNDP/FAO project PDY/75/5/019. Ministry of Agriculture and Agrarian Reform. Aden.

Soil Survey Staff. United States Department of Agriculture (USDA), Soil Conservation Service. 1994. Keys to Soil Taxonomy (Sixth Edition).

Van Wambeke, A.(editor) 1986. Guidelines for using Soil Taxonomy in the names of soil map units. Soil Management Support Services, Soil Conservation Service. USDA. New York College of Agriculture and Life Sciences. Cornell University, Department of Agronomy. 75 pp.

Ting-tiang, Wen 1995. Bibliography, partly annotated, on Natural Resources, Agriculture, Rural Development and related subjects in Yemen. FAO project GCP/YEM/021/NET. Agricultural Research and Extension Authority (AREA), Min. of Agric. and Natural Resources. Dhamar, Yemen.

van Waveren, E., G.J. Rhebergen and A.A. Al Hemiary. 1989. Soil Database for the Yemen Arab Republic. Guidelines for soil description. Field Document 1. UNDP/FAO project YEM/87/002. 48 pp. Min. of Agriculture and Fisheries. Sana'a

Landon, J.R.(editor) 1991. Booker Tropical Soil Manual. (A handbook for soil survey and agricultural land evaluation in the tropics and subtropics)

APPENDICES

APPENDIX 1

Statistical Analysis Tables

Table 1: Calculation of relative variance of the clay contents within and among map units

The profiles are analyzed to a depth of 105 cm. Deeper layers are not included.
The clay contents are calculated as the total clay content of the first 105 cm of the profile.
The contents as indicated in the database are multiplied with the thickness of the layer (depth bottom - depth top)
The contents of the layers are summarized and the summarized value is used for the statistical analysis.

DETERMINATION OF RELATIVE VARIANCE

Mapunit (MU)	Profile No.	Total clay	r	sum P	sum (P^2)	(sum P)^2/r	SS
ZB-NQv2	ABI003	1651	2	3987	8182697	7948085	234613
ZB-NQv2	ABI005	2336					
NQ-ZB	ABI002	2466	3	7244	18170920	17491845	679075
NQ-ZB	ABI004	1808					
NQ-ZB	ABI010	2970					
NQ-ZB	ABI011						
NQ-NQv1	ABI014	7213	1	7213	52027369	52027369	0
NQ-NQv1	ABI015						
NS	ABI008	1826	2	3677	6760477	6760165	313
NS	ABI009	1851					
ZB	ABI001	1582	1	1582	2502724	2502724	0
NS-ZBv1	AB013	1725	2	3851	7495501	7415101	80401
NS-ZBv1	ABI012	2126					
TR-ZB	ABI006	1855	2	6763	27529489	22869085	4660405
TR-ZB	ABI007	4908					
		TOTALS	13	34317	122669177	117014372	5654805

ANOVA table

Source	CF	df	SS	MS	F		Criteria 10% *	5% **	1% ***
Among MU		6	26425412	4404235	4.67	**	3.05	4.28	8.47
Within MU		6	5654805	942467					
Total	90588961	12	32080216	2673351					

Significant difference among MU's at 5% probability level

Table 2: Calculation of relative variance of the silt content within and among map units

The profiles are analyzed to a depth of 105 cm. Deeper layers are not included.
The silt contents are calculated as the total silt content of the first 105 cm of the profile.
The contents as indicated in the database are multiplied with the thickness of the layer (depth bottom - depth top)
The contents of the layers are summarized and the summarized value is used for the statistical analysis.

DETERMINATION OF RELATIVE VARIANCE

Mapunit (MU)	Profile No.	Total silt	r	sum P	sum (P^2)	(sum P)^2/r	SS
ZB-NQv2	ABI003	6657	2	12038	73270810	72456722	814088
ZB-NQv2	ABI005	5381					
NQ-ZB	ABI002	7285	3	20790	144446750	144074700	372050
NQ-ZB	ABI004	7055					
NQ-ZB	ABI010	6450					
NQ-ZB	ABI011						
NQ-NQv1	ABI014	7213	1	7213	52027369	52027369	0
NQ-NQv1	ABI015						
NS	ABI008	7256	2	13332	89567312	88871112	696200
NS	ABI009	6076					
ZB	ABI001	4770	1	4770	22752900	22752900	0
NS-ZBv1	AB013	4770	2	10898	60305284	59383202	922082
NS-ZBv1	ABI012	6128					
TR-ZB	ABI006	5004	2	7472	31131040	27915392	3215648
TR-ZB	ABI007	2468					
		TOTALS	13	76513	473501465	467481397	6020068

ANOVA table

Source	CF	df	SS	MS	F	Criteria 10% *	5% **	1% ***
Among MU		6	17155307	2859218	2.85	3.05	4.28	8.47
Within MU		6	6020068	1003345				
Total	450326090	12	23175375	1931281				

NO Significant difference among MU's

Table 3: Calculation of relative variance of the contents of SILT + CLAY within and among map units

The profiles are analyzed to a depth of 105 cm. Deeper layers are not included.
The contents of SILT + CLAY are calculated as the total silt content of the first 105 cm of the profile.
The contents as indicated in the database are multiplied with the thickness of the layer (depth bottom - depth top)
The contents of the layers are summarized and the summarized value is used for the statistical analysis.

DETERMINATION OF RELATIVE VARIANCE

Mapunit (MU)	Profile No.	Total silt + clay	r	sum P	sum (P^2)	(sum P)^2/r	SS
ZB-NQv2	ABI003	8308	2	16025	128574953	128400313	174641
ZB-NQv2	ABI005	7717					
NQ-ZB	ABI002	9751	3	28034	262371170	261968385	402785
NQ-ZB	ABI004	8863					
NQ-ZB	ABI010	9420					
NQ-ZB	ABI011						
NQ-NQv1	ABI014	14426	1	14426	208109476	208109476	0
NQ-NQv1	ABI015						
NS	ABI008	9082	2	17009	145320053	144653041	667013
NS	ABI009	7927					
ZB	ABI001	6352	1	6352	40347904	40347904	0
NS-ZBv1	AB013	6495	2	14749	110313541	108766501	1547041
NS-ZBv1	ABI012	8254					
TR-ZB	ABI006	6859	2	14235	101451257	101317613	133645
TR-ZB	ABI007	7376					
		TOTALS	13	110830	996488354	993563231	2925123

ANOVA table

Source	CF	df	SS	MS	F		Criteria 10% *	5% **	1% ***
Among MU		6	48694854	8115809	16.65	***	3.05	4.28	8.47
Within MU		6	2925123	487520					
Total	944868377	12	51619977	4301665					

Significant difference among MU's at 1% probability level

Table 4: Calculation of relative variance of the content of SILT + VFS within and among map units

The profiles are analyzed to a depth of 105 cm. Deeper layers are not included.
The contents of SILT + VFS are calculated as the total silt content of the first 105 cm of the profile.
The contents as indicated in the database are multiplied with the thickness of the layer (depth bottom - depth top)
The contents of the layers are summarized and the summarized value is used for the statistical analysis.

DETERMINATION OF RELATIVE VARIANCE

Mapunit (MU)	Profile no	Total silt + VFS	r	sum P	sum (P^2)	(sum P)^2/r	SS
ZB-NQv2	ABI003	8099	2	15456	119719250	119443968	275282
ZB-NQv2	ABI005	7357					
NQ-ZB	ABI002	7821	3	23204	180209990	179475205	734785
NQ-ZB	ABI004	8293					
NQ-ZB	ABI010	7090					
NQ-ZB	ABI011						
NQ-NQv1	ABI014	8257	1	8257	68178049	68178049	0
NQ-NQv1	ABI015						
NS	ABI008	8313	2	15537	121292145	120699185	592961
NS	ABI009	7224					
ZB	ABI001	7117	1	7117	50651689	50651689	0
NS-ZBv1	ABI012	7537	2	14203	101241925	100862605	379321
NS-ZBv1	ABI013	6666					
TR-ZB	ABI006	6294	2	10870	60554212	59078450	1475762
TR-ZB	ABI007	4576					
		TOTALS	13	94644	701847260	698389150	3458110

ANOVA table

Source	CF	df	SS	MS	F	Criteria 10% *	5% **	1% ***
Among MU		6	9351709	1558618	2.70	3.05	4.28	8.47
Within MU		6	3458110	576352				
Total	689037441	12	12809819	1067485				

NO Significant difference among MU's

Table 5: Calculation of relative variance of the variability in clay content of profile pits within and among map units

The profiles are analyzed to a depth of 105 cm. Deeper layers are not included.
The clay contents are taken as the clay content in % of the layers in the first 105 cm of the profile.
Measure of variability is the variance of the clay percentage of the layers in the first 105 cm of the profile.

DETERMINATION OF RELATIVE VARIANCE

Mapunit (MU)	Profile No	Variance clay prof.		r	sum P	sum (P^2)	(sum P)^2/r	SS
ZB-NQv2	ABI003	34.58		2	67.54	2282.4	2281.1	1.3
ZB-NQv2	ABI005	32.96						
NQ-ZB	ABI002	36.41		3	101.45	3577.8	3430.6	147.2
NQ-ZB	ABI004	24.24						
NQ-ZB	ABI010	40.80						
NQ-ZB	ABI011							
NQ-NQv1	ABI014	30.89		1	30.89	954.1	954.1	0.0
NQ-NQv1	ABI015							
NS	ABI008	29.56		2	70.60	2557.8	2491.9	65.9
NS	ABI009	41.04						
ZB	ABI001	242.80		1	242.80	58951.8	58951.8	0.0
NS-ZBv1	AB013	28.22		2	93.98	5120.9	4416.3	704.5
NS-ZBv1	ABI012	65.76						
TR-ZB	ABI006	5.50		2	189.90	34033.6	18031.0	16002.6
TR-ZB	ABI007	184.40						
			TOTALS	13	797.16	107478.4	90556.8	16921.6

ANOVA table

Source	CF	df	SS	MS	F	Criteria 10% *	5% **	1% ***
Among MU		6	41675.2	6945.9	2.46	3.05	4.28	8.47
Within MU		6	16921.6	2820.3				
Total	48881.63	12	58596.8	4883.1				

NO Significant difference among MU's

Table 6: Calculation of relative variance of the variability in silt content of profile pits within and among map units

The profiles are analyzed to a depth of 105 cm. Deeper layers are not included.
The silt contents are taken as the silt content in % of the layers in the first 105 cm of the profile.
Measure of variability is the variance of the silt percentage of the layers in the first 105 cm of the profile.

