FOOD AND AGRICULTURAL ORGANIZATION OF THE UNITED NATIONS
ENVIRONMENTAL RESOURCE ASSESSMENT FOR RURAL LAND USE PLANNING
GCP/YEM/021/NET *Field Document 12*

LAND RESOURCE STUDY OF HODEIDAH GREEN BELT AREA

RENEWABLE NATURAL RESOURCES RESEARCH CENTRE
AGRICULTURAL RESEARCH AND EXTENSION AUTHORITY
MINISTRY OF AGRICULTURE AND IRRIGATION
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by

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ABSTRACT

In this report the results are presented from the soil survey carried out in the Green Belt area around Al-Hodeidah. This report covers the relevant parts of the Tihama coastal plain, including part of the wadi Siham alluvial plain. A soil map, land use map, vegetation map and physiographic map, all at a scale of 1 : 50.000, were prepared. The total area covered is approximately 15200 ha, situated in a half circle around Hodeidah city.

The soils are in general homogeneous with little pedogenetic development, and variable degrees of salinity and sodium content. Apart from the more sandy soils that generally cover the coastal plain, the flood irrigated alluvial parts have more loamy textures. These soils have a low organic matter content, moderate fertility and a moderate internal drainage. The quality of groundwater used for irrigation is poor with high levels of sodium.

The soil map indicates that about 25% of the area is occupied by active duneland, and another 35% consists of flat and hummocky sandy areas affected by shifting sands. These areas are used mainly for grazing. A considerable part of the survey area (about 40%) is used for traditional rainfed and irrigated farming by mainly small scale farmers.

Based on the above findings it is recommended that a development plan should consider the three different environments :

- The duneland areas where afforestation for sand stabilisation is urgently needed.
- The relatively flat sandy areas which are suitable for grazing can be planted with drought resistant tree species which are suitable for forage, while some parts, depending on water availability, could be turned into plantation forests.
- The agricultural land requires agro-forestry to provide fruit trees and fuelwood trees to local farmers, and shelterbelts to protect crops against the strong prevailing winds.

Treated sewage water from the nearby sewage plant could be used for the sandy lands and dune lands to irrigate selected trees tolerant to salinity (e.g. *Azadirachta indica*). Underground water should be used mainly for irrigation of vegetables and fruit trees. In the farming areas, attention should also be paid to introducing special management practices, such as crop rotations, to increase yields and protect the soils. The development of recreation areas and protected natural areas within the Green Belt should also be considered. However, the development of infrastructure and built-up areas inside the Green Belt must be strictly controlled to reduce the hazard of land degradation.

ACKNOWLEDGMENTS

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INTRODUCTION

This study was requested by FAO Urban Forestry TCP Project with the objective of assessing the environmental resources in a semi-circular belt around Hodeidah for their suitability with regard to the establishment of a Green Belt of vegetation to protect the city and the surrounding villages against sand encroachment. Senior soil surveyor Mr. Mohammed Hezam Al-Mashreki was assigned by the Renewable Natural Resources Research Centre, supported by FAO's Environmental Resources Assessment For Rural Land Use Planning Project (GCP/YEM/021/NET), to carry out this study and write the final report.

The aims of this study are :

1. Identification and location of main types of soils and map there distribution.
2. Characterize the soils in terms of chemical and physical properties.
3. Determine suitability of the different soils for the development of vegetation for the Green Belt.
4. Characterize water resources and their suitability for irrigation.
5. Identify and map the present land use and land cover.

The development of the Green Belt around Hodeidah is meant mainly as environmental protection for :

a. Controlling sand encroachment.
b. Utilize the large amounts of water from the sewage treatment plant for irrigating the Green Belt.
c. Benefit that can be obtained from the existence of the Green Belt are its use as a recreational area for the residents of Hodeidah, and as a landscape element that will add more beauty to the scenic view of the city.

The field study was carried out in three phases :

1. Exploratory study covering all aspects of the study (soils, vegetation, land use, water resources).
2. Semi-detailed for soil survey study to identify the main mapping units and describe the properties of their components.
3. Socio-economic study to identify the different farming systems and to characterize the dominant ones.

The fieldwork was started on 16 September 1996 and was completed after one and half month.

Chapter 1 ENVIRONMENT

1.1 LOCATION

The survey area is that part of the Tihama coastal plain which lies between UTM grid lines 1635000m-1649000mN and 280000m-293000mE (14°40'48" - 14°54'24" N and 42°56'42" -43°04'00" E), surrounding Hodeidah city (see figure 1). It starts from the coast at about 6.5 km north of Hodeidah along the road to Jayzan, and continues south east, crossing the Sana'a - Hodeidah road at km 16 and extending in south west direction towards the coast south of Hodeidah, thus making a half circle around the city. The width of the area is about 5 km in most places, and the whole area encompasses about 15,200 ha.

1.2 GENERAL CHARACTERISTIC OF THE AREA

The survey area is shown on figure 1, and in greater detail on the physiographic map (Appendix 4). It comprises an extensive, largely featureless sedimentary coastal plain, with an alluvial plain cutting through it, and sloping gently towards the Red Sea. In the north-east, close to the sea, some variation in landscape is provided by extensive though discontinuous expanses of sand dunes, mostly longitudinal and barchans. Soil distribution, current land use and micro-relief in the southern part of the study area have been strongly influenced by the practice, over many centuries, of flood irrigation from Wadi Siham.

1.3 GEOLOGY

According to studies done by Geukens (1966) and Grolier and Overstreet (1978), the Hodeidah coastal plain lies within the Quaternary alluvium deposits, which have been divided on the basis of their mode of transportation into wind-laid (aeolian) and water-laid (fluvial) deposits. A generalized geological map is shown in figure 2.

1.3.1 Aeolian deposits

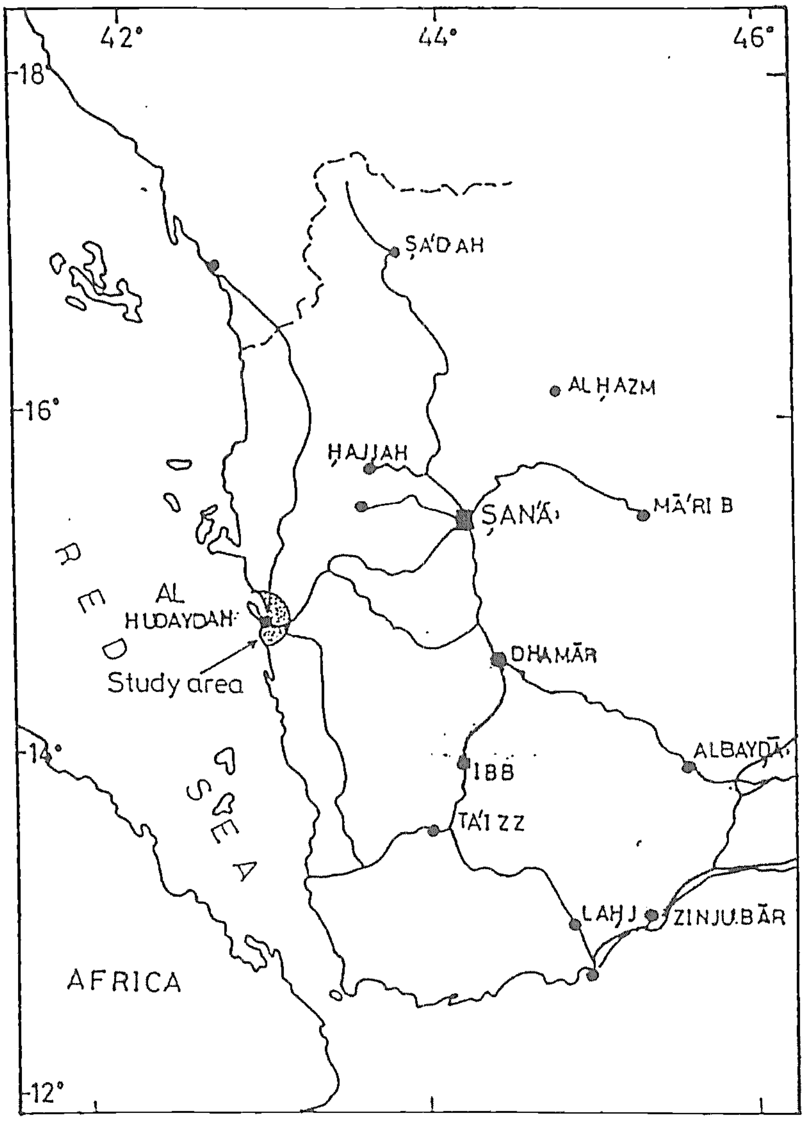
1.3.1.1 Loess

Loess deposits are found in areas where mountains present a barrier to the wind, causing it to slow down and drop its sediment load. The loess of Yemen probably originated in the Rub Al-Khali to the northeast, the direction of the prevailing winds. Many of the loess deposits, particularly in the inter-montane plains, have been reworked by alluvial processes. Some authors have indicated that loess deposits occur also in Tihama coastal plain.

1.3.1.2 Dunes

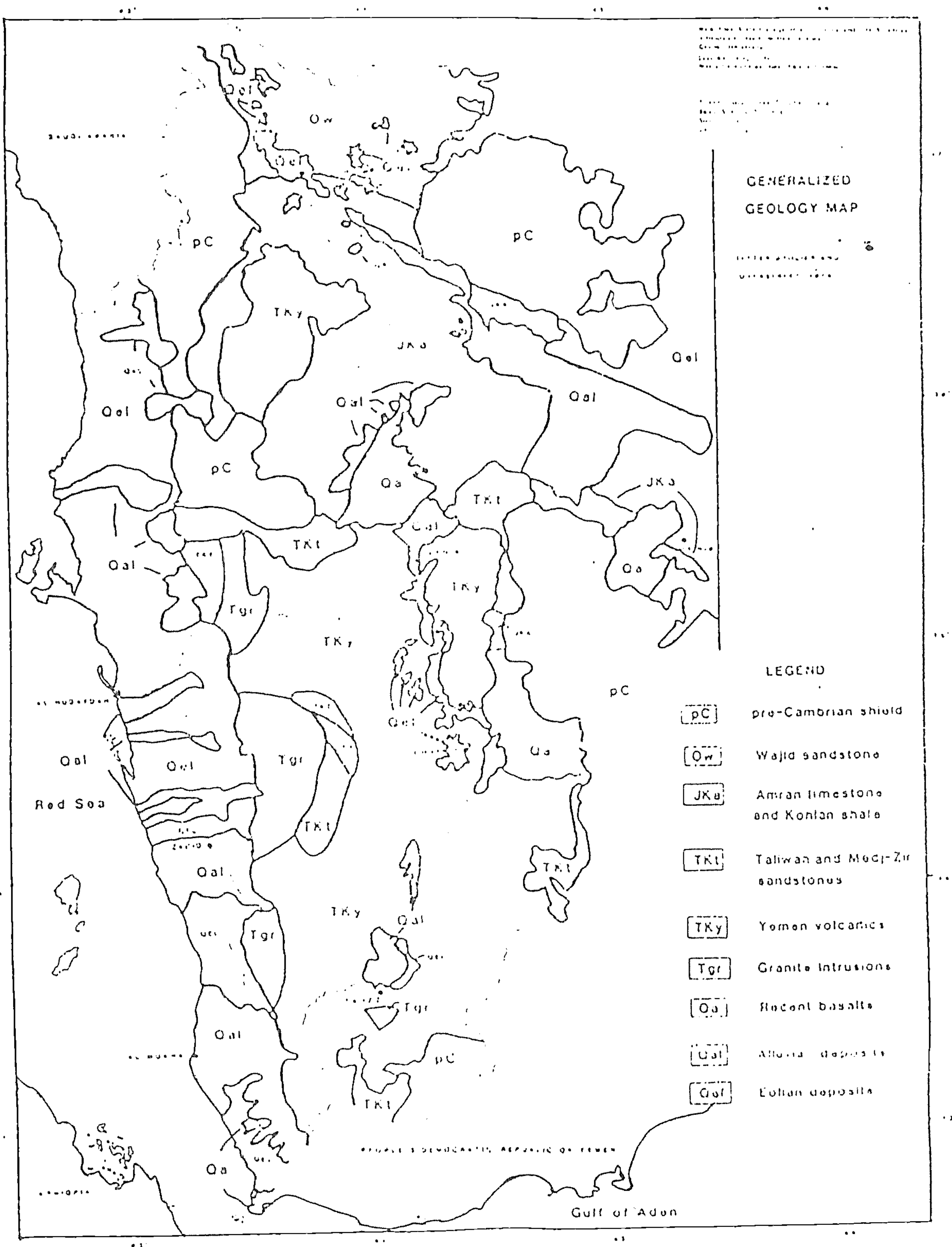
In the survey area, round sand dunes are found primarily to the north and east of Hodeidah where the ground is level (mapping units C223, C222, C221, C144). Barchan and longitudinal dunes are found particularly on units C122 and C111, indicating that sand supply is the limiting factor of dune formation. The source of the sand is probably the wadi beds and

Fig. 1 Location map of the study area



alluvial fans, which receive sand from wadies emanating from the mountains. The great sand seas of the Rub Al-Khali are outside of the survey area.

Figure 2 Generalized geological map of Yemen
(units Qa1 and Qe1 occur in the study area)



Source: King Jack W 11, Abu Ghanem (1983)

1.3.1.3 Fluvial deposits

Alluvial plains form broad, flat areas of low relief in the study area. The processes of sediment deposition which form alluvial plains are similar to those which form wadi beds. The sediments, however. are generally finer in texture than those in the active wadi beds. and are spread over a much larger area. The source of the sediments is the weathering debris from the highlands mixed with alluvial loess.

The coastal plain consists of sedimentary deposits which, away from the mountain front, are at least 200 m thick. The subsurface geology is basically a continuum with two broad facies based on grain-size. The deposits on the alluvial plain are finer-grained and some what better sorted, coarse pebbly sand, gravels and pebble beds pass westwards into medium sands with subsidiary pebbly sands, gravel, silty sand and even silty clays.

The deposits are rather uniform with depth and exceed 150 cm. The main wadi Siham valley is floored by bouldery and cobbly alluvium, up to several tens of meters thick, flanked by a series of alluvial terraces, rising to at least 15 m above the wadi bed. North and north-east of Hodeidah, and particularly towards the coast, superficial sand dunes are prominent, stabilized in part by sparse vegetation. Grey lagoonal clay, probably of marine origin, and overlain by a discontinuous veneer of aeolian fine sand, form a low raised beach in the level coastal areas to the south of wadi Siham.

1.4 MAIN LAND UNITS

Three main physiographic units have been recognized, viz.:

1. Alluvial plain.
2. Aeolian sand plain
3. Alluvio-Marine platform

The text on map 3 (appendix 4) indicates the relationship between these units and their distribution.

1.4.1 Alluvial plain

The alluvial plain of wadi Siham lies to the east of Hodeidah, the transition with the eolian and marine deposits being marked by a slight decrease in slope, a more pronounced surface relief and the increasing influence of windblown sands. To the south-east the plain is bordered for the most of its length by the main eastern wadi Siham channels. The plain also receives and disperses flow from the southern channel through a complex irrigation network, which now mostly relies on pump irrigation, but apparently was subject to regular spate irrigation in the past. Aeolian erosion and deposition affect the entire area and is locally severe. Natural vegetation, which in many places flanks former wadi channels, also stabilizes a micro-relief of aeolian hummocks.

A further physiographic subdivision can be made into:

1. Present wadi floors and channels
2. Levees
3. Wadi terraces

1.4.1.1 Wadi floors and channels

The textural composition of the sediments in the present stream beds of Wadi Jahef (Siham) varies from rounded gravel and stones at the apex of the fans to sands in the central part and to well sorted silts in the braided channels forming the southwestern fringes of the alluvial system. Consequently the present wadi deposits rise above the surrounding older alluvial plain.

1.4.1.2 Levees

Levees are embankments gradually built by the wadi along their channels. Levees do occur in the alluvial system of wadi Siham. The levees rise 1-2 m above the level of the adjacent subrecent wadi terraces, towards which they slope gradually on the side away from the river. Consequently they have a good external drainage. They are generally coarse textured (sands), but due to long term spate irrigation often overlain by a 0.5 to 1 m thick layer of silts.

1.4.1.3 Wadi terraces

The wadi terraces include recent and sub-recent alluvium of wadi Siham. The most recent terraces are found along the wadi beds, up to 1 m above the present base levels. They are flooded regularly. Their textural composition roughly follows that of the wadi floors, with coarse textured material in the eastern parts, which becomes more silty towards the southwest. Only some of the higher, more silty terraces are under cultivation.

The subrecent terraces are higher and generally separated from the wadi beds by levees and wadi incisions. South of wadi Siham these terraces have been built on top of older alluvial deposits, and have a moderate slope towards the wadi (2-5%), gradually merging into the alluvial plain. Sedimentation on these subrecent terraces has been clearly influenced by spate irrigation, as the upper layers of parent material consists mainly of well sorted silts.

1.4.2 Aeolian sand plain

This occupies much of the land to the north and north-east of Hodeidah, between the Jayzan and Sana'a roads. Although mostly bare of vegetation, the lower dunes are partially stabilized by a sparse ground cover. Higher dunes are mostly active and mobile, contributing in creating barchan and longitudinal dunes. The dune area is both depository and a source of wind-blown sand.

1.4.3 Alluvio-marine platform

This is the level coastal area where medium and fine textured alluvio-marine sediments are overlain by a discontinuous cover of aeolian sand derived from shoreline deposits. With the exception of the alluvial part of the study area, most of the remainder is underlain by this platform.