DETERMINATION OF RELATIVE VARIANCE

Mapunit (MU)	Profile No	Variance silt prof.	r	sum P	sum (P^2)	(sum P)^2/r	SS
ZB-NQv2	ABI003	69.89	2	191.25	19612.7	18288.1	1324.6
ZB-NQv2	ABI005	121.36					
NQ-ZB	ABI002	29.06	3	54.90	1184.3	1004.7	179.6
NQ-ZB	ABI004	14.64					
NQ-ZB	ABI010	11.20					
NQ-ZB	ABI011						
NQ-NQv1	ABI014	30.89	1	30.89	954.1	954.1	0.0
NQ-NQv1	ABI015						
NS	ABI008	15.81	2	126.37	12473.3	7984.1	4489.2
NS	ABI009	110.56					
ZB	ABI001	433.84	1	433.84	188217.1	188217.1	0.0
NS-ZBv1	AB013	226.22	2	399.18	81091.7	79673.2	1418.4
NS-ZBv1	ABI012	172.96					
TR-ZB	ABI006	426.19	2	496.35	186558.2	123180.4	63377.8
TR-ZB	ABI007	70.16					
		TOTALS	13	1732.77	490091.5	419301.8	70789.7

ANOVA table

Source	CF	df	SS	MS	F	Criteria 10% *	5% **	1% ***
Among MU		6	188339.8	31390.0	2.66	3.05	4.28	8.47
Within MU		6	70789.7	11798.3				
Total	230962.1	12	259129.4	21594.1				

NO Significant difference among MU's

Table 7: Calculation of relative variance of the variability in the content of SILT+CLAY of profile pits within and among map units

The profiles are analyzed to a depth of 105 cm. Deeper layers are not included.
The contents of SILT+CLAY are taken as the content in % of the layers in the first 105 cm of the profile.
Measure of variability is the variance of the percentage of SILT+CLAY in the first 105 cm of the profile.

DETERMINATION OF RELATIVE VARIANCE

Mapunit (MU)	Profile No	Variance silt+clay prof.	r	sum P	sum (P^2)	(sum P)^2/r	SS
ZB-NQv2	ABI003	113.81	2	267.01	36421.9	35646.0	776.0
ZB-NQv2	ABI005	153.20					
NQ-ZB	ABI002	31.10	3	97.26	3660.3	3153.3	507.0
NQ-ZB	ABI004	48.96					
NQ-ZB	ABI010	17.20					
NQ-ZB	ABI011						
NQ-NQv1	ABI014	123.56	1	123.56	15266.0	15266.0	0.0
NQ-NQv1	ABI015						
NS	ABI008	29.14	2	287.30	67495.7	41270.3	26225.3
NS	ABI009	258.16					
ZB	ABI001	387.84	1	387.84	150419.9	150419.9	0.0
NS-ZBv1	AB013	399.33	2	709.33	255567.1	251576.9	3990.2
NS-ZBv1	ABI012	310.00					
TR-ZB	ABI006	527.19	2	805.35	355299.6	324292.3	31007.3
TR-ZB	ABI007	278.16					
		TOTALS	13	2677.64	884130.5	821624.6	62505.8

ANOVA table

Source	CF	df	SS	MS	F		Criteria 10% *	5% **	1% ***
Among MU		6	270103.8	45017.3	4.32	**	3.05	4.28	8.47
Within MU		6	62505.8	10417.6					
Total	551520.9	12	332609.6	27717.5					

Significant difference among MU's at 5% probability level

Table 8: Calculation of relative variance of the variability in the content of SILT + VFS of profile pits within and among map units

The profiles are analyzed to a depth of 105 cm. Deeper layers are not included.
The contents of SILT+VFS are taken as the silt content in % of the layers in the first 105 cm of the profile.
Measure of variability is the variance of the percentage of SILT+VFS in the first 105 cm of the profile.

DETERMINATION OF RELATIVE VARIANCE

Mapunit (MU)	Profile No	Variance silt+vfs prof.	r	sum P	sum (P^2)	(sum P)^2/r	SS
ZB-NQv2	ABI003	26.81	2	65.45	2211.6	2141.6	70.0
ZB-NQv2	ABI005	38.64					
NQ-ZB	ABI002	31.71	3	82.51	2482.0	2269.5	212.4
NQ-ZB	ABI004	15.76					
NQ-ZB	ABI010	35.04					
NQ-ZB	ABI011						
NQ-NQv1	ABI014	24.67	1	24.67	608.4	608.4	0.0
NQ-NQv1	ABI015						
NS	ABI008	25.81	2	73.65	2954.6	2711.8	242.8
NS	ABI009	47.84					
ZB	ABI001	255.44	1	255.44	65249.6	65249.6	0.0
NS-ZBv1	AB013	59.89	2	99.09	5123.3	4909.3	214.0
NS-ZBv1	ABI012	39.20					
TR-ZB	ABI006	619.50	2	706.06	391272.9	249260.4	142012.5
TR-ZB	ABI007	86.56					
		TOTALS	13	1306.86	469902.4	327150.6	142751.8

ANOVA table

Source	CF	df	SS	MS	F	Criteria 10% *	5% **	1% ***
Among MU		6	195774.8	32629.1	1.37	3.05	4.28	8.47
Within MU		6	142751.8	23792.0				
Total	131375.8	12	338526.6	28210.5				

NO Significant difference among MU's

Table 9: Comparison of levels of significance for different soil textural properties

Descriptive item	Observed F	Indication
Clay content	4.67	**
Silt content	2.85	
Silt plus Clay content	16.65	***
Silt plus Very Fine Sand content	2.70	
Clay stratification	2.46	
Silt stratification	2.66	
Silt plus Clay stratification	4.32	**
Silt plus Very Fine Sand stratification	1.37	

	Criteria		
Probability level	10%	5%	1%
F-value	3.05	4.28	8.47
Indication	*	**	***

APPENDIX 2

Methods of Laboratory Analysis

APPENDIX 2

Methods of Laboratory Analysis

Soil and water laboratory analysis:

Following is a summary of analytical methods used in AREA Dhamar laboratory to analyze soil and water samples collected from different parts of the country. The summary was prepared by Dr. A.E.Fadl - Soil chemical analysis expert.

Analytical methods used:

Soils analysis:

All results refer to oven dry soil sieved through 2 m/m sieve.

1 Soil Reaction (pH) is determined by pH meter in soil saturation extract. A model WTW pH 422 pH meter is used

2 Total soluble salts (E.C.)
Saturation paste is prepared by adding soil to a known quantity of distilled water to the saturation point. Saturation extract is sucked off using vacuum. E.C. of saturation extract is read off an E.C. model WTW meter and expressed in dS/cm at 25°C.

3 Calcium carbonate : Acid neutralization method is used.

4 Organic carbon : Modified Walkley - Black method is used.

5 Total Nitrogen : Measured according to the standard Kjeldahl method using distillation and titration units as applaud.

6 Available phosphorus : Olsen method (0.5 M sodium bicarbonate extraction).

7 Cation Exchange Capacity : Saturation of the soil colloidal complex is effected with IN sodium acetate at pH 8.2 and excess salt is removed with ethanol. Sodium is then replaced by ammonium, using IN ammonium acetate at pH 7.0 and concentration of sodium is determined in the final solution by flame photometry.

8 Exchangeable cations : Exchangeable Na and K are determined in ammonium acetate leachate. Results are corrected for water soluble Na and K and net exchangeable values are reported. Exchangeable Ca and Mg are determined in the same leachate if soils are non-calcareous, or by difference calculation from CEC in calcareous soils.

9 The following parameters are obtained by direct calculation.

1. ESP
2. SAR

10 Mechanical Analysis : A modified hydrometer method is used which involves the following three stages :

a. Removal of soluble salts and complete dispersion in calgon
b. Separation of total sand by wet sieving followed by division into 5 sand components, (USDA) system, by dry sieving.

c. Determination of the clay fraction in the dispersed sample by hydrometer and calculation of silt by difference.

The soils rich in $CaCO_3$ and organic matter will have a special treatment. The fine earth fraction (less than 2 millimeters) is used for the test, and USDA system of the particle size grade is adopted to express results of the different fractions i.e.

very coarse sand	2.0 - 1.0 mm
Coarse sand	1.0 - 0.5 "
Medium sand	0.5 - 0.25 "
Fine sand	0.25 - 0.1 "
V. fine sand	0.1 - 0.05 "
Silt	0.05 - 0.002 "
Clay	< 0.002 "

Water analysis:

The methods used for analysis of water are essentially those used for the analysis of water extracts of soil obtained at saturation. The methods described in FAO Bulletin No.10 "Physical and Chemical Methods of Soil and Water Analysis" 1988

SOIL PROFILE OF DESCRIPTION

PROFILE : ABI001 UNITS : ZB1 STATUS : 2

Sheet	:	Sheet D 38115 (1:100,000)	Grid	:	Northing 1448358, Easting 539125
Location	:	Block 3 plot 1.			
Survey area	:	El-Kod Research Farm	Elevation	:	15m
Authors	:	M.H.Meshraki, A.M Abdo	Date	:	25/01/95
Soil series	:	Zinjibar silt loam			
Classification FAO	:	Calcaric Fluvisols			
ST	:	Typic Torrifluvents, coarse loamy, mixed, hyperthermic.			
Soil climate	:	Aridic	Land form	:	Alluvial-aeolian, coastal plain
Topography	:	Almost flat	Slope	:	0.1 -25
Element/position	:	Wadi flood plain (upper terrace)			
Micro topography	:	Low hummocks			
Land use	:	Irrigated, large scale, furrow, pump	Human influence	:	Irrigation (long continue)
Vegetation	:	Grassland	Grasscover	:	0-10%
Parent material	:	Alluvium			
Effective soil depth	:	> 150 cm			
Erosion	:	Moderate wind erosion			
Drainage	:	Well			
Permeability	:	Moderate			
External drainage	:	Moderate			
Watertable	:	Not observed			
Flooding	:	Rare			
Moisture condition	:	Dry 0-100 cm			

Remarks : As research plots were left uncultivated for sometime; some persistent grasses covered almost all fields (e.g. Dismostachy abipinnata - locally called Sod'a (means headache).

Samples :

Ap	0 - 31 cm	10YR 7/4 (dry) and 10YR 4/3 (moist); loam; moderate fine subangular blocky structure; slightly hard (dry), very friable (moist), slightly sticky (wet), slightly plastic (wet); very few very fine pores; common fine-medium roots; clear wavy boundary.
C	31 - 42 cm	10YR 7/3 (dry) and 10YR 4/3 (moist); loam; weak to moderate fine and medium subangular blocky structure; slightly hard (dry), very friable (moist), slightly sticky (wet), slightly plastic (wet); common medium-coarse pores; few fine roots; strongly calcareous; clear wavy boundary.
2C	42 - 70 cm	10YR 7/3 (dry) and 10YR 4/3 (moist); loamy fine sand; weak to moderate fine and medium subangular blocky structure; hard (dry), very friable (moist), non sticky (wet), non plastic (wet); few very fine pores; few fine-medium roots; strongly calcareous; clear smooth boundary.
3C	70 - 95 cm	10YR 7/3 (dry) and 10YR 4/3 (moist); clay loam; weak to moderate fine subangular blocky structure; soft (dry), loose (moist), non sticky (wet), non plastic (wet); very few very fine pores, strongly calcareous; abrupt wavy boundary.
4C	95 - 110cm	10YR 7/4 (dry) and 10YR 4/3 (moist); silty clay loam; weak to moderate fine subangular blocky structure; slightly hard (dry), very friable (moist), slightly sticky (wet), slightly plastic (wet); very few very fine pores; strongly calcareous; abrupt wavy boundary.
5C	110 - 130cm	10YR 7/4 (dry) and 10YR 4/3 (moist); loamy very fine sand; very weak fine subangular blocky structure; slightly hard (dry), very friable (moist), slightly sticky (wet), slightly plastic (wet); very few very fine pores, strongly calcareous; abrupt wavy boundary.
6C	130 - 155cm	10YR 7/4 (dry) and 10YR 5/3 (moist); loamy very fine sand; very weak fine subangular blocky structure; soft (dry), very friable (moist), non sticky (wet), non plastic (wet); strongly calcareous; abrupt wavy boundary.
7C	155 cm +	10YR 7/4 (dry) and 10YR 4/3 (moist); very fine sand; very weak fine subangular blocky structure; slightly hard (dry), loose (moist), non sticky (wet), non plastic (wet).

Analytical data for profile ABI001

Depth cm	Mechanical Analysis				pH 1.1	EC dS/m	$CaCo_3$ (g/Kg)
	Sand	Silt	Clay	Texture class			
0 - 31	24	62	14	SiL	8.3	4.4	111.8
31 - 42	36	53	11	SiL	8.3	3.3	93.8
42 - 70	76	15	9	LS	8.2	2.5	54.3
70 - 95	24	65	11	SiL	8.3	3.2	113.0
95 - 110	28	22	50	C	8.3	4.0	120.5
110 - 130	69	8	23	SCL	8.3	3.6	68.0

Depth cm	Organic C (g/kg)	Total N (g/kg)	Available P (mg/kg)	CEC Soil Cmol/kg	ESP (%)	SAR
0 - 31	2.8	0.03	4	20.0	85	41
31 - 42	1.3	0.01	2	17.0	70	34
42 - 70			2	7.5	53	24
70 - 95						
95 - 110						
110 - 130						

Texture Class

LS - loamy sand
L - loam
SiCL - silty clay loam
C - clay
SL - sandy loam
SiL - silt loam
SCL - sandy clay loam
CL - clay loam

SOIL PROFILE DESCRIPTION

PROFILE : ABI002 UNIT : BT-AH STATUS :2

Sheet	:	Sheet D 38115 (1:100,000)	Grid	:	Northing 1448483, Easting 539548
Location	:	Block 2 plot 2			
Survey area	:	Al-Kod Researcah Farm	Elevation	:	15m
Authors	:	M.H. Meshraki, A.M. Abdo	Date	:	28/01/95
Soil series	:	Nuqub silt loam			
Classification FAO	:	Calcaric Fluvisols			
ST	:	Typic Torrifluvent, fine silty, mixed, hyperthermic			
Soil climate	:	Aridic			
Topography	:	Almost flat	Land form	:	Alluvial-aeolian, coastal plain
Element/position	:	Wadi flood plain (upper terrace)	Slope	:	0.1 - 2%
Micro topography	:	Furrows and bunded basins for irrigation			
Land use	:	Irrigated, large scale, furrow, pump; experimental and commercial farming	Human Influence	:	Irrigation (long continued)
Vegetation	:	Grassland	Grasscover	:	10-30%
Parent material	:	Alluvium			
Eff. soil depth	:	> 150 cm			
Erosion	:	None	Sealing/crusting	:	Slight
Drainage	:	Well			
Permeability	:	Moderate			
External drainage	:	Moderate			
Waterable	:	Not observed			
Flooding	:	Rare			
Moist cond	:	Dry 0-50 cm			

Samples :

Ap	0 - 25 cm	10YR 6.5/3 (dry) and 10YR 4/3 (moist); silty loam; very weak very coarse subangular and angular blocky strong medium structure; hard (dry), firm (moist), sticky (wet), plastic (wet); common fine-medium pores; common fine-medium roots; strongly calcareous; abrupt wavy boundary.
C	25 - 33 cm	10YR 7/3 (dry) and 10YR 4.5/3 (moist); silt loam; weak very fine subangular blocky structure; slightly hard (dry), friable (moist); common fine pores; few very fine roots; strongly calcareous; clear smooth boundary.
2C	33 - 41 cm	10YR 6/3 (dry) and 10YR 4/3 (moist); silt loam; moderate fine and medium platy structure; slightly hard (dry), friable (moist) slightly sticky (wet), slightly plastic (wet); common fine pores; very few very fine roots; strongly calcareous; abrupt wavy boundary.
3C	41 - 48 cm	10YR 6/4 (dry) and 10YR 4/3 (moist); common fine faint clear yellow mottles; silty clay loam; weak fine and medium subangular blocky structure; hard (dry), firm (moist), sticky (wet), plastic (wet); common very fine pores; strongly calcareous; clear wavy boundary.
4C	48 - 70 cm	10YR 7/3 (dry) and 10YR 4/3 (moist); sandy loam; weak fine and medium angular blocky structure; soft (dry), loose (moist), non sticky (wet), non plastic (wet); common fine-medium pores; strongly calcareous; abrupt smooth boundary.
5C	70 - 86 cm	10YR 6/4 (dry) and 10YR 4/3 (moist); silty clay loam; weak medium subangular blocky structure; slightly hard (dry), friable (moist), sticky (wet), plastic (wet); few fine pores; strongly calcareous; abrupt wavy boundary.
6C	86 - 110 cm	10YR 7/3 (dry) and 10YR 5/3 (moist); sandy loam; weak fine subangular and angular blocky structure; soft (dry), loose (moist), non sticky (wet), non plastic (wet); few very fine pores; abrupt smooth boundary.
7C	110-115 cm	10YR 7/3 (dry) and 10YR 4/3 (moist); few fine faint sharp yellow mottles; silty clay loam; weak very fine subangular and angular blocky structure; slightly hard (dry), friable (moist), sticky (wet), plastic (wet); few very fine pores; nil roots; abrupt smooth boundary.
8C	115 - 150 cm	10YR 6.5/3 (dry) and 10YR 4.5/3 (moist), sandy loam to loamy very fine sand; weak medium and coarse subangular blocky structure; soft (dry), loose (moist), non sticky (wet), non plastic (wet); common very fine pores.

Analytical data for profile ABI002

Depth cm	Mechanical Analysis				pH 1.1	EC dS/m	$CaCo_3$ (g/Kg)
	Sand	Silt	Clay	Texture class			
0 - 25	3	77	20	SiL	8.4	2.2	129.3
25 - 33	4	66	30	SCL	8.4	1.6	142.5
33 - 41	11	73	16	SiL	8.4	1.7	136.8
41 - 48	2	66	32	SiCL	8.4	1.6	128.8
48 - 70	18	66	16	SiL	8.4	1.5	130.5
70 - 86	11	63	26	SiL	8.4	1.7	113.0
86 - 110	11	66	23	SiL	8.4	2.4	120.0

Depth cm	Organic C (g/kg)	Total N (g/kg)	Available P (mg/kg)	CEC Soil Cmol/Kg	ESP (%)	SAR
0 - 25	4.6	0.05	11	29.0	21	21
25 - 33	4.8	0.05	5	20.0	28	25
33 - 41				55.0		
41 - 48						
48 - 70						
70 - 86						
86 - 110						

Texture Class

LS - loamy sand
L - loam
SiCL - silty clay loam
C - clay
SL - sandy loam
SiL - silt loam
SCL - sandy clay loam
CL - clay loam

SOIL PROFILE DESCRIPTION

PROFILE : ABI003 UNIT : BT STATUS : 2

Sheet	: Sheet D 38115 (1:100,000)	Grid	: Northing 1448305, Easting 539265
Location	: Block 3 plot 2		
Survey area	: El-Kod research farm	Elevation	: 15 m
Authors	: A.A. Al-Borani, Fadl H. Mohamed, Baraka M. Saleh	Date	: 25/01/95
Soil series	: Zinjibar silt loam		
Classification FAO	: Calcaric Fluvisols		
ST	: Typic Torrifluvent, coarse loamy, mixed, hyperthermic		
Soil climate	: Aridic		
Topography	: Almost flat	Land form	: Alluvial-aeolian, coastal plain
Element/position	: Wadi flood plain (upper terrace)	Slope	: 0.1 - 2%
Micro topography	: Furrows and bunded basins for irrigation.		
Land use	: Irrigated, large scale, furrow, pump	Human influence	: Irrigation (long continued)
Vegetation	:	Grasscover	:
Parent material	: Alluvium		
Effect. soil depth	: > 100 cm		
Erosion	: Slight wind erosion	Sealing/crusting	: Slight
Drainage	: Moderately well		
Permeability	: Moderate		
External drainage	: Moderate		
Watertable	: Not observed		
Flooding	: Rare		
Moist cond	: Dry 0-95 cm		
Remarks	: 1-2 cm very thin stratified silt		

Samples :

Ap1	0 - 25 cm	10YR 6/3 (dry) and 10YR 4/3 (moist); loam; moderate fine and medium granular structure; hard (dry), friable (moist), sticky (wet), slightly plastic (wet); common fine pores; clear smooth boundary.
Ap2	20 - 32 cm	10YR 6/3 (dry) and 10YR 4/3 (moist); loam; weak medium and coarse subangular blocky structure; hard (dry), friable (moist) sticky (wet), slightly plastic (wet); few fine pores; clear smooth boundary.
2C	32 - 46 cm	10YR 5.5/3 (dry) and 10YR 4.5/3 (moist); silty clay loam, moderate fine and medium granular structure; slightly hard (dry), very friable (moist) sticky (wet), plastic (wet); few fine-medium pores; clear smooth boundary.
3C	46 - 74 cm	10YR 6/3 (dry) and 10YR 4.5/3 (moist); loamy sand; massive single grain; loose (dry), clear smooth boundary.
4C	74 - 94 cm	10YR 6.5/3 (dry) and 10YR 4.5/3 (moist); loam; porous massive; soft (dry); common medium pores; few insect activity; clear wavy boundary.
5C1	94 - 125 cm	10YR 6/3 (dry) and 10YR 4/3 (moist); common medium faint sharp reddish mottles; clay loam; weak medium subangular blocky structure; slightly hard (dry), firm (moist), sticky (wet), plastic (wet); few fine-medium pores, common medium roots; few insect activity; clear wavy boundary.
5C2	125 - 160 cm	10YR 6/3 (dry) and 10YR 4/3 (moist); common medium faint sharp reddish mottles; clay loam; weak medium and coarse subangular blocky structure; slightly hard (dry), firm (moist), sticky (wet), plastic (wet); common fine-medium pores, few fine roots .