1.5 VEGETATION

The different plant formations and plant communities in the Tihama are not so much connected with climatic differences as with other important ecological factors such as elevation above the water-table, water salinity, texture and mobility of sands. Where the tidal range of the Red Sea is protected by sand bars, the shallow water lagoon is the habitat for a Mangrove (*Avicennia marina*) woodland. A large zone, sometimes up to 5 km inland. is usually sterile, due to its high salinity. Only periodically better drained places may be covered by a few halophytic plants like *Suaeda fruticosa* and, when topped with thin wind-borne sand-layer, by grasses. This is a very poor herbaceous and half-woody salt swamp formation.

The next plant formation further inland may be called a sub-desert shrubland with halophytic succulents. Here the most important community is a salt-bush community with *Suaeda monoica*. on slightly elevated but still very compact marine deposits with high salinity, situated just above the current flood level. These deposits are often overlain by aeolian sand and the *Suaeda* bushes form small hillocks reaching one meter high and leaving space where annuals like *Zygophyllum simplex* appear after heavy rainfall. Vast stretches of land can be covered by this community. The plant cover may reach a surprising density of more than 50%.

The vegetation of the adjacent sub-desert plain shows a mosaic pattern, depending on such factors as topography. texture, depth and mobility of the surface deposits and different forms of human interference. Many different plant communities here belong to three plant formations. Among this the first and most important one is a drought deciduous mixed dwarf-shrubland with deciduous and evergreen dwarf-shrubs, and only a few microphyllous or leafless shrubs with green stem. with tussock-forming grasses, succulents and other life-forms.

On a few mobile dunes. where the wind is the main agent for deposition and deflation good sand binders like the grasses *Panicum turgidum* and *Odyssea mucronata* as well as the dwarf-shrub *Indigofera spinosa* can be found. On the valley bottom between the higher and larger dunes phytogenetic mounds and hillocks are very common. The evergreens *Cadaba rotundifolia* and *Cadaba glandulosa* collect the moving sand with their leaves and branches, forming hillocks up to two meters high. They are often associated with some succulents like the *Euphorbia triaculeata*. After rainy periods, on silty and fine sandy deposits around the hillocks. dense ephemeral growth of *Corchorus depressus*. *Fagonia indica*. *Euphorbia indica*. *Tephrosia purporea*, *Dipterygium glaucum*, and *Schouwia purporea* is fairly common. A vegetation map of the study area is included in Appendix 4.

1.5.1 Man's influence on the vegetation of the Tihama

At some time in the past a fairly dense forest, or at least open woodland, of *Acacia ehrenbergiana* and *Acacia tortilis* was the dominant natural vegetation of the Tihama (DHV. 1990) except on the coast near salt pans. Today most of the trees are gone and much of the area is cultivated either by flood irrigation or by modern pump irrigation.

One positive effect of the human influences is the establishment in some places of a tree vegetation along the edges of the many terraces lining the wadi. However, no vegetation was planted along the terraces in some parts of the Wadi bottom, as these are prone to destruction by large floods which happen once every one to two decades.

1.6 LAND USE

The area with permanent agricultural fields, mostly dominated by pump irrigation, starts from the Hodeidah-Sana'a road, going towards the south of Hodeidah city until Quzaat Aldubal and Alselah villages. The fields consist of rich alluvial soils capable of producing several crops per year under irrigation. Wadi Jahef is particularly favourable for intensive agriculture. It should be noted that this area is now no longer affected by floods (probably due to a higher water use in the upstream parts of the wadi) and hence pumped groundwater is being used increasingly. In fact, the groundwater used for irrigation is saline and has a high concentration of sodium, which imposes a great risk to the soil quality and negatively affects crop yields. For more details on the land use see the land use map in appendix 4.

On regularly irrigated fields, numerous crops are cultivated, including vegetables like tomatoes, beans, watermelon, and other crops such as sesame, cotton, tobacco, maize and different local sorghum species.

The proposed Green Belt area is sparsely inhabited by villagers who live scattered in groups of small huts. All large villages or towns are located outside the study area. Many of their inhabitants commute to Hodeidah for daily paid jobs. It is understood that all existing agricultural land will remain as part of the Green Belt, and will benefit from the development of the Green Belt to protect them from sand encroachment and sand storms.

1.6.1 Main land use type

The three main types of land use found in the study area are :

1. Arable land
2. Grazing land
3. Dune land (unused)

1.6.1.1 Arable farming

The main arable farming areas are located at the southern part of the Green Belt. These areas generally consist of irrigated land cultivated by cereals, vegetables and cotton. Spate or flood irrigation is practised in years of high floods. The dominant size of holdings varies from small to large (5-30 ha) and is owned by local farmers. The smallholder type of agriculture is mainly traditional subsistence farming with very limited production for markets, while the larger landowners either rent out their land to sharecroppers or produce for the market.

1.6.1.2 Grazing land

Grazing land is located on both sides of the wadi Siham valley (north and the south), occupying large part of the study area. It is in general covered by natural grasses and shrubs. After the harvest some of the arable lands are used for grazing, especially around villages.

Camels. goats, sheep and cows can normally be found grazing all over the area. It should be noted that the number of animals living within the Green Belt area is not that much. but large numbers of them are daily brought in from outside this area. These grazing lands are also owned by local farmers.

1.6.1.3 Dunes

The active or mobile dunes occupy a large part of the study area, starting from Al-Baidah at the Hodeidah-Jayzan highway in the north and continuing to the eastern part of the study area, bordered by the Hodeidah-Sana'a highway. In fact two types of dunes can be recognized: longitudinal and barchan dunes. The area covered by these dunes is not suitable for agriculture. Some kind of shrubs and dwarf shrubs grow in the interdune depressions. It is believed that this area used to be a sand plain, but due to deforestation a major part became susceptible to sand displacement. The ensuing intensive sand blowing process lead to the formation of recent mobile dunes. This is a continuous process, resulting in the dunes now encroaching onto urban areas and their infrastructures.

1.6.2 Dominant land utilization types

Land utilization types are a refined kind of land use, with special emphasis on management aspects of the land use, and suitable for land evaluation purposes. The main land utilization types in the study are described below.

1.6.2.1 Irrigated cereals (small sized farms of 2-5 ha)

Irrigated summer cereals (sorghum and millet). grown for about 130 days under gravity irrigation relying on pumped groundwater. Smallholder farms of 2-5 ha owned by one farmer. but some parts may be used for sharecropping (subsistence farming). Family and hired labour work with traditional equipment. There is a limited application of green manure only, and no pesticides are used. Livestock (goat. sheep, cows, and camels) are kept for meat and milk. Oxen are used for traction and donkeys and camels for transportation. Surplus grains from smallholder farms are sold in local markets. The stalks of sorghum and millet are used for fodder, part of it being sold at the farm gate. Cereal yields vary from 0.3 to 0.5 ton/ha. These farms are affected by sand blowing which covers young plants at early stages of growth. Wadi terraces cultivation is much affected by this problem.

1.6.2.2 Irrigated cereals (medium sized farms 10-50 ha)

Crops and their irrigation are similar to those grown on small sized farms. However, medium sized farms are mostly cultivated by sharecroppers, the owner receiving one quarter or one third of the produce. Green manure and pesticides are widely used. Cereal yields are only marginally better than those attained at smallholder farms. Apart from farm management operations, which are mainly done by tractors, hired labour works with traditional equipment. Livestock reared on the farm is sold in local markets (much of it being bought for transport to the cities, including Sana'a). Fodder is also largely sold in local markets.

1.6.2.3 Irrigated vegetables

Limited acreage of irrigated vegetables (e.g. okra, cucumber, pepper, tomato, squash, sweet melon, jew's mallow, cabbage etc.) are grown by most farmers for domestic consumption, but produce from medium sized farms is sold in local markets. The growing period for vegetables is about 7-9 weeks. Also water melon and sweet melon are commonly cultivated in both small and medium sized farms. The farmer sells it direct from the field or in the local market. Pesticides are used in vegetable cultivation.

1.6.2.4 Irrigated cotton and sesame

Irrigated cotton and sesame are found mainly in an areas with medium and large size farms in the downstream part of the alluvial plain. At its present price, cotton is of little interest to the farmers, mainly on account of the excessive variable costs in relation to the value of the crop. Sesame is a crop that is well suited to the irregularly flooded areas, since it requires relatively little water. At present price levels of sesame are acceptable. However, these price are somewhat artificial since the sesame imported by industry is much cheaper, and substitute products (palm oil in particular) are retailed at much lower price.

1.7 WATER RESOURCES

Over the last few years there has been a considerable increase in the use of groundwater. For agriculture this resource was hardly exploited at all in the past.

With regard to water quality, the American "Riverside" water classification provides criteria for assessing the suitability of groundwater for agriculture, based on a combination of the following factors (Appendix 2 provides some information on the water quality in the survey area) :

- Total concentration of soluble salt, measured by electric conductivity (EC).
- Sodium content in relation to calcium and magnesium content.

Water in the wadi Siham plains is the factor limiting agricultural production when rainfed agriculture is practised. In general, where a possibility for irrigation exists, yields are limited by production factors such as crop and soil management and irrigation techniques, and inadequate use of improved seeds, fertilizer and pesticides. Such that the quantities of water to be applied and the state of technical advance of agriculture must be considered as going hand in hand. For this reason, given the low level of farm management in the study area, it is expected that yields will remain much lower in the foreseeable future than those corresponding to the genetic potential of the plants cultivated. Under these conditions, it would be better to spread the scarce water resources over a much wider area of crops, receiving a water allocation considerably lower than what is necessary to compensate for the potential evapotranspiration loss, as a large area with a low yield per ha will still produce more that a smaller area with only a marginally better yield.

1.8 CLIMATE

The Tihama has a tropical arid climate. The mean temperature is very high (30°C) with inconsiderable seasonal fluctuation. Absolute minima and maxima, however, range

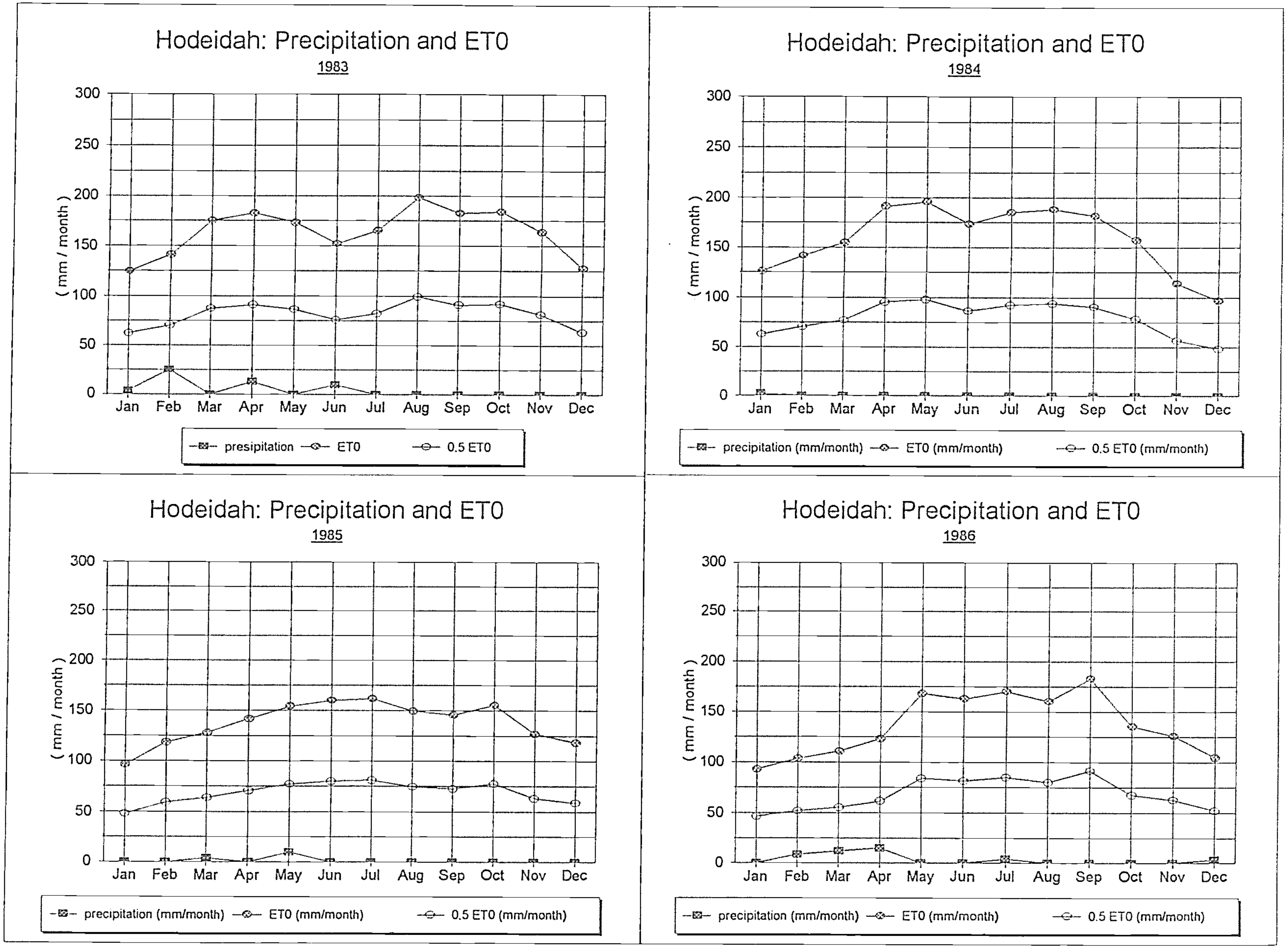
Table 1 Climatic data for Hodeidah (1983-1990)

station	Hodeidah	(Airport)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
latitude	14.76	Tmax (°C)	31.3	31.8	32.8	34.5	37.4	38.2	39.5	37.9	38.1	36.1	32.0	29.8
altitude	11	Tmin (°C)	19.9	22.4	24.2	26.4	27.6	28.4	29.0	28.2	27.0	24.9	19.0	19.9
		RH (%)	72	69	68	72	78	71	73	59	64	63	63	71
year	1983	windrun (km/day)	261.1	188.2	314.9	249.6	226.6	203.5	234.2	199.7	218.9	253.4	368.6	291.8
		sun (hour/day)	8.0	9.0	9.0	10.0	9.0	5.0	6.0	9.0	8.0	10.0	10.0	9.0
		precipitation (mm/month)	3.3	25.0	0.0	12.9	0.0	9.7	0.0	0.0	0.0	0.0	0.0	0.0
		ET0 (mm/month)	124	141	175	183	173	152	165	198	182	184	164	127
		0.5 ET0 (mm/month)	62	71	88	91	87	76	83	99	91	92	82	64
		Tmean (°C)	25.6	27.1	28.5	30.5	32.5	33.3	34.3	33.1	32.6	30.5	25.5	24.9
station	Hodeidah	(Airport)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
latitude	14.76	Tmax (°C)	28.0	28.3	29.3	34.1	33.8	35.1	35.6	34.6	35.2	33.0	30.8	29.9
altitude	11	Tmin (°C)	19.6	19.1	22.6	23.8	27.7	28.3	28.8	28.1	27.3	23.1	20.6	20.1
		RH (%)	75	76	77	74	74	73	72	74	75	77	86	89
year	1984	windrun (km/day)	449.3	614.4	495.4	518.4	549.1	499.2	483.8	414.7	460.8	403.2	433.9	407.0
		sun (hour/day)	8.2	9.3	9.4	10.2	8.7	4.4	5.5	8.6	8.0	9.8	9.7	9.2
		precipitation (mm/month)	2.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		ET0 (mm/month)	126	142	155	191	195	173	185	188	181	157	114	97
		0.5 ET0 (mm/month)	63	71	77	95	98	87	92	94	91	79	57	48
		Tmean (°C)	23.8	23.7	26.0	29.0	30.8	31.7	32.2	31.4	31.3	28.1	25.7	25.0
station	Hodeidah	(Airport)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
latitude	14.76	Tmax (°C)	29.6	29.0	31.3	33.1	34.4	36.8	36.8	37.6	37.1	36.3	32.8	39.8
altitude	11	Tmin (°C)	19.6	20.7	22.6	26.6	27.3	27.8	28.1	28.5	27.0	24.5	23.2	19.2
		RH (%)	88	82	88	88	84	79	80	85	81	77	82	84
year	1985	windrun (km/day)	241.9	361.0	314.9	295.7	241.9	241.9	284.2	238.1	192.0	253.4	257.3	241.9
		sun (hour/day)	8.3	8.2	9.1	8.5	8.7	7.7	7.7	7.2	7.1	9.2	9.4	8.5
		precipitation (mm/month)	0.0	0.0	4.0	0.0	9.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		ET0 (mm/month)	96	118	128	142	154	160	162	150	145	155	127	118
		0.5 ET0 (mm/month)	48	59	64	71	77	80	81	75	73	78	63	59
		Tmean (°C)	24.6	24.9	27.0	29.9	30.9	32.3	32.5	33.1	32.1	30.4	28.0	29.5
station	Hodeidah	(Airport)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
latitude	14.76	Tmax (°C)	27.5	29.6	30.8	33.2	35.2	35.2	38.3	35.6	36.7	34.0	32.5	30.9
altitude	11	Tmin (°C)	18.4	22.4	23.3	25.7	27.5	30.1	29.5	30.5	27.2	24.8	22.6	20.9
		RH (%)	85	90	92	94	83	80	78	79	57	88	83	85
year	1986	windrun (km/day)	368.6	372.5	326.4	337.9	291.8	288.0	295.7	249.6	199.7	238.1	288.0	265.0
		sun (hour/day)	7.2	7.9	7.6	8.1	9.8	7.7	7.2	7.1	7.7	9.7	9.8	8.7
		precipitation (mm/month)	0.0	8.5	12.0	15.0	0.0	0.0	4.0	0.0	0.0	0.0	0.0	3.7
		ET0 (mm/month)	93	104	111	123	168	163	170	160	183	136	126	105
		0.5 ET0 (mm/month)	46	52	55	62	84	82	85	80	92	68	63	52
		Tmean (°C)	23.0	26.0	27.1	29.5	31.4	32.7	33.9	33.1	32.0	29.4	27.6	25.9