Analytical data for profile ABI003

Depth cm	Mechanical Analysis				pH 1.1	EC dS/m	$CaCo_3$ (g/Kg)
	Sand	Silt	Clay	Texture class			
0 - 32	15	67	18	SiL	8.3	1.8	113.6
32 - 46	22	57	21	SiL	8.3	3.1	108.8
46 - 74	40	51	9	SiL	8.3	2.1	98.3
74 - 94	11	77	12	SiL	8.2	2.5	125.0
94 - 125	8	65	27	SiCL	8.0	3.9	139.5
125 - 160	11	67	22	SiL	8.0	3.9	140.0

Depth cm	Organic C (g/kg)	Total N (g/kg)	Available P (mg/kg)	CEC Soil Cmol/Kg	ESP (%)	SAR
0 - 32	4.4	0.04	8	29.0	24	27
32 - 46		0.04	3	20.0	25	12
46 - 74		0.04	3		9	33
74 - 94						
94 - 125						
125 - 160						

Texture Class

LS - loamy sand
L - loam
SiCL - silty clay loam
C - clay
SL - sandy loam
SiL - silt loam
SCL - sandy clay loam
CL - clay loam

SOIL PROFILE DESCRIPTION

PROFILE : ABI004 UNIT:BT-AH STATUS : 2

Sheet	: Sheet D 38115 (1:100,000)		Grid	:	Northing 1448388, Easting 539645
Location	: Block 2 plot 2				
Survey area	: El-Kod research farm		Elevation	:	15 m
Authors	: A.A. Al-Hemairi, Zahra A. Musa		Date	:	30/1/95
Soil series	: Zinjibar silt Loam				
Classification FAO	: Calcaric Fluvisols				
ST	: Typic Torrifluvent, Coarse loamy, mixed, hyperthermic				
Soil climate	: Aridic				
Topography	: Almost flat		Land form	:	Alluvial-aeolian, coastal plain
Element/position	: Wadi flood plain (upper terrace)		Slope	:	0-0.15 straight
Micro topography	: Furrows and bunded basins for irrigation				
Land use	: Irrigated, large scale, furrow, pump		Crops	:	Cereals
			Human influence	:	Irrigation (long continued)
Vegetation	: Grassland		Grasscover	:	10-30%
Parent material	: Alluvium				
Effect. soil depth	: 100-150 cm				
Erosion	: Slight wind erosion		Sealing/crusting	:	Slight
Drainage	: Moderately well				
Permeability	:				
External drainage	: Moderate				
Watertable	: Not observed				
Flooding	: Rare				
Moist conditions	: Dry 0-160 cm				

Remarks : Thin layer of 7 cm at depth of 50 cm with 10YR 4/3 D, 10YR 3/3 M color

Samples

Ap	0 - 25 cm	10YR 5/4 (dry) and 10YR 4/3 (moist); silt loam; moderate coarse subangular blocky moderate medium and coarse subanugular blocky structure; very hard (dry), friable (moist), slightly sticky (wet), slightly plastic (wet); few fine pores, continuous by silica; few medium roots; strongly calcareous; clear smooth boundary.
2C	25 - 50 cm	10YR 5/4 (dry) and 10YR 4/3 (moist); silty clay loam; very weak fine and medium subangular blocky structure; slightly hard (dry), friable (moist), sticky (wet), slightly plastic (wet); few fine-medium pores; few fine-medium roots; strongly calcareous; clear smooth boundary.
3C	50 - 83 cm	10YR 5/3 (dry) and 10YR 4/4 (moist); loam to loamy very fine sand; porous massive; soft (dry), friable (moist), non sticky (wet), non plastic (wet); very few fine pores; very few fine-medium roots; strongly calcareous; clear smooth boundary.
4C	83 - 95 cm	10YR 5/3 (dry) and 10YR 4/3 (moist); silt loam; very weak fine and medium subangular blocky structure; slightly hard (dry), friable (moist), slightly sticky (wet), slightly plastic (wet); common fine-medium pores; very few very fine roots; strongly calcareous; clear smooth boundary.
5C	95 - 140 cm	10YR 4/3 (dry) and 10YR 3.5/3 (moist), many fine distinct brown mottles; silty clay loam; very weak medium and coarse columnar moderate medium and coarse subangular blocky structure; slightly hard (dry), friable (moist), slightly sticky (wet), slightly plastic (wet); many fine-medium pores; nil roots; strongly calcareous.

Analytical data for profile ABI004

Depth cm	Mechanical Analysis				pH 1.1	EC dS/m	$CaCo_3$ (g/Kg)
	Sand	Silt	Clay	Texture class			
0 - 25	15	66	19	SiL	8.2	3.1	125.0
25 - 50	15	66	19	SiL	8.3	1.6	116.8
50 - 83	23	65	12	SiL	8.4	2.0	110.5
83 - 95	9	75	16	SiL	8.3	2.3	139.3
95 - 140	2	71	27	SCL	8.1	2.4	142.5

Depth cm	Organic C (g/kg)	Total N (g/kg)	Available P (mg/kg)	CEC Soil Cmol/Kg	ESP (%)	SAR
0 - 25	3.8	0.03	9	19	10	28
25 - 50		0.03	4	13	56	25
50 - 83		0.02	3	10	100	26
83 - 95						
95 - 140						

Textural class

LS - loamy sand
L - loam
SiCL - silty clay loam
C - clay
SL - sandy loam
SiL - silt loam
SCL - sandy clay loam
CL - clay loam

SOIL PROFILE DESCRIPTION

PROFILE : ABI005 UNIT : BT STATUS : 2

Sheet	: Sheet D 38115 (1:100,000)	Grid	: Northing 1448178, Easting 539263
Location	: Block 3 plot 3		
Survey area	: El-Kod research farm	Elevation	: 15 m
Authors	: A.A. Al-Hemairi; Zahra A. Musa	Date	: 25/1/95
Soil series	: Nuqub variant-2 silt loam		
Classification FAO	: Calcaric Fluvisols		
ST	: Typic Torrifluvent, fine loamy, mixed, hyperthermic		
Soil climate	: Aridic		
Topography	: Almost flat	Land form	: Alluvial-aeolian, coastal plain
Element/position	: Flood plain (upper terrace)	Slope	: 0.1 - 2% straight
Micro Top	: Furrows and bunded basin for irrigation		
Land Use	: Irrigated, large scale, furrow, pump	Crops	: Cereals
		Human influence	: Irrigation (long continued)
Vegetation	: Grassland	Grasscover	: 10-30%
Parent material	: Alluvium		
Effect. soil depth	: 100-150 cm		
Erosion	: Slight wind erosion	Sealing/crusting	: nil
Surface salts	: Not observed		
Drainage	: Moderately well		
Permeability	: Slow		
External drainage	: Moderate		
Watertable	: Not observed		
Flooding	: Rare		
Moist conditions	: Dry 0-160 cm		

Remarks : At the depth of 40-45 cm, discontuous layer, massive loamy very fine sand. At depth of 124 cm, small platy layer, about 1-3 mm thick. At the third layer mottles colour is a mixed colour.

Samples

Ap1	0 - 23 cm	10YR 5/4 (dry) and 10YR 3.5/4 (moist); loam to very fine sandy loam; very strong medium and coarse angular blocky structure; slightly hard (dry), friable (moist), slightly sticky (wet) slightly plastic (wet); very few very fine pores, few fine-medium roots; strongly calcareous; clear smooth boundary.
Ap2	23 - 47 cm	10YR 5/4 and 10YR 4/4 (moist); clayloam; weak medium and coarse subangular blocky structure; hard (dry), friable (moist), sticky (wet), plastic (wet); very few fine pores; few fine-medium roots; strongly calcareous; clear smooth boundary.
2C	47 - 57 cm	10YR 4.5/3 (dry) and 10YR 4/3 (moist); few fine distinct clear brown mottles; silty clay loam; weak fine and medium subangular blocky structure; slightly hard (dry), firm (moist), sticky (wet), plastic (wet); very few very fine pores, very few fine roots; strongly calcareous; clear smooth boundary.
3C	57 - 95 cm	10YR 5/3 (dry) 10YR 4/3 (moist); loamy very fine sand; massive structure; loose (dry); very friable (moist); nil pores, very few very fine roots; strongly calcareous; clear smooth boundary.
4C	95 - 112 cm	10YR 5/4 (dry) and 10YR 4/3 (moist); common fine distinct clear reddish-yellow mottles; silty clay loam; fragments; weak fine and medium subangular blocky structure; slightly hard (dry), very friable (moist), sticky (wet), plastic (wet); few fine pores; very few very fine roots; strongly calcareous; clear smooth boundary.
5C	112 - 124 cm	10YR 5/4 (dry) and 10YR 4/4 (moist); silty clayloam; very weak fine platy structure; hard (dry), very friable (moist), sticky (wet), plastic (wet); many medium-coarse pores; very few very fine roots; strongly calcareous; clear smooth boundary.
6C	124 - 136 cm	10YR 5/4 (dry) and 10YR 4/4 (moist); common medium distinct clear reddish-yellow mottles; silty clayloam; weak to moderate medium subangular blocky structure; slightly hard (dry) friable (moist), sticky (wet), plastic (wet); common fine-medium pores, few very fine roots; strongle calcareous; clear smooth boundary.
7C	136 - 160 cm	10YR 4.5/4 (dry) and 10YR 4/4 (moist); loam; porous massive; hard (dry), very friable (moist), slighty sticky (wet), slighty plastic (wet); very few fine pores; very few very fine roots; strongly calcareous.

Analytical data for profile ABI005

Depth cm	Mechanical Analysis				pH 1.1	EC dS/m	$CaCo_3$ (g/Kg)
	Sand	Silt	Clay	Texture class			
0 - 23	16	62	22	SiL	8.4	2.8	121.5
23 - 47	16	64	20	SiL	8.4	2.3	117.0
47 - 57	27	55	18	SiL	8.4	1.7	112.0
57 - 95	47	33	20	L	8.4	1.6	191.0
95 - 112	14	52	34	SCL	8.4	1.1	132.5
112 - 124	25	59	16	SiL	8.4	2.4	120.0

Depth cm	Organic C (g/kg)	Total N (g/kg)	Available P (mg/kg)	CEC Soil Cmol/kg	ESP (%)	
0 - 23	5.2	0.05	10	26	36	26
23 - 47	4.3	0.04	3	28	55	20
47 - 57		0.03	2	25	56	18
57 - 95						
95 - 112						
112 - 124						

Texture Class

LS - loamy sand
L - loam
SiCL - silty clay loam
C - clay
SL - sandy loam
SiL - silt loam
SCL - sandy clay loam
CL - clay loam

SOIL PROFILE DESCRIPTION

PROFILE : ABI006 UNIT : ZB2-TR STATUS : 2

Sheet	: Sheet D 38115 (1:100,000)	Grid	: Northing 1448285, Easting 539570
Location	: Block 2 plot 3		
Survey area	: El-Kod research farm	Elevation	: 15 m
Authors	: A.A. Al Hemairi, Zahra A. Musa	Date	: 30/1/95
Soil series	: Zinjibar variant-1 silt loam		
Classification FAO	: Calcaric Fluvisols		
ST	: Typic Torrifluvents, coarse loamy, mixed, hyperthermic		
Soil climate	: Aridic		
Topography	: Almost flat	Land form	: Alluvial-aeolian, coastal plain
Element/position	: Flood plain (upper terrace)	Slope	: 0 - 0.1% straight
Micro topography	: Furrows and bunded basins for irrigation		
Land use	: Irrigated, large scale, furrow, pump	Crops	: Cereals
		Human influence	: Irrigation (long continued)
Vegetation	: Grassland	Grasscover	: 10-30%
Parent material	: Alluvium		
Effect. soil depth	: 100-150 cm		
Erosion	: Slight wind erosion	Sealing/Crusting	: Moderate sealing
Surface salts	: Not observed		
Drainage	: Well		
Permeability	: Moderate		
External drainage	: Moderate		
Watertable	: Not observed		
Flooding	: Rare		
Moist conditions	: Dry 0-160 cm		

Remarks : There is a layer about 5 cm appears within the third layer at depth of 62-69 cm, 4/3 dry, 3/3 moist with common distinct, clear mottles.

Samples :

Ap	0 - 25 cm	10YR 5.5/3 (dry) and 10YR 4/3 (moist); clayloam; moderate very coarse subangular blocky structure; hard (dry), friable (moist), sticky (wet), plastic (wet), few very fine pores, very few fine roots; strongly calcareous; clear wavy boundary.
2C	25 - 62 cm	10YR 5.5/3 (dry) and 10YR 4/3 (moist); loam; weak fine and medium subangular blocky structure; slightly hard (dry), friable (moist), slightly sticky (wet), slightly plasitc (wet); few fine and few medium pores; very few very fine roots; strongly calcareous; clear wavy boundary.
3C	62 - 92 cm	10YR 5/3 (dry) and 10YR 4/3 (moist); few medium distinct sharp brown mottles; sandy clay loam; weak fine subangular blocky structure; slightly hard (dry), friable (moist), sticky (wet), plastic (wet); very few fine pores, very few very fine roots; strongly calcareous; clear wavy boundary.
4C	92 - 122 cm	10YR 6/2 (dry) and 10YR 5/3 (moist); loamy very fine sand; massive single grain; loose (dry); very few very fine pores, very few very fine roots; strongly calcareous; abrupt smooth boundary.
5C	122 - 160 cm	10YR 5.5/3 (dry) and 10YR 4/3 (moist); loam; weak fine and medium subangular blocky structure; soft (dry), friable (moist), non sticky (wet), non plastic (wet); few fine-medium pores, very few very fine roots; strongly calcareous.

Analytical data for profile ABI006

Depth cm	Mechanical Analysis				pH 1.1	EC dS/m	$CaCo^3$ (g/Kg)
	Sand	Silt	Clay	Texture class			
0 - 25	28	54	18	SiL	8.3	2.3	110.0
25 - 62	29	53	18	SiL	8.3	2.1	102.0
62 - 92	27	54	19	SiL	8.3	1.9	111.9
92 - 122	81	6	13	LS	8.5	1.4	-
122 - 160	32	51	17	SiL	8.3	1.4	118.7

Depth cm	Organic C (g/kg)	Total N (g/kg)	Available P (mg/kg)	CEC Soil Cmol/Kg	ESP (%)	SAR
0 - 25	3.3	0.03	5	23	40	11
25 - 62	2.6	0.03	3	21	36	9
62 - 92		0.03			43	8
92 - 122						
122 - 160						

Texture Class

LS - loamy sand
L - loam
SiCL - silty clay loam
C - clay
SL - sandy loam
SiL - silt loam
SCL - sandy clay loam
CL - clay loam

SOIL PROFILE DESCRIPTION

PROFILE : ABI007 UNIT: ZB2-TR STATUS : 2

Sheet	:	Sheet D 38115 (1:100,000)	Grid	:	Northing 1448178, Easting 539483
Location	:	Block 2 plot 4			
Authors	:	M.H. Meshraki, Ahmed M. Abdo	Elevation	:	15 m
Survey area	:	El-Kod research farm	Date	:	26/1/95
Soil series	:	Tarim clay			
Classification FAO	:	Calcaric Fluvisols			
ST	:	Typic Torrifluvent, fine loamy, mixed, hyperthermic			
Soil climate	:	Aridic			
Topography	:	Flat	Land form	:	Coastal plain
Element/position	:	Flood plain (Slightly concave site)	Slope	:	0.1 - 2%
Micro topography	:	Low hummocks			
Land use	:	Irrigated, large scale, furrow, pump	Crops	:	Vegetables, papaya
			Human influence	:	Irrigation (long continued)
Vegetation	:	Grassland	Grasscover	:	
Parent material	:	Alluvium			
Effect. soil depth	:	> 150 cm			
Erosion	:	Slight wind erosion	Sealing/crusting	:	
Drainage	:	Moderately drained			
Permeability	;	Moderate			
External drainage	:	Moderate			
Watertable	:	Not observed			
Flooding	:	Rare			
Moist conditions	:	Dry 0-17 cm, moist 77-150 cm			
Remarks	:				

Samples :

Ap	0 - 27 cm	10YR 7/4 (dry) and 10YR 4/3 (moist); silty clay loam; moderate medium and coarse subangular blocky structure; hard (dry), friable (moist), sticky (wet), plastic (wet); common fine-medium pores, many medium-coarse roots; strongly calcareous; clear irregular boundary.
2C	27 - 52 cm	10YR 7/3 (dry) 10YR 5/3 (moist); sandy loam; weak fine subangular blocky structure; soft (dry), friable (moist), non sticky (wet), non plastic (wet); few fine pores; common fine-medium roots; strongly calcareous; abrupt irregular boundary.
3C	52 - 77 cm	10YR 7/3 (dry) and 10YR 5/2 (moist); loamy sand; massive single grain; loose (moist), non sticky (wet), non plastic (wet); very few (very) fine pores; common fine-medium roots; strongly calcareous; abrupt wavy boundary.
4C	77 - 100cm	10YR 7/3 (dry) and 10YR 4.5/3 (moist); common medium distinct mottles; silty clay loam; weak fine subangular blocky structure; hard (dry), friable (moist), sticky (wet), plastic (wet); common fine-medium pores; very few very fine roots; strongly calcareous; abrupt wavy boundary.
5C	100 - 132cm	10YR 7/3 (dry) and 10YR 4/3 (moist); sandy loam; weak fine subangular blocky structure; soft (dry), friable (moist), non sticky (wet), non plastic (wet); common fine pores; common fine-medium roots; strongly calcareous; abrupt wavy boundary.
6C	132 - 142cm	10YR 4/3 (moist); common medium distinct mottles; silty clay loam; weak medium and coarse subangular blocky structure; hard (dry), friable (coist), sticky (wet), plastic (wet); common fine pores; common distinct clay-sesquioxides cutans on horizontal pedfaces; few fine-medium roots; strongly calcareous; abrupt wavy boundary.
7C	142 - 160cm	10YR 4/3 (moist); sandy loam; weak medium and coarse subangular blocky structure; few fine pores; strongly calcareous.

Analytical data for profile ABI007

Depth cm	Mechanical Analysis				pH 1.1	EC dS/m	$CaCo_3$ (g/Kg)
	Sand	Silt	Clay	Texture class			
0 - 27	18	30	52	C	8.3	3.6	130.0
27 - 52	43	20	37	CL	8.3	1.6	91.8
52 - 77	52	16	32	SCL	8.3	1.4	73.8
77 - 100	6	31	63	C	8.4	1.9	146.8
100 - 132	25	9	66	C	8.4	1.3	113.0
132 - 142	20	28	52	C	8.4	1.6	128.0

Depth cm	Organic C (g/kg)	Total N (g/kg)	Available P (mg/kg)	CEC Soil Cmol/Kg	ESP (%)	SAR
0 - 27	4.1	0.05	7	34	32	45
27 - 52	1.5	0.01	3	17	26	45
52 - 77		0.01	2	10	75	23
77 - 100						
100 - 132						
132 - 142						

Texture Class

LS - loamy sand
L - loam
SiCL - silty clay loam
C - clay
SL - sandy loam
SiL - silt loam
SCL - sandy clay loam
CL - clay loam

SOIL PROFILE DESCRIPTION

PROFILE : ABIOO8 UNITS : KN STATUS : 2

Sheet	:	Sheet D 38115 (1:100,000)	Grid	:	Northing 1447993, Easting 539288
Location	:	Block 3 plot 5			
Survey area	:	El-Kod research farm	Elevation	:	15 m
Authors	:	M.H. Mashraki, Fadl H. Mohamed	Date	:	30/1/95
Soil series	:	Al-Nash silty clay loam			
Classification FAO	:	Calcaric Fluvisol			
ST	:	Typic Torrifluvents, coarse loamy, mixed, hyperthermic			
Soil climate	:	Aridic			
Topography	:	Flat	Land form	:	Alluvial-aeolian, coastal plain
Element/position	:	Flood plain (upper terrace)	Slope	:	0.1 - 2% straight
Micro topography	:	Furrows and bunded basins for irrigation			
Land use	:	Irrigated, large scale, furrow, pump	Crops	:	Vegetables
Vegetation	:		Human influence	:	Irrigation (long continued)
Parent material	:	Alluvium			
Effect. soil depth	:	> 150 cm			
Erosion	:	Slight			
Drainage	:	Moderately well			
Permeability	:	Moderate			
External drainage	:	Moderate			
Watertable	:	Not observed			
Flooding	:	Rare			
Moist conditions	:	Dry 0-100 cm			
Remarks	:				

Samples :