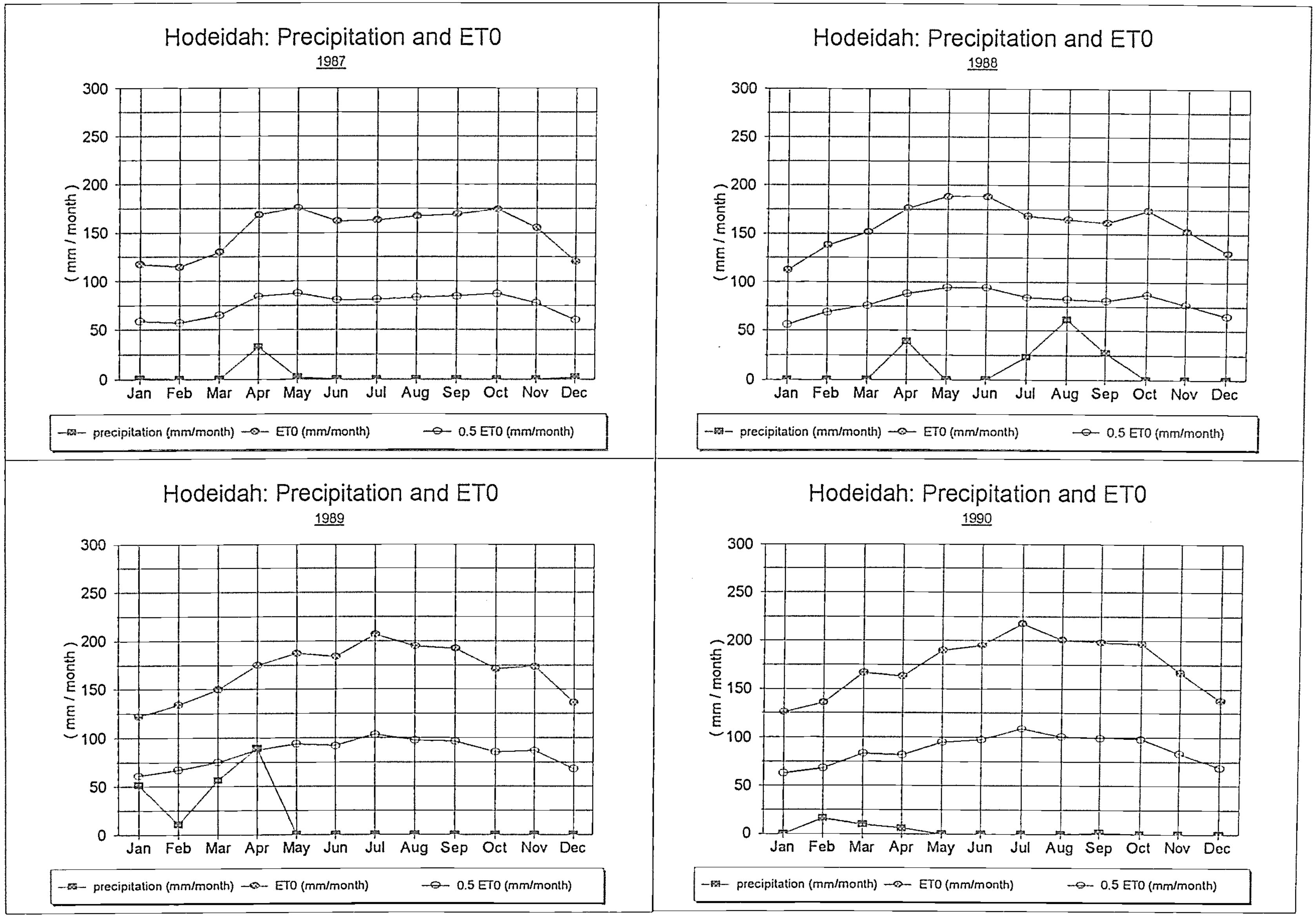
Table 1 Climatic data for Hodeidah (1983-1990)

station	Hodeidah	(Airport)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
latitude	14.76	Tmax (°C)	28.9	29.5	31.6	33.2	34.4	36.0	37.3	37.7	37.4	34.4	31.6	29.6
altitude	11	Tmin (°C)	18.8	20.0	24.6	25.3	27.4	29.0	29.9	29.5	29.1	27.0	21.7	20.0
		RH (%)	81	86	85	78	82	82	83	79	80	76	71	79
year	1987	windrun (km/day)	583.7	576.0	487.7	399.4	844.8	384.0	361.0	357.1	337.9	399.4	399.4	430.1
		sun (hour/day)	8.9	9.1	7.2	9.1	8.8	7.6	7.5	6.6	8.0	9.9	10.0	9.1
		precipitation (mm/month)	0.8	0.0	0.0	32.5	2.0	0.0	0.0	0.0	0.0	0.0	0.0	1.9
		ET0 (mm/month)	117	114	130	168	176	162	163	167	169	174	155	120
		0.5 ET0 (mm/month)	59	57	65	84	88	81	81	84	85	87	78	60
		Tmean (°C)	23.9	24.8	28.1	29.3	30.9	32.5	33.6	33.6	33.3	30.7	26.7	24.8
station	Hodeidah	(Airport)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
latitude	14.76	Tmax (°C)	29.2	30.4	31.4	33.5	35.3	37.5	37.4	36.7	36.5	34.7	31.7	29.2
altitude	11	Tmin (°C)	21.1	23.3	24.6	26.8	27.9	29.9	30.3	29.0	27.9	25.7	21.0	19.3
		RH (%)	81	76	78	78	75	73	71	75	72	69	69	72
year	1988	windrun (km/day)	291.8	337.9	376.3	422.4	303.4	253.4	272.6	280.3	241.9	288.0	357.1	353.3
		sun (hour/day)	8.6	8.0	8.3	9.4	10.1	9.0	5.4	6.4	6.6	9.5	9.7	9.5
		precipitation (mm/month)	0.0	0.0	0.0	39.0	0.0	0.0	23.3	61.4	27.5	0.0	0.0	0.0
		ET0 (mm/month)	112	138	151	176	188	188	168	165	161	174	153	130
		0.5 ET0 (mm/month)	56	69	76	88	94	94	84	82	81	87	76	65
		Tmean (°C)	25.2	26.9	28.0	30.2	31.6	33.7	33.9	32.9	32.2	30.2	26.4	24.3
station	Hodeidah	(Airport)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
latitude	14.76	Tmax (°C)	28.7	28.8	29.8	31.6	34.3	35.6	37.0	37.0	37.5	34.7	32.3	30.7
altitude	11	Tmin (°C)	21.0	21.8	22.4	24.5	26.8	28.1	29.2	28.7	27.6	25.4	21.8	21.1
		RH (%)	75	74	73	72	74	71	63	65	65	68	63	71
year	1989	windrun (km/day)	280.3	303.4	368.6	380.2	299.5	307.2	314.9	291.8	280.3	276.5	380.2	353.3
		sun (hour/day)	8.9	8.3	7.6	8.9	10.5	8.2	7.8	7.4	8.0	9.0	9.9	8.5
		precipitation (mm/month)	51.4	10.5	56.4	89.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		ET0 (mm/month)	122	134	150	175	187	184	207	195	192	171	173	136
		0.5 ET0 (mm/month)	61	67	75	87	94	92	103	97	96	85	87	68
		Tmean (°C)	24.9	25.3	26.1	28.1	30.6	31.9	33.1	32.9	32.6	30.1	27.1	25.9
station	Hodeidah	(Airport)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
latitude	14.76	Tmax (°C)	30.4	30.4	31.9	33.6	35.5	36.9	37.6	37.3	37.0	35.4	32.8	31.3
altitude	11	Tmin (°C)	21.3	23.5	24.3	25.1	27.0	28.1	28.7	28.6	27.3	24.4	21.5	19.8
		RH (%)	74	69	68	77	72	71	64	66	67	63	67	74
year	1990	windrun (km/day)	349.4	272.6	357.1	368.6	349.4	326.4	384.0	314.9	314.9	349.4	395.5	460.8
		sun (hour/day)	7.0	6.0	7.0	8.0	9.0	9.0	8.0	8.0	9.0	10.0	10.0	9.0
		precipitation (mm/month)	0.0	16.3	9.9	5.8	0.0	0.0	0.0	0.0	1.6	0.0	0.0	0.0
		ET0 (mm/month)	126	136	167	163	190	195	218	201	198	197	167	138
		0.5 ET0 (mm/month)	63	68	83	81	95	97	109	101	99	98	83	69
		Tmean (°C)	25.9	27.0	28.1	29.4	31.3	32.5	33.2	33.0	32.2	29.9	27.2	25.6

Fig. 3 Hodeidah : Precipitation and evapotranspiration graphs 1983 - 1986



Hodeidah : Precipitation and evapotranspiration graphs 1987 - 1990



between below 20°C (rarely) in winter to over 40°C in summer. Rainfall is very inconsistent in time and space. The entire region is under the influence of the monsoon, which brings summer rain with cloudbursts, mainly in July and August. Rainfall during the winter season is very rare.

The total amount of precipitation is usually less than 200 mm. The average annual air humidity is about 70%, but can be as much as 90% and more at night and dew is very common. Winds generally blow from south-west or north-west, sometimes at high speed, causing sand movement and deflation, especially on cultivated fields. Table 1 provides the climatic data for Hodeidah airport (1983-1990), which can be considered representative for the survey area.

1.8.1 Rainfall in the Tihama

Yemen as a whole is characterized by very intense showers, but the highest intensities are experienced in the Tihama. Within the Tihama itself, rainfall is very rare along the desert-like coast and increases both in frequency and intensity towards the interior.

The inhabitants of the Tihama have developed the cultivable land in such a way as to derive the greatest possible benefit from this precipitation. In the upper area of the coastal zone fields are designed to trap rainwater which can not infiltrate as fast as it falls, thus preventing it from running off downstream.

In the sandy part of Tihama, the sand dunes are sown after each heavy shower and infiltration water, held within the sand, the dry surface of which became impermeable, is sufficient for millet to grown. If, by stroke of luck, two or three heavy showers occur soon afterward then the millet may ripen and provide a grain harvest. This happens about once every 3 or 4 years. Otherwise the crop will still be useful as fodder.

1.8.2 Rainfall distribution

Figure 3 displays the variation in annual rainfall. It can be seen that the Hodeidah area in fact exhibits one rainfall pattern. Along the coastal strip there is a desert climate with an annual rainfall of less than 50 mm falling in the form of 5 or 6 showers per year. Every year, on average there is one shower exceeding 20 mm. According to the available records, a heavy shower of 89 mm capable of effectively irrigating the soil occurred only once in the year 1989. This zone cannot be cultivated using rainwater alone. For this reason, this zone requires complementary irrigation by floodwater or from wells in order to make up for the deficiency and irregularity of the precipitation.

It should be added that the spring rains represent the maximum percentage as average throughout 8 years. In other words, there is almost certain to be a shower of at least 25 mm in spring.

The Hodeidah airport station series, which includes recorded values taken over a period of 8 years (1983 - 1990), indicates that the low rainfall of the coastal strip remains valid in the Hodeidah area. The length of the series is obviously too short for a precise appreciation of average rainfall at this measuring station, but it can well be seen that there is an overall consistency. Hence this rainfall pattern is identical in the whole of the study area. The mean monthly rainfall has been plotted in figure 4.

To show more detail with respect to aridity, a classification proposed by UNESCO 1979 can be used. It is based on the ratio between average annual precipitation (P) and annual potential evaporation (Eo) and in principle distinguishes five different classes :

Hyper-arid	P/Eo <0.03
Arid	0.03< P/Eo <0.25
Semi-arid	0.25< P/Eo <0.50
Sub-humid	0.50 <P/Eo <0.75
Humid	P/Eo >0.75

According to this classification, the study area falls in the arid class. For more details see figure 5.

1.8.3 Temperature

Average temperature are dominantly high as shown in table 2 (29.2-37.4°C). The annual range in temperature (i.e. the difference between the average temperatures of the summer and winter) is fairly constant, as it is only 7-9°C (see table 1) in the coastal zone in which Al-Hodeidah is situated. The proximity to the sea and the moisture content of the air are the controlling factors. Average minimum temperatures vary between 20°C in December and January, and 37.4°C in July.

1.8.4 Evapotranspiration

The theoretical water balance established using the figures from Hodeidah airport (figure 4) uses 3 curves representing the monthly mean rainfall in mm, the potential evapotranspiration and a value equal to half the potential evapotranspiration (calculated by using the Penman method). It is conventionally assumed that plants are in vegetative activity when rainfall equals or exceeds ETp/2. From this graph it may be seen that the rainfall is always considerably less than half the potential evapotranspiration. This situation is characteristic of a dry tropical climate.

1.8.6 Other directly observed meteorological parameters

Important meteorological variables other than precipitation and temperature, observed at the meteorological station at Al-Hodeidah airport include the following (average monthly data and average annual totals are listed in table 2):

- Sunshine duration
- Relative humidity
- Wind velocity.

Comparison between records and impressions from field visits indicate that the accuracy and reliability of these meteorological data may be questionable for part of the records.

Table 2 Average climatic data for Hodeidah (8 years)

station	Hodeidah	(Airport)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
latitude	14.76	Tmax (°C)	29.2	29.7	31.1	33.4	35.0	36.4	37.4	36.8	36.9	34.8	32.1	31.4
altitude	11	Tmin (°C)	20.0	21.7	23.6	25.5	27.4	28.7	29.2	28.9	27.6	25.0	21.4	20.0
		RH (%)	79	78	79	79	78	75	73	73	70	73	73	78
year	avg. 83-90	windrun (km/day)	353.3	378.3	380.2	371.5	388.3	313.0	328.8	293.3	280.8	307.7	360.0	350.4
		sun (hour/day)	8.1	8.2	8.2	9.0	9.3	7.3	6.9	7.5	7.8	9.6	9.8	8.9
		precipitation (mm/month)	7.2	7.5	10.3	24.3	1.5	1.2	3.4	7.7	3.6	0.0	0.0	0.7
		ET0 (mm/month)	115	128	146	165	179	172	180	178	177	169	147	121
		0.5 ET0 (mm/month)	57	64	73	83	90	86	90	89	88	84	74	61
		Tmean (°C)	24.6	25.7	27.3	29.4	31.2	32.6	33.3	32.8	32.2	29.9	26.7	25.7

Fig. 4

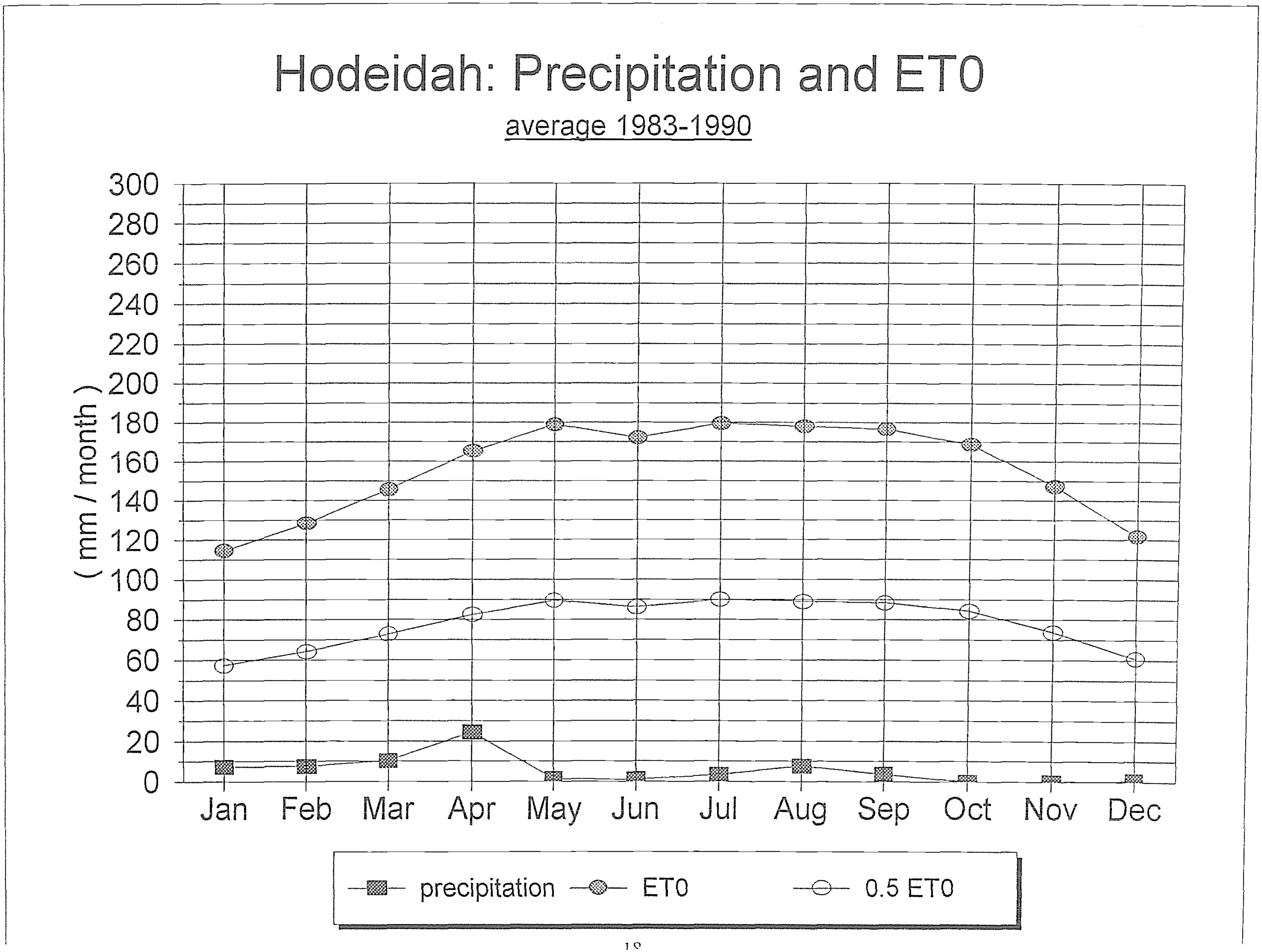
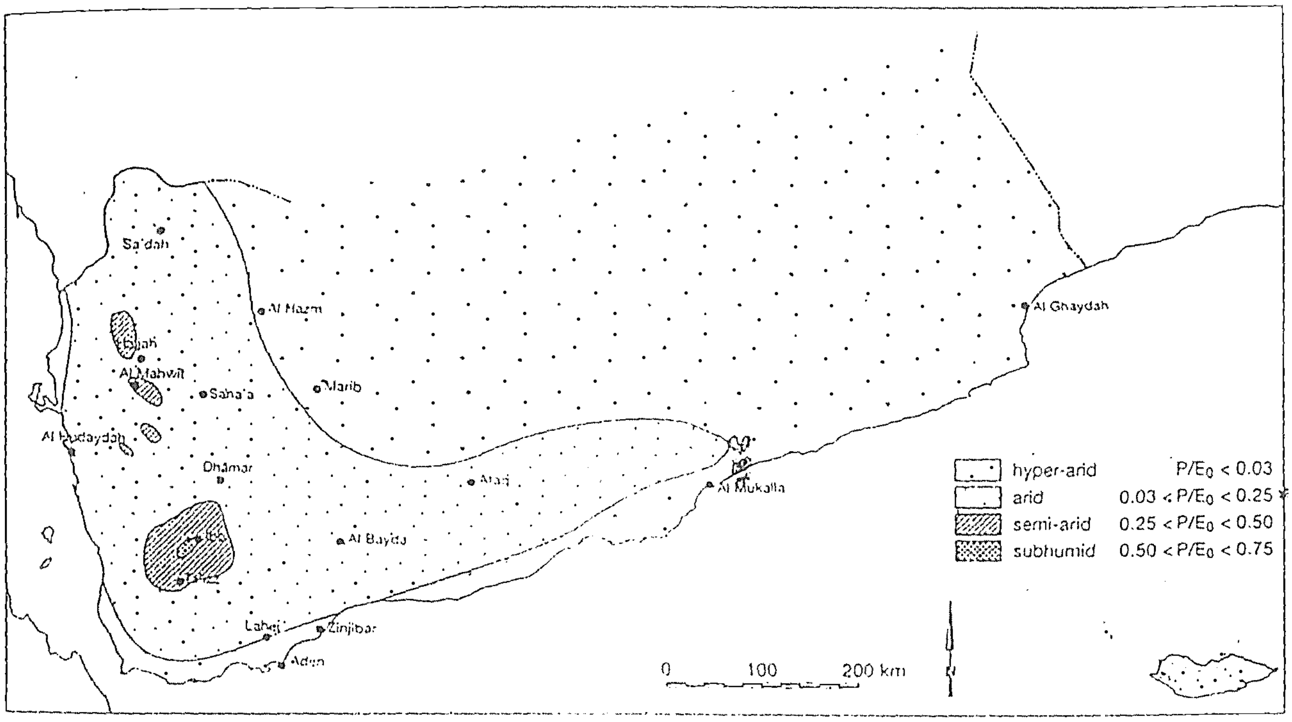

Hodeidah: Precipitation and ET0
average 1983-1990
300
280
260
240
220
200
180
160
140
120
100
80
60
40
20
0
(mm / month)
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
precipitation
ET0
0.5 ET0

FIG. 5   CLIMATIC ZONES IN YEMEN



Source: The Water Resource of Yemen (1995) Report WRAY-35

Careful quality assessment is certainly needed, but this is beyond the scope of this report. Relative humidity data are perhaps the most suspect data in this respect, because calibration and processing is more difficult for these than for other data types. Although in general data recorded at a station are not necessarily representative for its wider surroundings, this is not the case in the Hodeidah area where relief is rather subdued.

Clear skies are the norm in the Tihama during most of the year. This is reflected in the records of sunshine duration, which on average vary between 7 and 9 hours per day, corresponding to 50 to 75 % of the theoretical maximum. Absence of sunshine during daytime is not only caused by clouds, but mountains may also shorten sunshine duration because of the shadows they produce after sunrise and before sunset, although this does not apply to the survey area.

The relative humidity varies between 70 and 80 % for the coastal plain.

Average wind speed is generally strong along the coast. The annual average values range between 307 and 388 km/day. It is believed that part of the difference in the survey area has to be attributed to effects from sand dunes (it has not been verified whether the wind speed at Hodeidah airport has been measured at the standard height of 2 m above surface). When are

Chapter 2 METHODS

2.1 PHOTOINTERPRETATION

Aerial photographs, scale 1:60,000 (1973) and topographic maps (1:50,000) were used during the survey. By examining aerial photographs, it was possible to establish a preliminary definition of landform, broad categories of vegetation, cultivated areas and to prepare a preliminary outline of the physiographic units based on common characteristics.

During fieldwork a final working legend was developed, as the boundaries of the mapping units were checked and progressively refined by API. The soil map, land use map, vegetation map and physiographic map were completed after final interpretation of the aerial photographs and compilation of mapping units on 1:50,000 topographic base map. Several reports on the soils and other physical features related to agricultural development of the Tihama coastal plain were consulted.

2.2 FIELDWORK

As a preliminary step in establishing a soil working legend, a rapid reconnaissance survey was made together with some auger checking to identify the main soil types. Based on this some areas were then selected from aerial photographs, and further ground observations were carried out at semi-detailed level to establish the pattern of soil distribution. The main soil types were characterized by profile pits. The described profiles were subsequently used to characterize each of the mapping units, with one or more soil pits being opened depending on the complexity of the soil pattern .

The actual fieldwork was completed after one and half month, excluding the time spent on a complementary study of soil characteristics. Profiles were examined, where possible, to a depth of 120 to 150 cm. Each observation includes a description of the site (parent material, landform, vegetation, land use), general information on the soil (drainage, depth, stoniness, erosion, human interference) and soil morphology. Water samples were collected from water pumped for irrigation throughout the area for analysis to determine their suitability class for irrigation.

Vegetation and land use studies were based on the preliminary photo interpretation and later on supported by field investigations. Previous studies were consulted and verified by the field identification.

2.3 LABORATORY ANALYSIS METHODS

All samples collected in the field were analyzed at the Dhamar laboratory of the ...ntly established Renewable Natural Resources Research Centre, where the analyses were ...d out under supervision of Dr. A.E. Fadl, the soil chemist of FAO's Environmental ...e Assessment for Rural Land Use Planning project. The methods used are listed in ... 3.

Chapter 3 SOILS

3.1 ORIGIN OF THE SOIL

The Tihama is mainly a region of deposition, starting with gravels and stones near the foothills and ending with fine sands and silts near the coast. As stated before, three main deposits can be identified in the coastal plain :

a. Alluvial (wadi Siham)
b. Aeolian
c. Fluvio-Marine

The soils derived from these deposits are generally little developed, due to the extremely dry climate and the short development period for the recent deposits. With the exception of the soils of the old wadi terraces, these soil are deep and somewhat compacted with a pH of between 8 and 9. They contain little organic matter and nitrogen and low to very low amounts of phosphorus, but plenty of potassium. All the soils are moderately to strongly calcareous, but the calcium carbonate content does generally not exceed 10%. They are generally well drained, but locally layers of fine elements (loam and clay) slow down infiltration. The material transported by wadi Siham, which covers part of the study area, varies considerably. In the alluvial plain along wadi Siham, it is clear from the deeply incised valleys of the wadi and its tributaries that the substratum is stony in nature. Sometimes even up to the surface the loamy cover is absent.

In this alluvial plain, the deposits are much finer in texture (loam) than in the accumulation plain which stretches to the edge of the Red Sea. The aeolian sand deposits form vast expanses on the north side of the alluvial plain. They have formed a round longitudinal and barchan dune network. These consolidated dunes date from an arid villafranchian period (Sogreah 1981). It became separated by the alluvial deposits of wadi Siham during the pluvial period at the beginning of the Quaternary.

These dunes are elongated sand hills to the north of study area, the hills often being 14.5 km long. Further on these bars become incoherent and form a vast dune field, partially fixed between Al-Baydah and km 16. The large number of these shifting dunes has restricted agricultural development. In the area of marine deposits, saline soils with a noticeable content of chlorides and sulphates of sodium dominate. They only bear a sparse vegetation cover, when they are topped by thin sand layers. On fluviatile and aeolian deposits we find a predominance of sandy and silty soils with a very low humus content (0.5-1.0 %) and almost no differentiation into strata. Dunes and mobile sands play important role for the vegetation though they are not true soils. So we may distinguish three major types of natural environments in the study area. distributed in a fairly regular pattern (see cross sections in appendix 4). This subdivision of the study area forms the basis of the legend of the 1:50,000 soil map, given at the end of this report (appendix 4).

1. The marine salt flats near the sea (alluvio-marine),
2. Aeolian sand deposits (dune land area)
3. Alluvial plain within the wadi systems.

3.2 SOIL PROFILE CHARACTERISTIC AND PROCESSES

The alluvial deposits, derived principally from wadi Siham, frequently show little indication of pedogenetic development. Where profile modification is evident, it is expressed as an A horizon overlying a Cambic B horizon. The aeolian deposits are common on the north and north-east of Hodeidah where there are elongated sand hills which occupy much of the land. Profile observations in the aeolian deposits were done in between the dunes. An Ochric A horizon occurs over a Cambic B horizon and in some part over the nodules of calcium carbonate of the substratum underlying the dunes. It should be noted that in a dry state hardened layers are very common in this area due to the presence of calcium carbonate and silt deposits which, upon drying, can become very compact and hard. These layers continue to a depth of 60-80 cm.

The alluvio-marine deposits are found in the northern and southern part of study area where the profiles show the presence of a Calcic B horizon and the shells throughout the profiles. In general, more recent sedimentation is reflected in increasing heterogeneity and stratification.

3.2.1 Soil texture and stratification

The soils of the alluvial deposits along wadi Jahef (wadi Siham tributary) starting from Al-Za'afaran extending to Quza'at-Aldupal towards Al-Mashaqenah in the west, show relatively little variation in texture. The silt + clay fraction is generally higher than 60% and the sand fraction is predominantly very fine and fine (see analytical data in Appendix 1). The main textural classes are loam, silt loam, clay loam and silty clay loam. Sedimentary stratification is not a prominent feature in the majority of soils.

Irrigation practices based on flood control and the diversion of flood waters have contributed to texture properties over the years. In regularly flood irrigated land, particularly towards the head of the valley terraces south of wadi Jahef (mapping unit W112) and east of Al-Dupal village, the soils are fine textured with a silt + clay content normally exceeding 90 % (profile HUE012). The soils are derived largely from sediments carried by spate flows. Further the soils north of wadi Jahef, starting from Al-Guraibah towards Al-Sharff villages and extending to the Hodeidah-Sana'a main road, are predominantly medium to coarse textured (profiles HUE020, HUE021, HUE022, HUE024). At a more detailed level, the finest textured soils are often restricted to the lowest-lying positions within individual fields. Apart from the finest sediments settling out in these depressed areas, the breaching of bunds at these low points, allowing irrigation water to pass to adjacent fields, is followed by the removal of surface soil during their repair resulting in the exposure of a finer textured subsoil. Other minor textural variations are occasionally found adjacent to irrigation channels where coarse material (sand or loamy sand) has accumulated as a thin surface deposit.

East of Quza'at Al-Dupal villages (unit W112 of alluvial terraces) borders the course of the incised wadi bed (profile HUE025, wadi Jahef terraces). Intermittent flooding and deposition, which at present affects only the lowest terrace level, have produced stratified soil profiles usually marked by contrasting layers of coarse and medium textures (profile HUE024, Al-Graibah village). This profile is characteristic of soils which can be described as levee soils. These medium textured profiles are frequently inter-stratified with gravel layers (HUE024). The bed of wadi Jahef is composed of subrounded gravel, stones or boulders but going westwards there is an increasing proportion of medium and coarse sand. The alluvial plain, bordered to the north and south by aeolian deposits of fine sand, has been subject, during historical times, to natural deposition. The distribution of sediments and their variability are related to past changes in the course of wadi Siham.

Soil showing very weak textural contrast or stratification compared with those elsewhere on the alluvial plain occur within three areas, straddled by the Hodeidah-Sana'a highway south of Al-Oga village, north of Al-Sharaf village and Quza'at Al-Dupal towards Al-Sela'a village. The uniform sandy loam profiles, as represented by profiles HUD052, HUD053, HUD051, HUE020, HUE022, HUE026, HUD055, have a distinctive particle size distribution with low (< 30%) silt contents. Very similar material occurs at depth in several profiles (e.g. HUE023, HUX025) and is probably the oldest alluvium exposed in wadi Siham.

The plains are affected throughout the year by the encroachment and redistribution of aeolian sand. Apart from the period between April/May and August/September, when the prevailing wind is from the N-NW, the principal direction of movement is from S-SW. Over-blown deposits of loose fine sand, loamy fine sand or occasionally fine sandy loam are prevalent immediately east of the Hodeidah-Jayzan highway and south and south east of the Hodeidah-Sana'a highway (HUD052, HUD051, HUD050), but are progressively less common towards the second water pumping station (Al-Baidah). Here high dunes stabilized by some vegetation constitute a microrelief of aeolian hummocks scattered over the alluvio-marine deposits in the south towards the sea, where the soils have developed within alluvio-marine sediments, probably originally deposited in the coastal salt flat. Texture is predominantly medium and fine (HUE029, HUE027), although an extensive area has been modified by sand encroachment from shore line deposits resulting in a superficial cover of variable thickness partially stabilized by *Odyssea* species.

3.2.2 Depth

The effective depth of most soils exceeds 250 cm as indicated by cuts and by auger borings within the survey area. Deposits of gravel or stones probably underlie the alluvial deposits, frequently occurring within 2 meters of the surface at Al-Guraiba village (HUE024). The majority of soils fringing the upper reaches of wadi Jahef have a nodular or massive carbonate horizon within 1 meter of the surface near Al Mashaqenah (profile HUE026). Nodular carbonate concretions occur at depth in other soils, usually within a uniform matrix of fine sandy loam (profiles HUD050, HUD051), located east of Jayzan road, and north and north-west of wadi Jahef (profile HUE028) in the alluvial plain.

3.2.3 Colour

Pedogenic processes which modify soil colour are weakly expressed in wadi Jahaf as a result of the arid climate and the recent deposition of much of the alluvial sediment. Colour generally reflects that of the parent material in the absence of a well developed B horizon and any significant accumulation of organic matter. Light yellowish brown (Munsell notation 10YR 6/4, dry) to dark yellowish brown (10YR 4/4, moist) colours are usual throughout the profile without any marked variation with change in the texture.

Free carbonate is evident in the finer textured layers of alluvial plain soils as white pseudomycelia occurring below the surface horizon, but this contributes to the matrix colours of the soil only in cases where it has formed a continuous impregnation of the soil mass, usually associated with nodules or weak cementation, giving a very pale brown (10YR 7/3, dry) to yellowish brown (10YR 5/4, moist) colour. A dark brown (10YR 4/3 to 10YR 3/3) horizon is occasionally found overlying a zone of carbonate accumulation.

Concentrations of iron oxides, principally magnetite derived from weathered basic igneous rocks of the catchment, probably cause the darkening of these horizons and are also found as scattered deposits of black volcanic beach sand along the coast. Soil mottling is uncommon, being restricted to occasionally rusty inter-lamella mottling in fine textured horizons with slightly impeded vertical permeability, in stratified soils and to gley and oxidation mottles in soils with a high water table near the coast.

3.3 TAXONOMIC SOIL CLASSIFICATION OF THE STUDY AREA

The soils are classified according to the Soil Taxonomy and the Legend of the FAO-Unesco Soil Map of the World (1988). However, the available soil analytical data are insufficient to proper classify the soils down to Soil Taxonomy family level. The very fine sand fraction is essential to determine the textural class correctly, and also mineralogical data have not been determined. Therefore, the family level classifications given in the soil profile descriptions (see Appendix 1) should be considered provisional and is not included in the soil legend.

To classify soils according to Soil Taxonomy, estimates of the climate regime are necessary. The available climatic data indicate that the soil moisture regime is aridic and the soil temperature regime is isohyperthermic, with a mean annual soil temperature >28°C and the difference of mean summer and winter soil temperature being more than 5°C (Rhebergen and van Waveren, 1990).

The following Soil Taxonomy subgroups and equivalent FAO soil units occur in the survey area :

Typic Torripsamment	- Calcaric Arenosol
Typic Torrifluvent	- Calcaric Fluvisol
Typic Torriorthent	- Calcaric Regosol
Typic Haplargid	- Haplic Luvisol
Typic Haplocalcid	- Calcaric Calcisol

3.3.1 Diagnostic horizons

Cambic horizon : recognized on basis of structural development rather than on colour. In the stratified alluvial deposits colour is a geogenetic phenomenon rather than pedogenetic.

Calcic horizon : in the survey area calcic horizons are found as light coloured bands with nodules and/or soft powdery lime occurrences.