Ap1	0 - 20 cm	10Yr 5.5/3 (dry) and 10YR 4/3 (moist); silty clay loam; weak medium and coarse crumb structure; hard (dry), firm (moist), sticky (wet), plastic (wet); few very fine pores; few very fine roots; strongly calcareous; diffuse smooth boundary.
BW	20 - 34 cm	10YR 5/3 (dry), and 10YR 4/3 (moist); silty clay loam; moderate very coarse subangular blocky structure; slightly hard (dry), friable (moist), stcky (wet), plastic (wet); very few fine and few medium pores; very few very fine roots; strongly calcareous; clear smooth boundary.
2C	34 - 62 cm	10YR 6/2.5 (dry) and 10YR 5/2.5 (moist); few medium distinct clear brown mottles; very fine sandy loam; massive; soft (dry), friable (moist); very few very fine pores; very few very fine roots; clear smooth boundary.
3C	62 - 70 cm	10YR 6/3 (dry) and 10YR 5/3 (moist); common fine distinct clear mottles; clay loam; massive; soft (dry), friable (moist), common fine-mediu pores, nil roots; few insect activity; clear smooth boundary.
4C	70 - 97 cm	10YR 6/3 (dry) and 10YR 5/3 (moist); very fine sandy loam; porous massive; soft (dry), friable (moist); few fine pores and few very fine pores, clear smooth boundary.
5C	97 - 105 cm	10YR 4/3 (moist); common fine distinct clear mottles; clay loam; weak fine angular blocky structure; soft (dry), friable (moist); few very fine pores; clear smooth boundary.
6C	105 - 116 cm	10YR 5/3 (moist); very fine sandy loam; weak fine subangular blocky structure; soft (dry), friable (moist); few fine pores; clear smooth boundary.
7C	116 - 135 cm	10YR 3/3 (moist); clay loam; moderate medium subangular blocky structure; soft (dry), friable (moist); very few very fine pores, very few fine soft calcareous white soft segregation; clear smooth boundary.
8C	135 - 160cm	10YR 4.5/3 (moist); common fine distinct clear brown and few fine faint clear reddish-yelow mottles; clay loam; weak coarse subangular blocky structure; soft (dry), friable (moist); very few very fine pores.

Remarks:

3C Mottles colour is 7.5YR 3/2 moist

5C Mottles colour is 7.5YR 3/2 moist

Analytical data for profile ABI008

Depth cm	Mechanical Analysis				pH 1.1	EC dS/m	$CaCo_3$ (g/Kg)
	Sand	Silt	Clay	Texture class			
0 - 20	9	64	27	SiL\ SiCL	8.2	6.3	133.8
20 - 34	9	68	23	SiL	8.1	6.3	136.3
34 - 62	17	71	12	SiL	7.8	4.3	130.0
62 - 70	6	75	19	SiL	7.8	10.3	149.3
70 - 97	20	68	12	SiL	7.0	11.8	
97 - 105	5	76	19	SiL	8.0	3.0	

Depth cm	Organic C (g/kg)	Total N (g/kg)	Available P (mg/kg)	CEC Soil Cmol/Kg	ESP (%)	SAR
0 - 20	5.3	0.02	12	24	76	45
20 - 34	3.9	0.02	4	25	62	20
34 - 62		0.02	2	14	82	29
62 - 70						
70 - 97						
97 - 105						

Texture Class

LS - loamy sand
L - loam
SiCL - Silty clay loam
C - clay
SL - sandy loam
SiL - silt loam
SCL - sandy clay loam
CL - clay loam

SOIL PROFILE DESCRIPTION

PROFILE : ABI009 UNIT : KN STATUS : 2

Sheet	:	Sheet D 38115 (1:100,000)	Grid	:	Northing 1448013, Easting 539288
Location	:	Block 3 plot 5			
Survey area	:	El-Kod research farm	Elevation	:	15 m
Authors	:	Fadl H. Mohamed, Baraka M., Saleh A.A. Al-Borini	Date	:	3/1/95
Soil series	:	Al-Nash silt loam			
Classification FAO	:	Calcaric Fluvisols			
ST	:	Typic Torrifluvent, coarse loamy, mixed, hyperthermic			
Soil climate	:	Aridic			
Topgraphy	:	Flat	Land form	:	Alluvial-aeolian, coastal plain
Element/position	:	Flood plain (upper terrce)	Slope	:	0.1 - 2% straight
Micro topography	:	Furrows and bunded basins for irrigation			
Land use	:	Irrigated, large scale, furrow, pump	Crops	:	Cereals
			Human influence	:	Irrigation (long continued)
Vegetation	:	Nil	Grasscover	:	10 - 30%
Parent material	:	Alluvium			
Effect. soil depth	:	100-150 cm			
Erosion	:	Slight	Sealing/crusting	:	Moderate sealing
Drainage	:	Moderately well			
Permeability	:	Moderate			
External drainage	:	Moderate			
Watertable	:	Not observed			
Flooding	:	Rare			
Moist conditions	:	dry 0-150 cm			

Remarks : Heavily infested with headache grass (5-10%). Surface cracks continue down to 1.5 m and create surface polygons of 30 cm size.

Samples :

Ap	0 - 40 cm	10YR 6/3 (dry) and 10YR 5/3 (moist); silty clay loam; moderate very coarse subangular blocky structure; slightly hard (dry), friable (moist); few fine pores; common fine-medium roots; clear smooth boundary.
2C	40 - 57 cm	10YR 6/4 (dry) and 10YR 5/3 (moist); common medium distinct brown mottles; silty clay; weak fine subangular blocky structure; slightly (dry), friable (moist); few medium pores and few very fine pores, few fine spherical soft argilleous white soft segregation; common fine-medium roots; abrupt smooth boundary.
3C	57 - 70 cm	10YR 7/3 (dry) and 10YR 5/4 (moist); few medium sharp brown mottles; very fine sandy loam; massive porous soft (dry), friable (moist); few fine-medium pores; few fine-medium roots; abrupt smooth boundary.
4C	70 - 100 cm	10YR 6/4 (moist); few fine distinct sharp brown mottles; loamy sand; massive porous; soft (dry) ,friable (moist); many very fine pores; common medium-coarse roots; abrupt smooth boundary.
5C	100 - 135 cm	10YR 6/3 (moist); common fine faint sharp brown mottles; silty clay; weak fine to coarse angular and subangular blocky structure; slightly hard (dry), friable (moist); many very fine pores; few fine-medium roots; abrupt smooth boundary.
6C	135 - 150 cm	10YR 6/3 (moist); loamy sand; weak medium subangular blocky structure; common fine pores; few fine-medium roots.

Analytical data for profile ABI009

Depth cm	Mechanical Analysis				pH 1.1	EC dS/m	$CaCo_3$ (g/Kg)
	Sand	Silt	Clay	Texture class			
0 - 40	14	65	21	SiL	8.3	5.5	118.8
40 - 57	8	68	24	SiL	8.2	4.4	131.3
57 - 70	29	60	11	SiL	8.2	2.0	93.4
70 - 100	49	40	11	L	8.2	3.7	70.0
100 - 135	6	68	26	SiCL	7.7	7.0	133.8
135 - 150	54	31	15	SCL	8.0	4.8	70.0

Depth cm	Organic C (g/kg)	Total N (g/kg)	Available P (mg/kg)	CEC Soil Cmol/Kg	ESP (%)	SAR
0 - 40	4.2	0.01	3	21	34	40
40 - 57		0.01	4	22	45	44
57 - 70		0.02	2			
70 - 100						
100 - 135						
135 - 150						

Texture Class

LS - loamy sand
L - loam
SiCL - Silty clay loam
C - clay
SL - sandy loam
SiL - silt loam
SCL - sandy clay loam
CL - clay loam

SOIL PROFILE DESCRIPTION

PROFILE : ABI010 UNIT : NQ STATUS : 2

Sheet	: Sheet D 38115 (1:100,000)	Grid	:	Northing 1448103, Easting 539440
Location	: Block 2 plot 5			
Survey area	: El-Kod research farm	Elevation	:	15 m
Authors	: Fadl H. Mohamed, A.A. Al-Borani, Baraka M. Saleh	Date	:	26/1/95
Soil series	: Nuqub silt loam			
Classification FAO	: Calcaric Fluvisol			
ST	: Typic Torrifluvent, fine silty, mixed, hyperthermic			
Soil climate	: Aridic			
Topography	: Almost flat	Land form	:	Alluvial-aeolian, coastal plain
Element/position	: Wadi flood plain	Slope	:	0.1 - 2 straight
Micro topography	: Furrows and bunded basins for irrigation			
Land use	: Irrigated, large scale, furrow, pump	Crops	:	Banana, papaya
		Human influence	:	Irrigation (long continued)
Vegetation	: Grass land	Grasscover	:	
Parent material	: Alluvium			
Effect. soil depth	: >150 cm			
Erosion	: Slight	Sealing/crusting	:	Slight
Drainage	: Moderately well			
Permeability	: Moderate			
External drainage	: Moderate			
Watertable	: Not observed			
Flooding	: Rare			
Moist conditions	: Dry 0-30 cm, moist 30-125 cm			
Remarks	:			

Samples :

Ap1	0 - 20 cm	10YR 6/3 (dry) and 10YR 4/3 (moist); silty clay loam; moderate medium and coarse angular blocky moderate fine granular structure; hard (dry), firm (moist), sticky (wet), plastic (wet); few fine pores; common fine-medium roots; strongly calcareous; gradual smooth boundary.
Ap2	20 - 40 cm	10YR 6/3 (dry) and 10YR 4/3 (moist); silty clay loam; weak medium angular blocky structure; hard (dry), friable (moist), sticky (wet), plastic (wet); few fine pores; common fine roots; strongly calcareous; clear smooth boundary.
2Bw	40 - 60 cm	10YR 6/3 (dry) and 10YR 4/3 (moist); common fine faint sharp mottles; clay loam; strong fine and medium granular structure; slightly hard (dry), friable (moist), sticky (wet), plastic (wet); few fine pores; common faint clay cutans on pedfaces; very few very fine roots extremely calcareous; clear smooth boundary.
3C	60 - 75 cm	10YR 6/3 (dry) and 10YR 4/3 (moist); clay loam to slity clay loam; weak fine and medium angular blocky structure; soft (dry), very friable (moist), sticky (wet), plastic (wet); few medium-coarse pores; very few very fine roots; few insect activity; extremely calcareous; clear smooth boundary.
3Bw	75 - 125 cm	10YR 6/3 (dry) and 10YR 4/3 (moist) ; clay loam; weak medium and coarse angular blocky structure; slightly hard (dry), friable (moist), sticky (wet), plastic (wet); few medium-coarse pores; very few fine roots; extremely calcareous; clear smooth boundary.
4C	125 cm	10YR 6/3 (moist); fine sandy loam; porous massive; soft (dry); few fine pores.

Analytical data for profile ABI010

Depth cm	Mechanical Analysis				pH 1.1	EC dS/m	$CaCo_3$ (g/Kg)
	Sand	Silt	Clay	Texture class			
0 - 20	14	63	23	SiL	8.2	1.9	115.0
20 - 40	14	59	26	SiCL	8.3	1.2	110.0
40 - 60	7	61	32	SiCL	8.2	1.7	115.0
60 - 75	14	68	18	SiL	8.2	1.0	115.0
75 - 125	5	59	36	SiCL	8.2	1.0	119.3
125 - 150	25	63	12	SiL	8.3	1.1	106.3

Depth cm	Organic C (g/kg)	Total N (g/kg)	Available P (mg/kg)	CEC Soil Cmol/Kg	ESP (%)	SAR
0 - 20	4.2	0.05	8	13	40	21
20 - 40	4.1	0.04	5	13	56	18
40 - 60		0.02	4	49	4	27
60 - 75						
75 - 125						
125 - 150						

Texture Class

LS - loamy sand
L - loam
SiCL - Silty clay loam
C - clay
SL - sandy loam
SiL - silt loam
SCL - sandy clay loam
CL - clay loam

SOIL PROFILE DESCRIPTION

PROFILE : ABI011 UNIT : NQ STATUS : 2

Sheet	:	Sheet D 38115 (1:100,000)	Grid	:	Northing 1448020, Easting 539718
Location	:	Block 2 plot 6			
Survey area	:	El-Kod research farm	Elevation	:	15 m
Authors	:	Zahra A. Musa, A.A. Al-Hemairi	Date	:	16/1/95
Soil series	:	Zinjibar silt loam			
Classification FAO	:	Calcaric Fluvisol			
ST	:	Typic Torrifluvent, coarse loamy, mixed, hyperthermic			
Soil climate	:	Aridic			
Topography	:	Almost flat	Land form	:	Alluvial-aeolian, coastal plain
Element/position	:	Interfluve	Slope	:	0 - 0.1% straight
Micro topography	:	Furrows and bunded basins for irrigation			
Land use	:	Irrigated, large scale, furrow, pump	Human influence	:	Irrigation (long continued)
Vegetation	:	Grassland	Grasscover	:	10-30%
Parent material	:	Alluvium			
Effect. soil depth	:	100-150 cm			
Erosion	:	Slight wind erosion			
Surface salts	:	Not observed	Sealing/crusting	:	Nil
Drainage	:	Moderately well			
Permeability	:	Slow			
External drainage	:	Moderate			
Watertable	:	Not observed			
Flooding	:	Rare			
Moist Conditions	:	Dry 0-165 cm			
Remarks	:				

Samples :

Ap1	0 - 30 cm	10YR 5/3 (dry) and 10YR 4/3 (moist); silty clay loam; moderate fine and medium subangular blocky structure; slightly hard (dry), friable (moist), slightly sticky (wet), slightly plastic (wet); common fine pores, common fine-medium roots; strongly calcareous; abrupt smooth boundary.
2C	30 - 40 cm	10YR 4.5/3 (dry) and 10YR 4/3 (moist); few fine faint clear brown mottles; clay loam; weak fine and medium subangular blocky structure; hard (dry), friable (moist), slightly sticky (wet), slightly plastic (wet); common fine-medium pores, many fine roots; strongly calcareous; clear wavy boundary.
3C	40 - 65 cm	10YR 4.5/4 (dry) and 10YR 4/4 (moist); few fine faint clear brown mottles; very fine sandy loam; weak fine and medium subangular blocky structure; soft (dry), very friable (moist), slightly sticky (wet); slightly plastic (wet); many fine roots; strongly calcareous; clear wavy boundary.
4C	65 - 75 cm	10YR 5/4 (dry) and 10YR 4/4 (moist); clay loam; weak fine and medium subangular blocky structure; soft (dry), very friable (moist), slightly sticky (wet), slightly plastic (wet); many medium-coarse pores; few very fine roots; strongly calcareous; abrupt smooth boundary.
5C1	75 - 85 cm	10YR 5.5/3 (dry) and 10YR 3.5/3 (moist); few fine faint clear mottles; very fine sandy loam; weak fine subangular blocky structure; soft (dry), very friable (moist), slightly sticky (wet), slightly plastic (wet); few fine pores; few very fine roots; strongly calcareous; abrupt smooth boundary.
5C2	85 - 105cm	10YR 5/4 (dry) and 10YR 4/4 (moist); very fine sandy loam; weak fine granular structure; soft (dry), very friable (moist), slightly sticky (wet), slightly plastic (wet); few fine pores; few very fine roots; strongly calcareous; abrupt smooth boundary.
6C	105 - 123cm	10YR 4/3 (dry) and 10YR 3/3 (moist); common fine distinct mottles; very fine sandy loam; weak fine and medium subangular blocky structure; soft (dry), friable (moist), slightly sticky (wet), slightly plastic (wet); few fine pores; very few very fine roots; strongly calcareous; abrupt smooth boundary.
7C	123 - 143 cm	10YR 5.5/4 (dry) 10YR 4.5/4 (moist); very fine sandy loam; weak fine and medium subangular blocky structure; soft (dry), friable (moist), slightly sticky (wet), slightly plastic (wet).

Analytical data for profile ABI011

Depth cm	Mechanical Analysis				pH 1.1	EC dS/m	$CaCo_3$ (g/Kg)
	Sand	Silt	clay	Texture class			
0 - 30	29	52	19	SiL	8.3	1.9	101.2
30 - 40	34	47	19	L	8.3	1.6	100.0
40 - 65	30	51	19	SiL	8.3	1.8	98.7
65 - 75					8.3	2.1	114.4
75 - 85					8.3	1.5	66.9
85 - 105					8.2	1.4	120.0

Depth cm	Organic C (g/kg)	Total N (g/kg)	Available P (mg/kg)	CEC Soil Cmol/Kg	ESP (%)	SAR
0 - 30	4.2	0.04	6	35	43	
40 - 65	4.0	0.03	3	35	57	
65 - 75			3	27	35	
75 - 85						
85 - 105						

Texture Class

LS - loamy sand
L - loam
SiCL - silty clay loam
C - clay
SL - sandy loam
SiL - silt loam
SCL - sandy clay loam
CL - clay loam

SOIL PROFILE DESCRIPTION

PROFILE : ABI012 UNIT: ZB3-AH STATUS : 2

Sheet	: Sheet D 38115 (1:100,000)		Grid	:	Northing 1447855, Easting 539470
Location	: Block 2 plot 7				
Survey area	: El-Kod research farm		Elevation	:	15 m
Authors	: M.H. Meshraki, Ahmed M. Abdo		Date	:	29/1/95
Soil series	: Al-Nash silt loam				
Classification FAO	: Calcaric Fluvisol				
ST	: Typic Torrifluvent, coarse loamy, mixed, hyperthermic				
Soil climate	: Aridic				
Topography	: Almost flat		Land form	:	Alluvial-aeolian
Element/position	: Interfluve		Slope	:	0.1 - 2%
Micro topography	: Low hummocks				
Land use	: Irrigated, large scale, furrow, pump		Crops	:	Vegetables
			Human influence	:	Irrigation (long continued)
Vegetation	: Grassland		Grasscover	:	10-30%
Parent material	: Alluvium				
Effect. soil depth	: > 150 cm				
Erosion	: Slight wind erosion		Sealing/crusting	:	
Drainage	: Well				
Permeability:	: Moderate				
External drainage	: Moderate				
Watertable	: Not observed				
Flooding	: Rare				
Moist conditions	: Dry 0-100 cm				
Remarks	:				

Samples :

Ap	0 - 38 cm	10YR 5.5/4 (dry) and 10YR 4/4 (moist); silty clay loam; moderate medium angular and subangular blocky structure; common fine-medium pores, common fine-medium roots; clear smooth boundary.
C	38 - 64 cm	10YR 4.5/4 (dry) loamy very fine sand; porous massive; many fine-medium roots; abrupt smooth boundary.
2C	63 - 75 cm	10YR 5/4 (dry) and 10YR 4/4 (moist); few fine faint brown mottles; silt loam to silty clay loam; weak coarse angular and subangular blocky structure; abrupt smooth boundary.
3C	75 - 95 cm	10YR 6/4 (dry) and 10YR 5/4 (moist); few medium faint brown mottles; silty clay loam; weak medium and coarse angular and subangular blocky structure; abrupt smooth boundary.
4C	95 - 140 cm	10YR 4.5/4 (dry) and 10YR 3.5/4 (moist); silty clay loam; weak medium and coarse angular and subangular blocky structure.

Analytical data for profile ABI012

Depth cm	Mechanical Analysis				pH 1.1	EC dS/m	$CaCo_3$ (g/Kg)
	Sand	Silt	Clay	Texture class			
0 - 38	16	58	26	SiL	8.3	4.4	120.0
38 - 63	50	40	10	L	8.3	2.3	87.5
63 - 75	7	76	17	SiL	8.4	2.5	132.5
75 - 95	3	75	22	SiL	8.3	3.4	136.0
95 - 140	4	62	34	SiCL	8.3	2.2	142.5

Depth cm	Organic C (g/kg)	Total N (g/kg)	Available P (mg/kg)	CEC Soil Cmol/Kg	ESP (%)	SAR
0 - 38	1.2	0.05	1	32	47	86
38 - 63		0.01	2	17	73	15
63 - 75		0.03				
75 - 95						
95 - 140						

Texture Class

LS - loamy sand
L - loam
SiCL - silty clay loam
C - clay
SL - sandy loam
SiL - silt loam
SCL - sandy clay loam
CL - clay loam

SOIL PROFILE DESCRIPTION

PROFILE : ABI013 UNIT: ZB3-AH STATUS :2

Sheet	:	Sheet D 38115 (1:100,000)	Grid	:	Northing 1447725, Easting 539408
Location	:	Block 3 plot 8			
Survey area	:	El-Kod research farm	Elevation	:	15 m
Authors	:	Ahmed M. Abdo, M.H.Al-Meshraki	Date	:	30/1/95
Soil series	:	Zinjibar variant-1 silt loam			
Classification FAO	:	Calcaric Fluvisol			
ST	:	Typic Torrifluvent, coarse loamy, mixed, hyperthermic			
Soil Climate	:	Aridic			
Topography	:	Almost flat	Land form	:	Alluvial-aeolian, coastal plain
Element/position	:	Wadi flood plain (leveled)	Slope	:	0.1 - 2%
Micro topography	:	Low hummocks			
Land use	:	Irrigated, large scale, furrow, pump	Crops	:	Mango, banana
			Human influence	:	Irrigation (long contined)
Vegetation	:	Grassland	Grasscover	:	10-30%
Parent material	:	Alluvium			
Effect. soil depth	:	> 150 cm			
Erosion	:	Slight wind erosion	Sealing/crusting	:	Slight
Drainage	:	Well			
Permeability	:	Moderate			
External drainage	:	Moderate			
Watertable	:	Not observed			
Flooding	:	Rare			
Moist Conditions	:	Dry 0-100 cm			
Remarks	:				

Samples :