Ochric horizon : generally weakly developed surface horizons which have low organic carbon contents, light colours, and often weak structures. It should be noted that according to the definition the finely stratified materials as found in basin irrigation areas do not qualify as Ochric horizon (such topsoil layers, not yet affected by soil-forming processes, lack the properties of any diagnostic horizon and are therefore considered C material).

The most common soil orders in the study area are the Entisols and Aridisols. There is some variation, primarily in a north-south relationship, in soil characteristics such as texture and carbonate content. In the legend soils are named by the predominant soil order. Each of these predominant soil orders is described below.

3.3.2 Entisols

Most soil in the study area are either subject to constant erosion and or deposition processes by wind and water or are the product of recent deposition with the result that strongly expressed profile development is rare. The dominant soil order is therefore the Entisols, which generally speaking are young undeveloped soils. Entisols are strongly influenced by alluvial or loessal calcareous silt parent materials, but on the plains where sand has accumulated in dunes, Psamments are common.

Orthents : Dominant in the most arid areas where organic matter decreases in a uniform manner with depth.

Fluvents : The most common soils of the alluvial terraces along Wadi Siham, but also in the south the study area where they occur together with the most extensive calciorthids.

Psamments : Soils formed in sandy material. In aeolian material (duneland) soil formation is often minimal due to the absence of vegetation and unstable nature of the sand.

3.3.3 Aridisols

In arid regions characterized by a stable surface, calcic horizons have developed so the soils are classified as calcids. Cambic horizon were observed in some soils and these have been classified as cambids.

3.3.4 Soil moisture regime

The importance of the soil moisture regime, which ranges from aridic to udic, are apparent to anyone with any practical agricultural experience in Yemen. The predominant soil moisture regime is usually given in the soil family name. The moisture regime are defined in terms of the groundwater level and in terms of the presence or absence of water held at a tension < 15 bars in the moisture control section by periods of the year. It is assumed in the definition that the soil supports whatever vegetation it is capable of supporting. In other words, it can be crops, grasses, or native vegetation. It is not being fallowed to increase the amount of stored moisture, nor is it being irrigated by man, as such cultural practices affect the soil moisture condition.

In the survey area, the prevailing soil moisture regime is aridic or torric (these terms are used for the same moisture regime but in different categories of the taxonomy). According to the Soil Taxonomy (1975), the aridic (torric) moisture regime is characterised as follows :

1. Dry in all parts more than half the time (cumulative) that the soil temperature at a depth of 50 cm is above 5°C and,
2. Never moist in some or all parts for as long as 90 consecutive days when the soil temperature at a depth of 50 cm is above 8°C.

Soils that have an aridic or torric moisture regime are normally in arid climates. A few are in semi-arid climates and either have physical properties that keep them dry, such as crusty surface that virtually precludes infiltration of water. There is little or no leaching in this moisture regime, and soluble salts accumulate in the soil if there is source of them.

3.3.5 Soil temperature regime

The importance of the soil temperature regime designation may not be as immediately evident as that of the soil moisture designation. This does not in any way, however, diminish its importance for agricultural planning. If the name of a soil temperature regime has the prefix "iso", the mean summer and winter soil temperature for June, July and August and for December, January, and February differ by less than 5°C at a depth of 50 cm.

The following description of the isohyperthermic soil temperature regime, which represent the study area, is taken verbatim from Soil Taxonomy 1975.

The mean annual soil temperature regime is 22°C or higher, and the difference between the mean winter and summer temperatures is less than or equal to 5°C

3.4 THE SOIL MAP

3.4.1 The soil legend

The legend to the soil map is given in tabular form. A more extensive description of each soil unit is given in the next section. The structure of the soil legend is hierarchical and consists of four levels. The soil information at the lowest level is comparable to that of the Soil Taxonomy family level. The four levels are:

1. Major landscape
2. Lithology
3. Relief
4. Landform

The soil units are identified by a four digit code following the same hierarchical system. The first character gives the major landscape. In this case C stands for coastal plain and W represents the Alluvial plain. The next three numbers give the lithology, relief and landform. The type of mapping units consists of undifferentiated groups, complexes, and consociations of two to four soil units, which can not be mapped separately at 1:50.000 scale.

The soil map legend was defined on the basis of soil genesis concepts and field survey principles discussed previously in this chapter, and the Soil Taxonomy (USDA-SCS, 1975) was used for soil classification. It was decided to divide the legend into nine parts based on the landscape, lithology, relief, landform, geomorphology and the predominant feature of each of the individual map units. Table 4 shows the legend with the main characteristics of each mapping unit.

Individual soil profiles are classified to the family level (Appendix 1). Twelve mapping units were identified based on their soil characteristics and physiographic characteristics of the dominant features in each unit.

The map at scale 1:50,000 was used to determine the approximate areas of the different mapping units classified at sub-group level. The calculation was made using a planimeter, and the results are shown in table 3. The total survey area amounts to about 15,195 ha. The percentage of total area of each mapping unit is given in the legend. The profiles representing the various mapping units are indicated in the legend by their profile codes. Full description of these profiles along with laboratory data are given in Appendix 1.

Table 3 Area measurement of soil mapping units.

	Soil mapping units	Area (ha)
1	C111	2622.5
2	C122	1017.5
3	C133	3375.0
4	C144	537.5
5	C211	657.5
6	C212	680.0
7	C221	760.0
8	C222	1002.5
9	C223	1412.5
10	W111	1447.5
11	W112	1440.0
12	wadi-bed	242.0
Total		15,194.5

Two cross sections (AB and CD), representing the various landscape features are shown in the soil map. The first one starts from a point in the sea west of the Jayzan road to Al-Oga village in the east. The second one shows the different features from a point in the sea west of Al-Manzar village to Al-Za'afaran village in the east. For more details refer to the soil map in Appendix 4.

Chapter 4 LAND SUITABILITY CLASSIFICATION

4.1 GENERAL

Land suitability is the fitness of a given type of land for a defined use. The land may be considered in its present condition or after improvements. The process of land suitability classification is the appraisal and grouping of specific areas of land in terms of their suitability for defined uses.

There may be certain parts of the area considered, for which particular kinds of use are not relevant, e.g. irrigated agriculture beyond the limit of water availability. In these circumstances, suitability need not be assessed. Such parts are shown on maps or tables by the symbol NR: Not Relevant.

4.1.1 STRUCTURE OF THE SUITABILITY CLASSIFICATION

The framework of suitability classification has a uniform structure, i.e. it recognizes similar suitability categories in all kinds of interpretative classification (see below). Thus, each category retains its basic meaning within the context of the different classifications and as applied to different kinds of land use. Four categories of decreasing generalization are recognized :

i. Land Suitability Order: reflecting kinds of suitability.
ii. Land Suitability Class: reflecting degrees of suitability within orders.
iii. Land Suitability Subclass: reflecting kinds of limitation, or main kinds of improvement measures required, within classes.
iv. Land Suitability Units: reflecting minor differences in required management within subclasses .

4.1.1.1 Land suitability orders

Land suitability orders indicate whether land is assessed as suitable or not suitable for the use under consideration. There are two orders, represented by the symbols S and N respectively.

Order S (Suitable): Land on which sustained use of the kind under consideration is expected to yield benefits which justify the inputs, without unacceptable risk of damage to natural resources.

Order N (Non-suitable): Land which has qualities that appear to preclude sustained use of the kind under consideration. Land may be classed as Not Suitable for a given use for a number of reasons. It may be that the proposed use is technically impracticable, such as the irrigation of rocky steep land, or that it would cause severe environmental degradation, such as the cultivation on steep slopes. Frequently, however, the reason is economic: that the value of the expected benefits does not justify the expected costs of the inputs that would be required.

4.1.1.2 Land suitability classes

Land suitability classes reflect degrees of suitability. The classes are numbered consecutively, by arabic numbers, in sequence of decreasing degrees of suitability within the order. Within order S the number of classes is not specified. There might, for example, be only two, S1 and S2. However, the number of classes recognized should be kept to the minimum necessary to meet interpretative aims. In general, five classes should probably be the most ever used. If three classes are recognized, as can often be recommended, the following names and definitions may be appropriate in a qualitative classification:

S1 Highly suitable: Land having no significant limitations to sustained application of a given use, or only minor limitations that will not significantly reduce productivity or benefits and will not raise inputs above an acceptable level.

S2 Moderately suitable: Land having limitations which in aggregate are moderately severe for sustained application of a given use; the limitation will reduce productivity or benefits and increase required inputs to the extent that the overall advantage to be gained from the use, although still attractive, will be appreciably inferior to that expected on class S1 land.

S3 Marginally suitable: Land having limitations which in aggregate are severe for sustained application of a given use and will so reduce productivity or benefits, or increase required inputs, that this expenditure will be only marginally justified.

In a quantitative classification, both inputs and benefits must be expressed in common measurable terms, normally economic. In different circumstances different variables may express most clearly the degree of suitability, e.g. the range of expected net income per unit area or per standard management unit, or the net return per unit or irrigation water applied to different types of land or a given use. Where additional refinement is necessary it is recommended that this should be achieved by adding classes, e.g. S4, and not by subdividing classes, since the latter procedure would contradict the principle that degrees of suitability are represented by only one level of the classification structure, that of the suitability class. This necessarily changes the meanings of class numbers, e.g. if four classes were employed for classifying land with respect to arable use and only three with respect to forestry, Marginally Suitable could refer to S4 in the former case but S3 in the latter.

An alternative practice has been adopted in some countries. In order to give a constant numbering to the lowest suitable class, classes have been subdivided as, e.g. S2.1, S2.2. This practice is permitted within the Framework, although for the reason given in the preceding paragraph it is not recommended. Suitability class S1, Highly Suitable, may sometimes not appear on a map of a limited area, but could still be included in the classification if such land is known or believed to occur in other areas relevant to the study.

Differences in degrees of suitability are determined mainly by the relationship between benefits and inputs. The benefits may consist of goods, e.g. crops, livestock products or timber, or services, e.g. recreational facilities. The inputs needed to obtain such benefits comprise such things as capital investment, labour, fertilizers and power. Thus an area of land might be classed as Highly Suitable for rainfed agriculture, because the value of crops produced substantially exceeds the costs of farming, but only Marginally Suitable for forestry, on grounds that the value of only slightly exceeds the costs of obtaining it.

It should be expected that boundaries between suitability classes will need renewal and revision with time in the light of technical development and economic and social change. Within the order Non-Suitable, there are normally two classes:

N1 Currently Not Suitable: Land having limitations which may be surmountable in time but which can not be corrected with existing knowledge and/or at currently acceptable costs; the limitation are so severe as to preclude successful sustained use the land in the given manner.

N2 Permanently Not Suitable: Land having limitations which appear so severe as to preclude any possibilities of successful sustained use of the land in the given manner.

Quantitative definition of these classes is normally unnecessary, since by definition both are uneconomic for the given use. The upper limit of class N1 is already defined by the lower limit of the least suitable class in Order S. The boundary of class N2, permanently Not Suitable, is normally physical and permanent. In contrast, the boundary between the two orders, Suitable and Not Suitable is likely to be variable over time through changes in the economic and social context.

4.1.1.3 Land suitability subclasses

Land suitability Subclasses reflect kinds of limitation, e.g. moisture deficiency, erosion hazard, etc. Subclasses are indicated by lower-case letters with a mnemonic significance, e.g. S2m, S2e, S3me. There are no subclasses in class S1. The number of subclasses recognized and the limitations chosen to distinguish them will differ in classifications for different purposes. There are two guidelines:

- The number of subclasses should be kept to the minimum necessary to satisfactorily distinguish lands within a class likely to differ significantly in their management requirements or potential for improvement due to differing limitations.

- As few limitations as possible should be used in the symbol for any subclass. One, rarely two, letters should normally suffice. The dominant symbol (i.e. that which determines the class) should be used alone if possible. If two limitations are equally severe, both may be given.

Land within class N1 may be divided into suitability subclasses according to kinds of limitation, e.g. N1m, N1me, N1m, although this is not essential. Land in class N2 will not be placed under management for the use concerned and should therefore not be subdivided.

4.1.2 Summary

The structure of the suitability classification, together with the symbols used, is summarized in table 5. Depending on the purpose, scale and intensity of the study, either the full range of suitability orders, classes, subclasses and units may be distinguished, or the classification may be restricted to the higher two or three categories.

table 5. Example of structured land suitability classification.

ORDER	CLASS	SUBCLASS	UNIT
S - Suitable	S1	----	---
	S2	S2e S2m S2em etc.	S2e-1 S2e-2 etc.
	S3	S3t	
N - Non suitable	N1	N1m N1d	--- ---
	N2	---	---

meaning of limitations : e = erosion t = texture m = soil moisture d = drainage

4.2 CLASSIFICATION CRITERIA

The land resources characterized in this study have been assessed for the following uses:

- irrigated agriculture in general
- cereals, vegetables and tree species under irrigation
- woodland, under rainfed conditions, for four tree species

The classification criteria for irrigation in general are discussed below, while those for particular crops and tree species are given in tables. The ensuing suitability classifications are also given in tabular form.

4.2.1 Soil texture

The particle size range or texture is an important factor, since it has a direct effect on numerous soil properties (structure, permeability, aeration.etc.).

The texture has been assessed as follows, in order of increasing particles size:

- Clay loam (CL)	S1	- Loamy sand (LS)	S3
- Loam (L)	S1	- Sand (S)	S4
- Sandy loam (SL)	S2	- Gravel and stones (X)	N

On referring to the texture triangle it was observed that the textures are mostly located within the coarse loamy and sandy family textural classes, and that there is therefore little distinction between the different texture classes. For this reason, there must be overlapping in the particle size range defining each class of use.

There are some areas, in the downstream part of the central alluvial plain, where the soil texture is very heterogeneous, as a result of mixed alluvial and aeolian deposits. These area are characterized by alternating loam, sandy loam, loamy sand, and sand. A soil texture of this kind is classified as class 3.

4.2.2 Soil depth

Soil depth can be a limiting factor of considerable importance in the case of the suitability of soils for gravity irrigation. Roots must be able to penetrate as great a depth as possible to be able to make use of the water stored in the soil profile.

Furthermore, the soil should be able to store the large quantities of water supplied when flood water is spread across fields. The depth scale adopted corresponds to that used for the suitability classification of soils.

- A soil more than 100 cm deep is classified as class 1
- A soil between 60 cm and 100 cm deep is classified as class 2.

4.2.3 Salinity

The electrical conductivity measurements of the soil water extract from the saturated paste were carried out in the laboratory. The salinity scale applied was the universally used scale of the Handbook of the US Salinty Laboratory. For the salinity assessment this scale is applied to the most saline soil horizon.

Thus, if the salinity were the only factor, the classification would be as follows :

- If the EC at 25°C of the paste extract is less than 0.5 dS/m, the soils falls into class 1,
- If the EC at 25°C of the paste extract is between 0.5 and 0.75 dS/m the soil falls into class 2
- If the EC at 25°C of the paste extract is between 0.75 and 1.5 dS/m the soil falls into class 3.

Problems raised by salinity are of considerable importance in the central alluvial plain, in areas where pumping of groundwater has developed over the last dozen years. The groundwater pumped is often saline, and the volumes of irrigation leaching water are inadequate to ensure satisfactory leaching of the soil, resulting in sodium accumulation.

4.2.4 Alkalinity

The soil where alkalinity is a problem are generally those where the salinity is fairly high. Alkalinity gives rise to a high pH, reaching and sometimes exceeding 9. The alkalinity scale used relies on the exchangeable sodium percentage. Limiting values retained are 10 and 15 % . If alkalinity were considered to be only limiting factor, the classification would be as follows :

- ESP less than 10 % : class 2
- ESP between 10 and 15 % :class 3
- ESP greater than 15 % : class 4

However soils with an alkaline phase, on the other hand, are more wide spread, in particular in the areas where pumped groundwater is used for irrigation.

4.2.5 Topography

The topography is a limiting factor throughout the study area. One of the reasons for this is that numerous mounds and dikes, sometimes over 2 m high, have been built to facilitate spreading and retaining floodwater in the alluvial plain and using rainwater and runoff in wadi Siham plains. These structures form a micro-relief which require further investigation if a large-scale irrigation project would be developed in these areas. Furthermore, in the downstream part of the alluvial plain, between Quza'at Al-Dopal and Al-Manzar villages in particular, there are a series of dunes and hummocks, fixed by vegetation, which also constitute an obstacle to development for irrigation, in addition to the textural constraint imposed by the sand itself. In the duneland area the topography is undulating as exhibited by the occurrence of sandhills, some of them over 5 m high due to active shifting sands. These structures makes development of these areas very difficult.

4.3 CLASSIFICATION TABLES

Table 6 shows the general suitability of the mapping units for irrigated agriculture, based on the criteria indicated in the previous section.

Table 6 Land suitability for irrigated agriculture

Mapping units	Classification	Suitability	Area (ha)	%
W111	S1	good	2887.5	19
C113	S2	moderate	3375	22.1
C144 C211 C212 C221 C222 C223	S3	poor	5050	33.3
C111 C112	N1	Temporarily unsuitable	3640	24
wadi bed	N2	unsuitable	242	1.6
Total			15195	100

Tables 7 and 8 show respectively the requirements for four important forestry species, and the suitability of the mapping units for each of these species. Tables 9 and 10 list the requirements and mapping unit suitabilities for irrigated crops and tree species respectively. The information for these tables came from the FAO Ecocrop database and El-Latifi (1995).

Table 7 Climate, soil and water requirements for some selected woodland species under rainfed conditions

Requirements / Tree type	Climate			Soil			Water need
	Temp. & Humidity	Rainfall	Elevation	pH	Texture	Salt tolerance	
Conocarpus Lancifolius	high	50-400 mm/yr	0-1000	high	sandy to clayey	moderate	moderate
Azadirachta indica	high	150-700 mm/year	0-1000	moderate to high	sandy to clayey	slight	moderate
Prosopis juliflora	high	50-700 mm/yr	0-1500	high	sandy	high	relatively small
Parkinsonia aculeata	high	200-1000 mm/year	0-1500	high	sandy, loamy	high	relatively small

Table 8 Land suitability classes for selected woodland species in the study area

Type of tree / Soil unit	*Conocarpus lancifolius*	*Azadirachta indica*	*Prosopis juliflora*	*Parkinsonia aculeata*
W111 W112	S2	S3	S2	S3
C113	S2	S3	S2	S3
C114 C211 C212 C221 C222 C223	S3	S2	S3	S2
C111 C112	S1	S2	S1	S2
wadi bed	S3	N	S3	N

Table 9 Climate, soil and water requirements for arable crops, vegetation and tree species under irrigation

Requirements / Crop	Climate				Soil			Water
	temp.	rainfall	elevation	humidity	pH	Texture	EC	
Cereals (sorghum, millet, etc.)	high	50-400 mm/year	0-1000	low to moderate	moderate	sandy to clayey	moderate	moderate quantities
Vegetables (tomatoes, potatoes, water melon, sweet melon, beans, okra, etc.)	moderate	50-400 mm/year	0-1000	low to moderate	moderate	sandy to clayey	moderate	moderate to high quantities
Date palm	high	100-400 mm/year	0-1500	high	high	sandy to clayey	high	relatively small quantities
Hyphaene thebaica	high	50-700 mm/year	0-1500	high	high	sandy to clayey	high	relatively small quantities
Tamarix nilotica	high	50-400 mm/year	0-1500	high	high	sandy to clayey	high	relatively small quantities
Acacia tortilis	high	50-400 mm/year	0-1500	high	high	sandy to clayey	high	relatively small quantities
Ziziphus spina-christi	high	50-700 mm/year	0-1500	high	high	sandy to clayey	high	relatively small quantities

Table 10 Land suitability classes for arable crops and tree species cultivated under irrigation

Crop and tree species Soil unit	Cereals (sorghum, millet. etc.)	Vegetables (tomatoes, potatoes, water melon, sweet melon, beans, okra, etc.)	Date palm (*Hyphaene thebaica*)	Woodland species e.g. *Tamarix nilotica* *Acacia tortilis* *Ziziphus spina-christi*
W111 W112	S1	S1	S2	S3
C113	S2	S3	S2	S2
C114 C211 C212 C221 C222 C223	S3	S2	S1	S1
C111 C112	N	N	S2	S2
Wadi bed	N	N	S3	S2

Chapter 5 CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

1. The soil survey carried out in the field and the analytical results show that the soils of the alluvial plains are generally homogeneous. Most of the soils encountered are slightly developed soils of marine, alluvial and aeolian origin. However, in the central alluvial plain, some soils have undergone considerable pedogenetic development. Certain soils in the alluvial plain, in the areas irrigated by pumped groundwater, have a marked sodium content, either in the soluble form or fixed on the exchange complex.

2. More generally speaking the soils studied are characterized by :

   - A low organic matter content,
   - Loamy sand to clay loam textures,
   - Moderate to good fertility,
   - Moderately well to well internal drainage,
   - Localized problems of salinity, associated with well irrigation.

   Table 10 lists the mapping units falling into each class of suitability for irrigated agriculture.

3. The chemical analysis of the underground water around the area revealed that the quality of this water which is used for irrigation is of poor standard, with dominantly high levels of salinity and moderate to high levels of sodium. Also the water analysis for the sewage treated water indicated that this water has a high salinity and high sodium content (class C4-S4 of the US Salinity Laboratory).

4. The soil map indicated that about 25% of the area is occupied by active duneland and about another 35% flat and hummocky sandy areas affected by active sand and wind blowing. These areas are used mainly for grazing.

5. A considerable part of the area (about 40%) is used for traditional rainfed and irrigated farming by the local farmers distributed in their scattered villages around the area. These include the arable areas (rainfed and irrigated) on flat- sand plain parts.

6. The afforestation effort carried already at a limited northern part of the area and close the Jayzan road was not successful due to lack of water for the trees and the trees types are not suitable for such environment (sand dune fixation in arid climate).

5.2 RECOMMENDATIONS

Based on the different soil types, topography, activity of wind and sand blowing, the development plans of the Green Belt around Hodeidah should take into consideration the three significantly different environments that were identified (see figure 1).

- The active duneland in which afforestation is highly needed to stabilize the shifting sands;
- The irrigated and rainfall arable lands, where there is considerable scope for agro-forestry;
- Grazing land that are in urgent need of rehabilitation, which amongst others could be achieved by reafforestation with drought resistant trees and shrubs.

The sewage treated water that is available at the northern side of the survey area could be used for afforestation of the sandy active dune lands, which should be planted with selected trees tolerant to salinity (e.g. *Azadirachta indica*). In view of the depletion and decrease in quality of the groundwater reserves, it should be used mainly for irrigation of vegetables and fruit trees, and not for cereal crops. To the extent that the latter can still be grown under floodwater irrigation, groundwater could be used as a supplementary water source to ensure an acceptable yield level, provided the abstraction for cash crops is not so high that the water table is adversely affected. There is an urgent need to advice farmers on the judicious use of such water for irrigation in order to avoid water wastage through over-irrigation and improper scheduling, while at the same time prevent salinization of the soil.

It is not sufficient to provide a shelterbelt around Hodeidah town, but shelter belt should also be established to protect agricultural land, provide additional fodder and fuelwood, and support beekeeping activities. It will be necessary to advise the farmers in the area on the importance of shelter belts. Farmers should also be encouraged to follow proper crop rotation in order to preserve the fertility of the soil. Livestock has to be considered in the rotation by growing fodder crops. This will lead to improved soil characteristics, produce fodder and reduce overgrazing.

The creation of recreation areas inside the Green Belt area would particularly benefit the population of Hodeidah and surrounding villages, but could also be an attraction for tourists from other parts of the country, and hence could contribute to local economic activity.

The whole Green Belt area should be considered as a protected area supported by strict government laws and regulations to conserve the national resources. An increase in wildlife (animals, birds, etc.) by protection their environment would add to the attractiveness of the green belt. However, without the support of the local population it will not be possible to achieve this. It is therefore imperative that villagers living near the Green Belt be involved in all aspects of the Green Belt: establishment, management, protection etc. This will not only create much needed employment opportunities, but will also contribute to the success of the Green Belt project.

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APPENDIX 1

SOIL PROFILE DESCRIPTIONS

and

ANALYTICAL DATA

The description of the soil profile is based on field observations. In particular the texture of the various horizons does therefore not necessarily correspond to the particle size distribution as given in the analytical data.

Profile code	: HUD050	Date	: 29/9/1996
Author(s)	: M.H. Al-Mashreki and L.K. Al-Asbahi	Toposheet	: 1442 B2
Location	: see soil map	Elevation	: 15 m
Soil classification	: sandy, mixed, isohyperthermic, typic Haplocalcid (Soil Taxonomy) haplic Calcisol (FAO/Unesco 1988)		
Soil moisture regime	: aridic	Soil temp. regime	: isohyperthermic
Topography	: almost flat	Micro topography	: shifting sand
Land use	: dryland farming	Vegetation	: shrubland
Crops	: nil	Slope	: 0.1-2 %
Parent material	: marine deposit	Surface stones	: nil
Sealing/crusting	: crusting	Erosion	: strong
Drainage	: well drained	Effective soil depth	: >150 cm deep

AC 0 - 15 cm brown (10YR 5/3, moist), pale brown (10YR 6/3, dry) sandy loam; massive structure; hard (dry), very friable (moist); common fine and medium pores; very few fine roots; abrupt, wavy boundary.

Ck 15 - 30 cm brown (10YR 5/3, moist), pale brown (10YR 6/3, dry) fine sandy loam; very weak, coarse, subangular blocky structure; slightly hard (dry), loose (moist); many very fine and fine pores; very few fine roots; common, nodules, fine, spherical, soft, concentration of carbonates; clear, smooth boundary.

C 30 - 140 cm dark grayish brown (10YR 4/2, moist), light brownish gray (10YR 6/2, dry) sandy loam; massive structure; soft (dry), loose (moist); few fine pores; no roots.

Soil physical analysis sheet

Hodeidah Green Belt survey - Profile no. HUD 050 - Date collected 29-09-96

Lab. No.	Depth (cm)	Particle size distribution (%)								Texture class
		>2 mm	VCS	CS	MS	FS	VFS	silt	clay	
798	0-15		0	1	22	34	24	11	8	sand
799	15-30		0	2	26	40	12	14	6	sand
800	30-140		1	6	31	30	20	12	0	sand

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Soil chemical analysis sheet

Hodeidah Green Belt survey - Profile no. HUD 050 - Date collected 29-09-96

Lab. No.	Depth (cm)	pH H_2O 1 : 1	pH KCl 1 : 1	pH paste	EC (mS/cm)	$CaCO_3$ (g/ kg)	Org. C (g/ kg)	Total N (g/ kg)	C/N ratio	Avail. P (mg/kg)
798	0-15			10.0	17.3	56.3	4.4	0.42	11	4
799	15-30			10.2	11.9	25.0	1.8	0.56	3	4
800	30-140			10.3	14.7	31.3				

Lab.	Depth	CEC(cmol/kg)		Exch. bases (cmol/kg)				BS	$CaSO_4$
No.	(cm)	soil	clay	Na	K	Ca	Mg	(%)	(g/kg)
789	0-15	16		10.7	1.3	4.0			
799	15-30	18		12.5	0.6	4.9			
800	30-140	20		13.9	0.1	6			

Lab.	Depth	Soluble Cations & Anions (cmol/1 sat. extract)								ESP	SAR
No.	(cm)	Na	K	Ca	Mg	Cl	CO_3	HCO_3	SO_4	(%)	
789	0-15	260	0.7	8.0	2.0	140	0.0	10.0	120.6	97	116
799	15-30	200	0.3	10.0	2.0	85	0.0	7.0	120.3	69	82
800	30-140	210	1.6	8.0	0.2	117	0.0	7.0	95.8	70	104

Profile code	: HUD051	Date	: 24/9/1996
Author(s)	: M.H. Al-Mashreki and L.K. Al-Asbahi	Toposheet	: 1443 A1
Location	: see soil map	Elevation	:
Soil classification	: coarse loamy, mixed, isohyperthermic typic Torriorthent (Soil Taxonomy)		
	: calcaric Regosol (FAO/Unesco 1988)		
Soil moisture regime	: aridic	Soil temp. regime	: isohyperthermic
Topography	: undulating	Micro topography	: shifting sand
Land use	: dryland farming	Vegetation	: dwarf shrubland
Crops	: nil	Slope	: 5-10 %
Parent material	: marine deposit	Surface stones	: nil
Sealing/crusting	: slight sealing	Erosion	: strong
Drainage	: well drained	Effective soil depth	: >150 cm deep

C1 0 - 35 cm dark yellowish brown (10YR 4/4, moist), light yellowish brown (10YR 6/4, dry) fine sandy loam; moderate, medium, subangular blocky structure; slightly hard (dry), friable (moist); many very fine and fine pores; very few very fine roots; strongly calcareous; clear, smooth boundary.

C2 35 - 85 cm dark yellowish brown (10YR 4/4, moist), light yellowish brown (10YR 6/4, dry) fine sandy loam; weak, fine and medium, subangular blocky structure; soft (dry), very friable (moist); common very fine pores; very few medium roots; strongly calcareous; clear, smooth boundary.

C3 85 - 125 cm yellowish brown (10YR 5/4, moist), light yellowish brown (10YR 6/4, dry) fine sandy loam; porous massive; soft (dry), very friable (moist); common very fine pores; very few medium roots; strongly calcareous; clear, smooth boundary.

C4 125 - 150 cm yellowish brown (10YR 5/4, moist), very pale brown (10YR 7/4, dry); loamy sand; porous massive; soft (dry), very friable (moist); common very fine pores; very few very fine roots; extremely calcareous.

Soil physical analysis sheet

Hodeidah Green Belt survey - Profile no. HUD 051 - Date collected 24-09-96

Lab.	Depth	Particle size distribution (%)								Texture
No.	(cm)	>2 mm	VCS	CS	MS	FS	VFS	silt	clay	class
756	0-35		1	1	16	40	26	9	7	sand
757	35-85		0	1	12	5	25	51	6	silty loam
758	85-125		0	1	11	48	22	10	8	sand
759	125-150		0	1	9	46	31	7	6	sand

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Soil chemical analysis sheet

Hodeidah Green Belt survey - Profile no. HUD 051 - Date collected 24-09-96

Lab. No.	Depth (cm)	pH H2O 1 : 1	pH KCl 1 : 1	pH paste	EC (mS/cm)	CaCO3 (g/kg)	Org. C (g/kg)	Total N (g/kg)	C/N ratio	Avail. P (mg/kg)
756	0-35			8.1	0.40	25	6.2	0.19	33	4
757	35-85			7.5	0.84	50				
758	85-125			7.6	1.4	15				
759	125-150			7.8	1.4	75				

Lab. No.	Depth (cm)	CEC(cmol/kg)		Exch. bases (cmol/kg)				BS	$CaSO_4$
		soil	clay	Na	K	Ca	Mg	(%)	(g/kg)
756	0-35	13		4.3	2.0	6.7			
757	35-85	13		5.2	1.8	8.0			
758	85-125	14		5.7	1.8	6.5			
759	125-150	12		5.1	1.8	5.1			

Lab. No.	Depth (cm)	Soluble Cations & Anions (cmol/1 sat. extract)								ESP	SAR
		Na	K	Ca	Mg	Cl	CO_3	HCO_3	SO_4	(%)	
756	0-35									33	
757	35-85									40	
758	85-125									41	
759	125-150									43	

Profile code	: HUD052	Date	: 21/9/1996
Author(s)	: M.H. Al-Mashreki and L.K. Al-Asbahi	Toposheet	: 1443 A1
Location	: see soil map	Elevation	:
Soil classification	: mixed, isohyperthermic, typic Toripsamment (Soil Taxonomy)		
	: calcaric Arenosol (FAO/Unesco 1988)		
Soil moisture regime	: aridic	Soil Temp. Regime	: isohyperthermic
Topography	: undulating	Micro topography	: shifting sand
Land use	: dryland farming	Vegetation	: nil
Crops	: nil	Slope	: 0.5-2 %
Parent material	: aeolian deposits	Surface stones	: nil
Sealing/crusting	: slight sealing	Erosion	: strong
Drainage	: well drained	Effective soil depth	: >150 cm deep

A 0 - 20 cm pale brown (10YR 6/3, moist), brown (10YR 4/3, dry) loamy sand; massive structure; soft (dry), loose (moist); many very fine pores; few fine roots; strongly calcareous: clear, smooth boundary.

B 20 - 40 cm pale brown (10YR 6/3, moist), brown (10YR 4/3, dry); loamy sand; moderate medium subangular blocky structure; soft (dry), loose (moist); many very fine pores; few very fine roots; moderately calcareous; abrupt, smooth boundary.

C1 40 - 80 cm brown (10YR 4/3, moist); loamy sand; moderate medium subangular blocky structure; soft (dry), loose (moist); common very fine pores; very few very fine roots; slightly calcareous; abrupt, smooth boundary.

C2 80 - 140 cm brown (10YR 4/3, moist) very fine sandy loam; single grain structure; soft (dry), loose (moist); common very fine pores; no roots; slightly calcareous.

Soil physical analysis sheet

Hodeidah Green Belt survey - Profile no. HUD 052 - Date collected 21-09-96

Lab.	Depth	Particle size distribution (%)								Texture
No.	(cm)	>2 mm	VCS	CS	MS	FS	VFS	silt	clay	class
744	0-20		0	1	10	43	30	13	3	loamy sand
745	20-40		1	1	13	44	19	17	5	loamy sand
746	40-80		1	1	16	51	22	4	5	sand
747	80-140		1	1	15	44	24	10	5	loamy sand

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Soil chemical analysis sheet

Hodeidah Green Belt survey - Profile no. HUD 052 - Date collected 21-09-96

Lab. No.	Depth (cm)	pH H_2O 1 : 1	pH KCl 1 : 1	pH paste	EC (mS/cm)	$CaCO_3$ (g/ kg)	Org. C (g/ kg)	Total N (g/ kg)	C/N ratio	Avail. P (mg/kg)
744	0-20			7.3	0.42	28.8	3.6	0.28	13	4
745	20-40			7.6	0.35	3.8				
746	40-80			8.0	0.42	1.0				
747	80-140			7.9	0.27	2.6				

Lab.	Depth	CEC(cmol/kg)		Exch. bases (cmol/kg)				BS	$CaSO_4$
No.	(cm)	soil	clay	Na	K	Ca	Mg	(%)	(g/kg)
744	0-20	12		0.6	2.8	8.6			
745	20-40	12		0.8	2.7	8.5			
746	40-80	13		5.3	3.8	3.9			
747	80-140	13		2.6	3.0	7.4			

Lab.	Depth	Soluble Cations & Anions (cmol/1 sat. extract)								ESP	SAR
No.	(cm)	Na	K	Ca	Mg	Cl	CO_3	HCO_3	SO_4	(%)	
744	0-20									5	
745	20-40									7	
746	40-80									40	
747	80-140									20	

Profile code	:	HUD053	Date	:	22/9/1996
Author(s)	:	M.H. Al-Mashreki and L.K. Al-Asbahi	Toposheet	:	1443 A1
Location	:	see soil map	Elevation	:	40 m
Classification.	:	mixed, isohyperthermic typic Torripsamment (Soil Taxonomy)			
	:	calcaric Arenosol (FAO/Unesco, 1988)			
Soil moisture regime	:	aridic	Soil temp. regime	:	Isohyperthermic
Topography	:	almost flat	Micro topography	:	medium hummocks
Land use	:	dryland farming	Vegetation	:	dwarf shrubland
Crops	:	nil	Slope %	:	0.5 - 2%
Parent material	:	aeolian deposit	Surface stones	:	nil
Sealing/crusting	:	nil	Erosion	:	strong
Drainage	:	well drained	Effective soil depth	:	>150 cm deep

A 0 - 12 cm brown (10YR 5/3, moist), pale brown (10YR 6/3, dry) sandy loam; weak, fine and medium subangular blocky; soft (dry), very friable (moist); common very fine pores; few fine roots; strongly calcareous; clear, wavy boundary.