Ap	0 - 35 cm	10YR 5.5/3 (dry) and 10YR 4/3 (moist); silty clay loam; weak very coarse subangular blocky structure; very hard (dry), friable (moist), sticky (wet), plastic (wet); common coarse pores; abundant coarse roots; abrupt wavy boundary.
2C	35 - 50 cm	10YR 6/2.5 (dry) and 10YR 5/3 (moist); loamy very fine sand; massive single grain; soft (dry), friable (moist), non sticky (wet), non plastic (wet); few coarse and very few very fine pores; many coarse roots; abrupt wavy boundary.
3C	50 - 67 cm	10YR 6/3.5 (dry) and 10YR 4/3 (moist); common fine faint clear brown mottles; silty clay loam; moderate coarse subangular blocky structure; slightly hard (dry), friable (moist), slightly sticky (wet), slightly plastic (wet); few (very) fine pores, common medium roots; abrupt smooth boundary.
4C	67 - 87 cm	10YR 6/2.5 (dry) and 10YR 5/3 (moist); loamy very fine sand; porous massive; soft (dry), friable (moist) non sticky (wet), non plastic (wet); few (very) fine pores; common fine roots; clear wavy boundary.
5C	87 - 95 cm	10YR 6/3 (dry) and 10YR 4/3 (moist); few fine faint clear brown mottles; silty clay loam; moderate medium and coarse subangular blocky structure; soft (dry), friable (moist), non sticky (wet), non plastic (wet); few fine pores, common fine roots; clear wavy boundary.
6C	95 - 109 cm	10YR 6/3 (dry) and 10YR 4.5/2 (moist); fine sandy loam; weak medium subangular blocky structure; soft (dry), friable (moist), non sticky (wet), non plastic (wet); very few very fine pores; very few very fine roots; abrupt smooth boundary.
7C	109 - 120 cm	10YR 4/3 (dry) and 10YR 3/3 (moist); silty clay loam; moderate fine and medium structure; slightly hard (dry), friable (moist), sticky (wet), plastic (wet); very few coarse pores.

Analytical data for profile ABI013

Depth cm	Mechanical Analysis				pH 1.1	EC dS/m	$CaCo_3$ (g/Kg)
	Sand	Silt	Clay	Texture class			
0 - 35	20	57	23	SiL	8.2	3.3	133.0
35 - 50	65	24	11	SL	8.1	1.3	132.5
50 - 67	24	57	19	SiL	8.3	1.9	69.3
67 - 87	65	27	8	SL	8.2	1.2	73.8
87 - 95	19	62	19	SiL	8.2	1.8	123.0
95 - 109	16	41	12	L	8.2	1.5	95.0

Depth cm	Organic C (g/kg)	Total N (g/kg)	Available P (mg/kg)	CEC Soil Cmol/Kg	ESP (%)	SAR
0 - 35	5.7	0.02	10	38	5	18
35 - 50		0.03	1	23	44	8
50 - 67			2	17	12	12
67 - 87						
87 - 95						
95 - 109						

Texture Class

LS - loamy sand
L - loam
SiCL - silty clay loam
C - clay
SL - sandy loam
SiL - silt loam
SCL - sandy clay loam
CL - clay loam

SOIL PROFILE DESCRIPTION

PROFILE : ABI014 UNIT : KD STATUS: 2

Sheet	:	Sheet D 38115 (1:100,000)	Grid	:	Northing 1447845, Easting 539955
Location	:	Block 2 plot 8			
Survey area	:	El-Kod research farm	Elevation	:	15 m
Authors	:	Ahmed M. Abdo, M.H. Al-Meshraki	Date	:	29/1/95
Soil series	:	Nuqub variant-1 silt loam			
Classification FAO	:	Calcaric Fluvisols			
ST	:	Typic Torrifluvent, coarse silty, mixed hyperthermic			
Soil climate	:	Aridic			
Topography	:	Almost flat	Land form	:	Alluvial-aeolian, coastal plain
Element/position	:	Wadi flood plain (leveled)	Slope	:	0.1 - 2%
Micro topography	:	Furrows and bunded basins for irrigation			
Land use	:	Irrigated, large scale, furrow, pump	Crops	:	Cereals
			Human influence	:	Irrigation (long continued)
Parent material	:	Alluvium			
Effect. soil depth	:	100 cm			
Erosion	:	Slight	Sealing/crusting	:	Slight
Drainage	:	Well			
Permeability	:	Moderate			
External drainage	:	Moderate			
Watertable	:	Not observed			
Flooding	:	Rare			
Moist Cond.	:	Dry 0-120 cm, moist 120-200 cm			

Remarks : Colour of third horizon is mixed. Weak fine stratification in the second and third horizons.

Samples:

Ap	0 - 23 cm	10YR 5.5/3 (dry) and 10YR 3.5/3 (moist); silty clay loam; massive very coarse prismatic structure; very hard (dry), friable (moist), very sticky (wet), very plastic (wet); many very fine pores; very few fine roots; extremely calcareous; gradual wavy boundary.
2C	23 - 74 cm	10YR 5/4 (dry) and 10YR 4.5/4 (moist); loamy very fine sand; massive porous; soft (dry), friable (moist); few very fine pores; common very fine roots; strongly calcareous; clear smooth boundary.
3C	74 - 174 cm	10YR 4/4 (moist); silty clay loam; weak coarse angular blocky moderate fine angular blocky structure; slightly hard (dry), friable (moist); few fine and many very fine pores; very few very fine roots; extremely calcareous.

Analytical data for profile ABI014

Depth cm	Mechanical Analysis				pH 1.1	EC dS/m	$CaCo_3$ (g/K)
	Sand	Silt	Clay	Texture class			
0 - 23	21	60	19	SiL	8.4	2.9	121.8
23 - 75	19	70	11	SiL	8.4	1.9	120.0
75 - 125	3	73	24	SiL	8.3	2.7	146.8
125 - 175	4	69	27	SiL	7.9	5.6	141.8

Depth cm	Organic C (g/kg)	Total N (g/kg)	Available P (mg/kg)	CEC Soil Cmol/kg	ESP (%)	SAR
0 - 23	9.0	0.01	5	26	71	27
23 - 75		0.01	2	26	73	30
75 - 125		0.05		20	70	39
125 - 175						

Texture Class

LS - loamy sand
L - loam
SiCL - silty clay loam
C - clay
SL - sandy loam
SiL - silt loam
SCL - sandy clay loam
CL - clay loam

SOIL PROFILE DESCRIPTION

PROFILE : ABI015 UNIT : KD STATUS: 2

Sheet	:	Sheet D 38115 (1:100,000)	Grid	:	Northing 1447718, Easting 540045
Location	:	Block 2 plot 9			
Survey area	:	El-Kod research farm	Elevation	:	15 m
Authors	:	Ahmed M. Abdo	Date	:	30/1/95
Soil series	:	Nuqub silt loam			
Classification FAO	:	Calcaric Fluvisols			
ST	:	Typic Torrifluvent, fine silty, mixed, hyperthermic			
Soil climate	:	Aridic			
Topography	:	Almost flat	Land form	:	Alluvial-aeolian, coastal plain
Element/position	:	Flood plain	Slope	:	0.1 - 2%
Micro topography	:	Low hummocks			
Land use	:	Irrigated, large scale, furrow, pump	Human influence	:	Irrigation (long contined)
Vegetation	:	Grassland	Grasscover	:	10 - 30%
Parent material	:	Alluvium			
Effect. soil depth	:	>150 cm			
Erosion	:	Slight wind erosion	Sealing/crusting	:	Slight
Drainage	:	Well			
Permeability	:	Moderate			
External drainage	:	Moderate			
Watertable	:	Not observed			
Flooding	:	Rare			
Moist conditions	:	Dry 0-50 cm			
Remarks	:				

Samples :

Ap	0 - 30 cm	10YR 6.5/4 (dry) 10YR 4.5/3 (moist); clay loam; moderate coarse and very coarse subangular blocky strong fine subangular blocky structure; hard (dry), friable (moist), sticky (wet), plastic (wet); common (very) fine pores; common (very) fine roots; strongly calcareous; clear very boundary.
BW	30 - 40 cm	10YR 6/3 (dry) and 10YR 4.5/3 (moist); silty clay loam; moderate coarse subangular blocky structure; slightly and hard (dry), friable (moist), sticky (wet), plastic (wet); many (very) fine pores, strongly calcareous; abrupt wavy boundary.
3C	40 - 70 cm	10YR 7/4 (dry) 10YR 5/4 (moist); sandy loam to very fine sandy loam; porous massive; soft (dry), very friable (moist), non sticky (wet), non plastic (wet); common very fine pores; strongly calcareous; abrupt wavy boundary.
4C	70 - 110 cm	10YR 5.5/4 (dry) and 10YR 4/3 (moist); silty clay loam; moderate fine and medium subangular blocky structure;slightly hard (dry), friable (moist), sticky (wet), plastic (wet); many fine pores; few (very) fine roots; strongly calcareous; gradual wavy boundary.
5C	110 - 122 cm	10YR 6.5/4 (dry) and 10YR 4/4 (moist); clay loam; weak fine and medium subangular blocky structure; slightly hard (dry), friable (moist), sticky (wet), plastic (wet); many very fine pores; few (very) fine roots; strongly calcareous; gradual wavy boundary.
6C	120 - 135 cm	10YR 6/4 (dry) and 10YR 4/3 (moist); sandy loam; very weak coarse and very coarse subangular blocky structure; soft (dry), very friable (moist), non sticky (wet), non plastic (wet); many (very) fine pores and few pores; few (very) fine roots; strongly calcareous;
7C	135 - 150 cm	10YR 6.5/4 (dry) and 10YR 4/4 (moist); silty clay loam; porous massive; slightly hard (dry), friable (moist), sticky (wet), plastic (wet), common very fine pores and few pores, strongly calcareous.

Analytical data for profile ABI015

Depth cm	Mechanical Analysis				pH 1.1	EC dS/m	$CaCo_3$ (g/Kg)
	Sand	Silt	Clay	Texture class			
0 - 30	12	69	19	SiL	8.3	2.6	128.7
30 - 40	22	57	21	SiL	8.0	-	126.2
40 - 70	11	69	20	SiL	8.0	0.8	113.1
70 - 110	15	44	41	SiC	8.0	1.7	133.1
110 - 122	25	50	25	L	8.0	0.9	147.6
122 - 135	18	66	16	SiL	8.2	0.5	131.2

Depth cm	Organic C (g/kg)	Total N (g/kg)	Available P (mg/kg)	CEC Soil Cmol/Kg	ESP (%)	SAR
0 - 30	4.6	-	5	35	40	37
30 - 40		0.03	2	35	40	27
40 - 70		0.02		30	49	28
110 - 122						
110 - 122						

Texture Class

LS - Loamy sand
L - loam
SiCL - silty clay loam
C - clay
SL - sandy loam
SiL - silt loam
SCL - sandy clay loam
CL - clay loam