Ck 12 - 55 cm brown (10YR5/3) moist, pale brown (10YR 6/3, dry) sandy loam; massive structure; soft (dry), very friable (moist); common fine and medium pores; very few very fine roots; strongly calcareous; abrupt, smooth boundary.

C 55 - 150 cm brown (10YR 5/3, moist); pale brown (10YR 6/3, dry) sandy loam; massive structure; soft (dry), very friable (moist); common very fine pores; no roots; strongly calcareous.

Soil physical analysis sheet

Hodeidah Green Belt survey - Profile no. HUD 053 - Date collected 22-09-96

Lab.	Depth	Particle size distribution (%)								Texture
No.	(cm)	>2 mm	VCS	CS	MS	FS	VFS	silt	clay	class
748	0-12		1	1	8	41	37	9	3	sand
749	12-55		0	0	5	55	34	4	2	sand
750	55-150		0	0	4	46	39	10	1	sand

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Soil chemical analysis sheet

Hodeidah Green Belt survey - Profile no. HUD 053 - Date collected 22-09-96

Lab. No.	Depth (cm)	pH H_2O 1 : 1	pH KCl 1 : 1	pH paste	EC (mS/cm)	$CaCO_3$ (g/ kg)	Org. C (g/ kg)	Total N (g/ kg)	C/N ratio	Avail. P (mg/kg)
748	0-12			7.7	0.62	7.5	3.6	0.14	26	6
749	12-55			7.6	2.0	2.7				
750	55-150			8.2	0.5	4.5				

Lab.	Depth	CEC(cmol/kg)		Exch. bases (cmol/kg)				BS	$CaSO_4$
No.	(cm)	soil	clay	Na	K	Ca	Mg	(%)	(g/kg)
748	0-12	13		0.4	5.0	7.6			
749	12-55	10		1.5	1.2	7.3			
750	55-150	11		0.4	4.0	6.6			

Lab.	Depth	Soluble Cations & Anions (cmol/1 sat. extract)								ESP	SAR
No.	(cm)	Na	K	Ca	Mg	Cl	CO_3	HCO_3	SO_4	(%)	
748	0-12									3	
749	12-55									15	
750	55-150									40	

Profile code	: HUD054	Date	: 22/9/1996
Author(s)	: M.H. Al-Mashreki and L.K. Al-Asbahi		Toposheet: 1443 A1
Location	: see soil map	Elevation	: 30 m
Soil classification	: fine loamy over sandy, mixed, isohypertherm typic Haplargid (Soil Taxonomy)		
	: haplic Luvisol (FAO/Unesco, 1988)		
Soil moisture regime	: aridic	Soil temp. regime	: isohyperthermic
Topography	: almost flat	Micro topography	: even
Land use	: dryland farming	Vegetation	: shrubland
Crops	: nil	Slope	: 0.5 - 2%
Parent material	: aeolian deposit	Surface stones	: nil
Sealing/crusting	: crusting	Erosion	: strong
Drainage	: moderately well drained	Effective soil depth	: >150 cm deep

A 0 - 18 cm brown (10YR 4/3, moist), pale brown (10YR 6/3, dry) silt loam; moderate, fine and medium subangular and angular blocky; soft (dry), very friable (moist), slightly sticky, non plastic (wet); common fine pores; few fine roots; strongly calcareous; clear, smooth boundary.

Bt 18 - 30 cm brown (10YR 4/3, moist), very pale brown (10YR 7/3, dry) silty clay loam; strong, coarse and very coarse subangular blocky; slightly hard (dry), friable (moist), sticky and plastic (wet); few faint clay cutans; many fine and medium pores; few very fine roots; strongly calcareous; clear, smooth boundary

Bk 30 - 40 cm brown (10YR 4/3, moist), very pale brown (10YR 7/3, dry) silty clay; strong, medium, angular blocky and platy structure; hard (dry), friable (moist) sticky and plastic (wet); few very fine pores; very few very fine roots; strongly calcareous; clear, smooth boundary.

2C1 40 - 80 cm grayish brown (10YR 5/2, moist), light gray (10YR 7/2, dry) loamy sand; porous massive; loose (dry); few very fine pores; no roots; moderately calcareous; abrupt, irregular boundary.

2C2 80 - 120 cm dark yellowish brown (10YR4/4, moist), yellowish brown (10YR 5/4, dry) sandy loam; porous massive; loose (dry); many very fine pores; no roots

Soil physical analysis sheet

Hodeidah Green Belt survey - Profile no. HUD 054 - Date collected 22-09-96

Lab.	Depth	Particle size distribution (%)								Texture
No.	(cm)	>2 mm	VCS	CS	MS	FS	VFS	silt	clay	class
751	0-18		1	1	2	12	66	13	5	sand
752	18-30		1	1	3	13	28	39	1	sandy loam
753	30-40		0	0	0	5	9	55	31	silty clay loam
754	40-80		1	1	13	42	36	6	1	sand
755	80-120		1	2	13	42	30	7	5	sand

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Soil chemical analysis sheet

Hodeidah Green Belt survey - Profile no. HUD 054 - Date collected 22-09-96

Lab. No.	Depth (cm)	pH H_2O 1 : 1	pH KCl 1 : 1	pH paste	EC (mS/cm)	$CaCO_3$ (g/ kg)	Org. C (g/ kg)	Total N (g/ kg)	C/N ratio	Avail. P (mg/kg)
751	0-18			8.3	0.94	41.3	4.5	0.42	11	5
752	18-30			8.6	1.1	27.5	8.0	0.42	19	4
753	30-40			8.1	1.3	18.8				
754	40-80			7.2	1.8	81.3				
755	80-120			8.0	2.3	18.8				

Lab.	Depth	CEC(cmol/kg)		Exch. bases (cmol/kg)				BS	$CaSO_4$
No.	(cm)	soil	clay	Na	K	Ca	Mg	(%)	(g/kg)
751	0-18	13		5.2	3.4	4.4			
752	18-30	16		12.1	3.5	0.4			
753	30-40	20		14.7	3.2	2.1			
754	40-80	11		6.2	2.0	2.8			
755	80-120	11		8.0	2.8	0.2			

Lab.	Depth	Soluble Cations & Anions (cmol/1 sat. extract)								ESP	SAR
No.	(cm)	Na	K	Ca	Mg	Cl	CO_3	HCO_3	SO_4	(%)	
751	0-18									40	
752	18-30									76	
753	30-40									74	
754	40-80									56	
755	80-120	19.5	0.26	3.2	1.6	8.6	0.0	1.6	14.4	73	13

Profile code	: HUD055	Date	: 2/10/1996
Author(s)	: M.H. Al-Mashreki and L.K. Al-Asbahi	Toposheet	: 1443 A1
Location	: see soil map	Elevation	: 25 m
Soil classification	: mixed, isohyperthermic, typic Torripsamment (Soil Taxonomy)		
	: calcaric Arenosol (FAO/Unesco 1988)		
Soil moisture regime	: aridic	Soil temp. regime	: isohyperthermic
Topography	: almost flat	Micro topography	: shifting sand
Land use	: dryland farming	Vegetation	: dwarf shrubland
Crops	: nil	Slope	: 0.5 - 2%
Parent material	: aeolian deposit	Surface stones	: nil
Sealing/crusting	: nil	Erosion	: strong
Drainage	: well drained	Effective soil depth	: >150 cm deep

C 0 - 75 cm — brown (10YR 4/3, moist), brown (10YR 5/3, dry) loamy sand; massive structure; soft (dry), loose (moist); common very fine pores; few very fine and fine roots; few, crystals, coarse, irregular, hard, carbonates concentrations; moderately calcareous; clear, wavy boundary.

Ck 75 - 180 cm — brown (10YR 4/3, moist), pale brown (10YR 6/3, dry) loamy sand; massive structure; soft (dry), loose (moist); common very fine pores; very few roots; few, coarse, irregular, hard, carbonate concentrations; moderately calcareous.

Soil physical analysis sheet

Hodeidah Green Belt survey - Profile no. HUD 055 - Date collected 2-10-96

Lab. No.	Depth (cm)	Particle size distribution (%)								Texture class
		>2 mm	VCS	CS	MS	FS	VFS	silt	clay	
801	0-75		0	1	6	58	18	13	4	sand
802	75-180		0	0	6	67	20	7	0	sand

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Soil chemical analysis sheet

Hodeidah Green Belt survey - Profile no. HUD 055 - Date collected 2-10-96

Lab. No.	Depth (cm)	pH H_2O 1 : 1	pH KCl 1 : 1	pH paste	EC (mS/cm)	$CaCO_3$ (g/ kg)	Org. C (g/ kg)	Total N (g/ kg)	C/N ratio	Avail. P (mg/kg)
801	0-75			7.7	0.73	32.0	2.6	0.70	4	3
802	75-180			7.3	2.2	42.8				

Lab. No.	Depth (cm)	CEC(cmol/kg)		Exch. bases (cmol/kg)				BS	$CaSO_4$
		soil	clay	Na	K	Ca	Mg	(%)	(g/kg)
801	0-75	16	25		0.8	14.5			
802	75-180	17	0	0.5	1.0	15.5			

Lab. No.	Depth (cm)	Soluble Cations & Anions (cmol/1 sat. extract)								ESP	SAR
		Na	K	Ca	Mg	Cl	CO_3	HCO_3	SO_4	(%)	
801	0-75									4	
802	75-180	5.6	0.2	20.4	3.6	2.5	0.0	1.6	26.7	3	2

Profile code	: HUE020	Date	: 24/9/1996
Author(s)	: M.H. Al-Mashreki and L.K. Al-Asbahi	Toposheet	: 1443 A1
Location	: see soil map	Elevation	: 35 m
Soil classification	: coarse loamy, mixed, isohyperthermic, typic Torriorthent(Soil Taxonomy)		
	: calcaric Regosol (FAO/Unesco 1988)		
Soil moisture regime	: aridic	Soil temp. regime	: isohyperthermic
Topography	: almost flat	Micro topography	: low hummocks
Land use	: mixed dryland and irrigated agriculture	Vegetation	: grassland
Crops	: cereal crops & vegetables	Slope	: 0.5 - 2%
Parent material	: marine deposits	Surface stones	: nil
Sealing/crusting	: crusting	Erosion	: nil
Drainage	: well drained	Effective soil depth	: >150 cm deep

Ap 0 - 30 cm brown (10YR 4/3, moist), brown (10YR 5/3, dry) sandy loam; very weak, fine and medium subangular blocky; soft (dry), very friable (moist); many very fine and fine pores; few very fine and fine roots; strongly calcareous; clear, smooth boundary.

C1 30 - 55 cm dark grayish brown (10YR 4/2, moist), brown (10YR 5/3, dry) sandy loam; very weak, fine and medium subangular blocky; slightly hard (dry), friable (moist); many very fine and fine pores; very few very fine roots; strongly calcareous; abrupt, smooth boundary.

C2 55 - 95 cm brown (10YR 4/3, moist), brown (10YR 5/3, dry), sandy loam; massive structure; soft (dry), very friable (moist); common very fine pores; no roots; very few medium, subrounded rock fragments; strongly calcareous; abrupt smooth boundary.

Ck 95 - 130 cm brown (10YR 4/3, moist), brown (10YR 5/3, dry), sandy loam; massive; soft (dry); common fine pores; no roots; few, coarse, irregular, soft and hard, carbonate concentrations; strongly calcareous.

Soil physical analysis sheet

Hodeidah Green Belt survey - Profile no. HUE 020 - Date collected 24-09-96

Lab. No.	Depth (cm)	Particle size distribution (%)								Texture class
		>2 mm	VCS	CS	MS	FS	VFS	silt	clay	
760	0-30		0	0	10	25	39	22	4	loamy sand
761	30-55		0	1	12	33	32	16	6	loamy sand
762	55-95		0	1	13	38	28	16	4	loamy sand
763	95-130		0	0	8	37	37	16	2	loamy sand

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Soil chemical analysis sheet

Hodeidah Green Belt survey - Profile no. HUE 020 - Date collected 24-09-96

Lab. No.	Depth (cm)	pH H_2O 1 : 1	pH KCl 1 : 1	pH paste	EC (mS/cm)	$CaCO_3$ (g/ kg)	Org. C (g/ kg)	Total N (g/ kg)	C/N ratio	Avail. P (mg/kg)
760	0-30			8.2	0.7	15.0	8.9	0.28	32	6
761	30-55			7.8	1.5	6.3				
762	55-95			7.7	2.1	12.5				
763	95-130			8.0	0.9	12.5				

Lab.	Depth	CEC(cmol/kg)		Exch. bases (cmol/kg)				BS	$CaSO_4$
No.	(cm)	soil	clay	Na	K	Ca	Mg	(%)	(g/kg)
760	0-30	12		303	1.8	6.8			
761	30-55	12		4.7	1.8	5.5			
762	55-95	12		11.5	3.6				
763	95-130	14		3.5	1.6	8.9			

Lab.	Depth	Soluble Cations & Anions (cmol/1 sat. extract)								ESP	SAR
No.	(cm)	Na	K	Ca	Mg	Cl	CO_3	HCO_3	SO_4	(%)	
760	0-30									28	
761	30-55									39	
762	55-95	16.5	0.27	4.8	4.4	8.0	0.0	1.8	23.4	96	8
763	95-130									25	

Profile code	: HUE021	Date	: 24/9/1996
Author(s)	: M.H. Al-Mashreki and L.K. Al-Asbahi	Toposheet	: 1443A1
Location	: see soil map	Elevation	: 35 m
Soil classification	: coarse loamy, mixed, isohyperthermic, typic Torriorthent (Soil Taxonomy)		
	: calcaric Regosol (FAO/Unesco 1988)		
Soil soisture regime	: aridic	Soil temp. regime	: isohyperthermic
Topography	: almost flat	Micro topography	: low hummocks
Land use	: mixed dryland and irrigated agriculture	Vegetation	: grassland
Crops	: cereal crops and vegetables	Slope	: 0.5 - 2%
Parent material	: aeolian sand	Surface stones	: nil
Sealing/crusting	: nil	Erosion	: nil
Drainage	: moderately well drained	Effective soil depth	: >150 cm deep

A 0 - 33 cm brown (10YR 4/3, moist), pale brown (10YR 6/3, dry); fine sandy loam; weak, medium, subangular blocky; soft (dry), very friable (moist); common very fine pores; many medium and coarse roots; extremely calcareous; clear, smooth boundary.

C1 33 - 80 cm brown (10YR 5/3, moist), very pale brown (10YR7/3, dry); loamy coarse sand; massive structure; soft (dry), very friable (moist); many very fine pores; few fine roots; extremely calcareous; abrupt, smooth boundary.

C2 80 - 110 cm brown (10YR 4/3, moist), light yellowish brown (10YR 6/4, dry); loamy coarse sand; massive structure; loose (dry); common very fine pores; few very fine roots; few, medium, subrounded rock fragments; extremely calcareous; abrupt smooth boundary.

Ck 110 - 140 cm brown (10YR 4/3, moist), pale brown (10YR 6/3, dry) fine sandy loamy; moderate, medium, subangular blocky; slightly hard (dry), friable (moist), slightly sticky, slightly plastic (wet); common very fine and fine pores; few very fine roots; common, medium, subrounded, rock fragments; common, coarse, irregular, hard, carbonate nodules; extremely calcareous.

Soil physical analysis sheet

Hodeidah Green Belt survey - Profile no. HUE 021 - Date collected 24-09-96

Lab. No.	Depth (cm)	Particle size distribution (%)								Texture class
		>2 mm	VCS	CS	MS	FS	VFS	silt	clay	
764	0-33		0	0	4	47	29	16	4	loamy sand
765	33-80		0	0	4	42	29	17	8	loamy sand
766	80-110		2	0	5	45	38	8	2	sand
767	110-140		1	1	4	20	21	51	2	silty loam

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Soil chemical analysis sheet

Hodeidah Green Belt survey - Profile no. HUE 021 - Date collected 24-09-96

Lab. No.	Depth (cm)	pH H_2O 1 : 1	pH KCl 1 : 1	pH paste	EC (mS/cm)	$CaCO_3$ (g/ kg)	Org. C (g/ kg)	Total N (g/ kg)	C/N ratio	Avail. P (mg/kg)
764	0-33			7.3	3.4	12.5	6.2			2
765	33-80			7.0	10.4	52.5				
766	80-110			7.0	10.8	56.3				
767	110-140			6.6	22.2	32.0				

Lab.	Depth	CEC(cmol/kg)		Exch. bases (cmol/kg)				BS	$CaSO_4$
No.	(cm)	soil	clay	Na	K	Ca	Mg	(%)	(g/kg)
764	0-33	14		10.2	2.3	1.5			
765	33-80	15		9.0	2.3	3.7			
766	80-110	13		4.8	1.0	7.2			
767	110-140	16		0.8	1.9	13.3			

Lab.	Depth	Soluble Cations & Anions (cmol/1 sat. extract)								ESP	SAR
No.	(cm)	Na	K	Ca	Mg	Cl	CO_3	HCO_3	SO_4	(%)	
764	0-33	31	0.27	4.0	1.2	32.0	0.0	1.2	3.3	73	19
765	33-80	72	0.30	9.6	27.2	45.0	0.0	1.2	62.9	60	17
766	80-110	69	0.27	14.8	38.0	115	0.0	1.4	5.7	40	13
767	110-140	120	0.27	69.2	64.8	50	0.0	1.2	203	5	15

Profile code	: HUE022	Date	: 25/9/1996
Author(s)	: M.H. Al-Mashreki and L.K. Al-Asbahi	Toposheet	: 1443 A1
Location	: see soil map	Elevation	: 30 m
Soil classification	: mixed, isohyperthermic, typic Torripsamment (Soil Taxonomy)		
	: calcaric Arenosol (FAO/Unesco 1988)		
Soil moisture regime	: aridic	Soil temp. regime	: isohyperthermic
Topography	: almost flat	Micro topography	: even
Land use	: mixed dryland and irrigated agriculture	Vegetation	: grassland
Crops	: cereal crops	Slope	: 0.5 - 2%
Parent material	: alluvium	Surface stones	: nil
Sealing/crusting	: slight sealing	Erosion	: nil
Drainage	: moderately well drained	Effective soil depth	: >150 cm deep

AC 0 - 15 cm — brown (10YR 4.5/3, moist), very pale brown (10YR 7/3, dry) fine sandy loam; single grain; soft (dry), very friable (moist); many very fine pores; very few fine roots; strongly calcareous; clear, smooth boundary.

C1 15 - 60 cm — brown (10YR 5/3, moist), pale brown (10YR 6/3, dry) fine sandy loam; single grain; soft (dry), very friable (moist); few fine and common very fine pores; very few fine roots; strongly calcareous; clear, smooth boundary.

C2 60 - 120 cm — brown (10YR 5/3, moist), pale brown (10YR 6/3, dry) coarse sandy loam: single grain; loose (dry); few fine and common very fine pores; very few very fine roots; strongly calcareous; abrupt smooth boundary.

C3 120 - 150 cm — brown (10YR 5/3, moist), light gray (10YR 7/2, dry) coarse sandy loam; single grain; loose (dry); common very fine pores; no roots; strongly calcareous.

Soil physical analysis sheet

Hodeidah Green Belt survey - Profile no. HUE 022 - Date collected 25-09-96

Lab. No.	Depth (cm)	Particle size distribution (%)								Texture class
		>2 mm	VCS	CS	MS	FS	VFS	silt	clay	
768	0-15		0	3	13	24	41	17	2	loamy sand
769	15-60		0	1	12	26	48	11	2	sand
770	60-120		0	0	7	23	56	13	1	sand
771	120-150		0	1	14	33	38	12	2	sand

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Soil chemical analysis sheet

Hodeidah Green Belt survey - Profile no. HUE 022 - Date collected 25-09-96

Lab. No.	Depth (cm)	pH H_2O 1 : 1	pH KCl 1 : 1	pH paste	EC (mS/cm)	$CaCO_3$ (g/ kg)	Org. C (g/ kg)	Total N (g/ kg)	C/N ratio	Avail. P (mg/kg)
768	0-15			7.9	0.54	28.4	5.3	0.28	19	1
769	15-60			7.9	0.95	32.0	4.5	0.28	16	2
770	60-120			7.5	1.20	33.2				
771	120-150			7.6	2.39	62.0				

Lab.	Depth	CEC(cmol/kg)		Exch. bases (cmol/kg)				BS	$CaSO_4$
No.	(cm)	soil	clay	Na	K	Ca	Mg	(%)	(g/kg)
768	0-15	15		1.8	1.9	11.3			
769	15-60	13		4.1	2.0	6.9			
770	60-120	10		3.9	3.0	3.1			
771	120-150	13		3.7	2.7	6.6			

Lab.	Depth	Soluble Cations & Anions (cmol/1 sat. extract)								ESP	SAR
No.	(cm)	Na	K	Ca	Mg	Cl	CO_3	HCO_3	SO_4	(%)	
768	0-15									12	
769	15-60									32	
770	60-120									39	
771	120-150	20	0.35	5.2	6.0	11.4	0.0	1.6	18.6	28	9

Profile code	: HUE023	Date	: 25/9/1996
Author(s)	: M.H. Al-Mashreki and L.K. Al-Asbahi	Toposheet	: 1443 A3
Location	: see soil map	Elevation	: 30 m
Soil classification	: coarse loamy, mixed, isohyperthermic, typic Torriorthent (Soil Taxonomy)		
	: calcaric Regosol (FAO/Unesco 1988)		
Soil moisture regime	: aridic	Soil temp. regime	: isohyperthermic
Topography	: almost flat	Micro topography	: shifting sands
Land use	: mixed dryland and irrigated agriculture	Vegetation	: grassland
Crops	: cereal crops	Slope	: 0.5 - 2%
Parent material	: alluvium	Surface stones	: nil
Sealing/crusting	: nil	Erosion	: moderate
Drainage	: well drained	Effective soil depth	: >150 cm deep

Ap 0 - 20 cm dark grayish brown (10YR 4/2, moist), brown (10YR 5/3, dry) sandy clay loam; massive structure; loose (dry), slightly sticky and slightly plastic (wet); many very fine and fine pores; common medium roots; slightly calcareous; clear, smooth boundary.

Bt1 20 - 50 cm very dark grayish brown (10YR 3/2, moist), brown (10YR 5/3, dry) loam; weak fine and medium subangular blocky; soft (dry), very friable (moist), slightly sticky (wet); common prominent clay cutans; many medium pores; common fine roots; slightly calcareous; abrupt, irregular boundary.

Bt2 50 - 100 cm very dark brown (10YR 2/2, moist) sandy clay loam; weak, fine and medium subangular blocky structure; slightly hard (dry), very friable (moist), slightly sticky and slightly plastic (wet); common, prominent clay cutans; common medium pores; few fine roots; moderately calcareous; gradual, irregular boundary.

B 100 - 120 cm dark brown (10YR 3/3, moist), brown (10YR 4/3, dry) very fine sandy loam; weak to moderate, medium subangular blocky structure; slightly hard (dry), very friable (moist); many distinct clay cutans; many, medium pores; nil roots; non calcareous.

Soil physical analysis sheet

Hodeidah Green Belt survey - Profile no. HUE 023 - Date collected 25-09-96

Lab. No.	Depth (cm)	Particle size distribution (%)								Texture class
		>2 mm	VCS	CS	MS	FS	VFS	silt	clay	
772	0-20		0	2	1	14	34	43	6	sandy loam
773	20-50		0.0	3	17	18	25	36	1	sandy loam
774	50-100									
775	100-120									

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Soil chemical analysis sheet

Hodeidah Green Belt survey - Profile no. HUE 023 - Date collected 25-09-96

Lab. No.	Depth (cm)	pH H_2O 1 : 1	pH KCl 1 : 1	pH paste	EC (mS/cm)	$CaCO_3$ (g/ kg)	Org. C (g/ kg)	Total N (g/ kg)	C/N ratio	Avail. P (mg/kg)
772	0-20			6.6	11.8	24.8	12.5	0.28	45	2
773	20-50			6.9	6.0	29.6	20.5	0.14	146	4
774	50-100			6.5	5.9	27.2				
775	100-120			6.6	4.0	24.8				

Lab.	Depth	CEC(cmol/kg)		Exch. bases (cmol/kg)				BS	$CaSO_4$
No.	(cm)	soil	clay	Na	K	Ca	Mg	(%)	(g/kg)
772	0-20	16		8.6	3.6	3.8			
773	20-50	16		10.4	4.0	1.6			
774	50-100	14		12.1	3.4				
775	100-120	14		9.9	2.4	1.7			

Lab.	Depth	Soluble Cations & Anions (cmol/1 sat. extract)								ESP	SAR
No.	(cm)	Na	K	Ca	Mg	Cl	CO_3	HCO_3	SO_4	(%)	
772	0-20	65	0.65	22.4	55.6	9.8	0.0	2.0	132.9	54	10
773	20-50	54	0.40	11.6	16.0	33.2	0.0	1.6	47.2	65	15
774	50-100	55	0.30	6.5	13.9	30.4	0.0	1.4	73.6	86	17
775	100-120	37	0.19	5.2	7.6	26.0	0.0	1.4	22.6	71	15

Profile code	: HUE024	Date	: 25/9/1996
Author(s)	: M.H. Al-Mashreki and L.K. Al-Asbahi	Toposheet	: 1443 A3
Location	: see soil map	Elevation	: 20 m
Soil classification	: coarse loamy. mixed, isohyperthermic. typic Torrifluvent (Soil Taxonomy)		
	: calcic Fluvisol (FAO/Unesco 1988)		
Soil moisture regime	: aridic	Soil temp. regime	: isohyperthermic
Topography	: almost flat	Micro topography	: even
Land use	: mixed dryland and irrigated agriculture	Vegetation	: grassland
Crops	: cereal crops	Slope	: 0.5 - 2%
Parent material	: alluvium	Surface stones	: nil
Sealing/crusting	: moderate sealing	Erosion	: moderate
Drainage	: well drained	Effective soil depth	: >150 cm deep

C1 0 - 20 cm — brown (10YR 4/3, moist). pale brown (10YR 6/3. dry) sandy loam; massive structure; soft (dry). loose (moist): common very fine pores: common medium roots; strongly calcareous: clear. wavy boundary.

C2 20 - 50 cm — brown (10YR 4/3. moist). brown (10YR 6/3, dry) sandy loam: massive structure; soft (dry), loose (moist): common very fine pores; few fine roots; strongly calcareous: clear. wavy boundary.

C3 50 - 80 cm — grayish brown (10YR 5/2. moist), light gray (10YR 7/2. dry) sandy loam: massive structure: loose (dry); common very fine pores: very few fine roots: very few medium. subrounded rock fragments: extremely calcareous; abrupt, irregular boundary.

Ck 80 - 140 cm — gray (10YR 5/1, moist), light gray (10YR 7/1. dry) coarse sandy loam: massive structure: loose (dry); common very fine pores; no roots; many medium. rounded rock fragments: common coarse hard, irregular carbonate concretions: extremely calcareous.

Soil physical analysis sheet

Hodeidah Green Belt survey - Profile no. HUE 024 - Date collected 25-09-96

Lab. No.	Depth (cm)	Particle size distribution (%)								Texture class
		>2 mm	VCS	CS	MS	FS	VFS	silt	clay	
776	0-20		1	4	26	22	23	23	1	loamy sand
777	20-50		1	13	32	23	16	14	1	sand
778	50-80		5	15	55	17	4	3	1	sand
779	80-140		5	15	53	17	4	5	1	sand

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Soil chemical analysis sheet

Hodeidah Green Belt survey - Profile no. HUE 024 - Date collected 24-09-96

Lab. No.	Depth (cm)	pH H_2O 1 : 1	pH KCl 1 : 1	pH paste	EC (mS/cm)	$CaCO_3$ (g/ kg)	Org. C (g/ kg)	Total N (g/ kg)	C/N ratio	Avail. P (mg/kg)
776	0-20			7.2	0.51	21.2	4.5	0.0	0	1
777	20-50			7.2	0.70	10.0	5.3	0.14	38	2
778	50-80			6.9	5.1	4.0				
779	80-140			7.2	2.9	62.0				

Lab.	Depth	CEC(cmol/kg)		Exch. bases (cmol/kg)				BS	$CaSO_4$
No.	(cm)	soil	clay	Na	K	Ca	Mg	(%)	(g/kg)
776	0-20	13		3.1	0.38	9.5			
777	20-50	10		4.0	0.38	5.6			
778	50-80	12		3.1	0.38	0.52			
779	80-140	11		1.6	0.36	9.0			

Lab.	Depth	Soluble Cations & Anions (cmol/1 sat. extract)								ESP	SAR
No.	(cm)	Na	K	Ca	Mg	Cl	CO_3	HCO_3	SO_4	(%)	
776	0-20									24	
777	20-50									40	
778	50-80	50	0.3	6.0	3.6	25.4	0.0	2.4	42.1	26	16
779	80-140	21.5	0.3	4.0	6.4	21.8	0.0	1.8	8.6	15	9

Profile code	: HUE025	Date	: 24/9/1996
Author(s)	: M.H. Al-Mashreki and L.K. Al-Asbahi	Toposheet	: 1443 A3
Location	: see soil map	Elevation	: 15 m
Soil classification	: coarse loamy, mixed, isohyperthermic, typic Torriorthent (Soil Taxonomy)		
	: calcaric Regosol (FAO/Unesco 1988)		
Soil moisture regime	: aridic	Soil temp. regime	: isohyperthermic
Topography	: almost flat	Micro topography	: even
Land use	: mixed dryland and irrigated agriculture	Vegetation	: dwarf shrubland
Crops	: cereal crops	Slope	: 0.5 - 2%
Parent material	: alluvium	Surface stones	: nil
Sealing/crusting	: crusting	Erosion	: nil
Drainage	: moderately well drained	Effective soil depth	: >150 cm deep

Ap 0 - 10 cm dark brown (10YR 3/3, moist), brown (10YR 5/3, dry) silt loam; moderate, medium, subangular blocky; soft (dry), very friable (moist), sticky and plastic (wet); many fine and medium pores; many fine roots; strongly calcareous; clear, smooth boundary.

Bt1 10 - 40 cm brown (10YR 4/3, moist), pale brown (10YR 6/3, dry) clay loam; moderate, medium, subangular blocky; slightly hard (dry), friable (moist), sticky and plastic (wet); very few, faint, clay-humus cutans on pedfaces; common fine and medium pores; few fine roots; few fine soft calcareous filaments; strongly calcareous; gradual, smooth boundary.

Bt2 40 - 120 cm dark yellowish brown (10YR 3/4, moist), pale brown (10YR 6/3, dry) clay loam; moderate and strong, medium and coarse subangular blocky; slightly hard (dry), friable (moist), sticky and plastic (wet); common, distinct, clay-humus cutans on pedfaces; many medium and coarse pores; very few very fine roots; few fine soft calcareous filaments; strongly calcareous.

Soil physical analysis sheet

Hodeidah Green Belt survey - Profile no. HUE 025 - Date collected 24-09-96

Lab. No.	Depth (cm)	Particle size distribution (%)								Texture class
		>2 mm	VCS	CS	MS	FS	VFS	silt	clay	
780	0-10		0	0	1.0	4.0	19.0	55.0	21.0	silt loam
781	10-40		0	1.0	1.0	5.0	17.0	51.0	25.0	silt loam
782	40-120									

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Soil chemical analysis sheet

Hodeidah Green Belt survey - Profile no. HUE 025 - Date collected 24-09-96

Lab. No.	Depth (cm)	pH H_2O 1 : 1	pH KCl 1 : 1	pH paste	EC (mS/cm)	$CaCO_3$ (g/ kg)	Org. C (g/ kg)	Total N (g/ kg)	C/N ratio	Avail. P (mg/kg)
780	0-10			6.6	30.9	74	10.6	0.70	15	4
781	10-40			6.7	12.1	36.8	13.4	0.56	24	2
782	40-120			6.7	11.7	32.0				

Lab.	Depth	CEC(cmol/kg)		Exch. bases (cmol/kg)				BS	$CaSO_4$
No.	(cm)	soil	clay	Na	K	Ca	Mg	(%)	(g/kg)
780	0-10	12		19.1	0.8				
781	10-40	13		11.8	0.7	0.5			
782	40-120	18		17.8	0.8				

Lab.	Depth	Soluble Cations & Anions (cmol/1 sat. extract)								ESP	SAR
No.	(cm)	Na	K	Ca	Mg	Cl	CO_3	HCO_3	SO_4	(%)	
780	0-10									159	
781	10-40	100	0.24	14.4	24.4	25.4	0.0	2.2	111.8	91	23
782	40-120	100	0.2	13.2	25.6	32.8	0.0	2.2	104	99	23

Profile code	: HUE026	Date	: 25/9/1996
Author(s)	: M.H. Al-Mashreki and L.K. Al-Asbahi	Toposheet	: 1443 A3
Location	: see soil map	Elevation	: 20 m
Soil classification	: mixed, isohyperthermic, typic Torripsamment (Soil Taxonomy)		
	: calcaric Arenosol (FAO/Unesco 1988)		
Soil moisture regime	: aridic	Soil temp. regime	: isohyperthermic
Topography	: almost flat	Micro topography	: low hummocks
Land use	: mixed dryland and irrigated agriculture	Vegetation	: dwarf shrubland
Crops	: cereal crops	Slope	: 0.5 - 2%
Parent material	: alluvium	Surface stones	: nil
Sealing/crusting	: moderate sealing	Erosion	: strong
Drainage	: moderately well drained	Effective soil depth	: >150 cm deep

C1 0 - 30 cm brown (10YR 4/3, moist), pale brown (10YR 6/3, dry) loamy sand; massive structure; soft (dry), loose (moist); common very fine and fine pores; few very fine roots; extremely calcareous; abrupt, irregular, boundary.

C2 30 - 85 cm brown (10YR 4/3, moist), pale brown (10YR 6/3, dry) loamy sand; massive structure; soft (dry), loose (moist); common very fine and fine pores; very few very fine roots; moderately calcareous; abrupt irregular boundary.

C3 85 - 140 cm brown (10Y 4/3, moist), brown (10YR 5/3, dry) loamy sand; massive structure; soft (dry), loose (moist); common fine pores; few fine roots; slightly calcareous

Soil physical analysis sheet

Hodeidah Green Belt survey - Profile no. HUE 026 - Date collected 25-09-96

Lab. No.	Depth (cm)	Particle size distribution (%)								Texture class
		>2 mm	VCS	CS	MS	FS	VFS	silt	clay	
783	0-30		0.0	1	16	41	27	11	4	sand
784	30-85		0.0	1	15	47	20	15	2	loamy sand
785	85-140		0.0	1	14	45	26	10	4	sand

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Soil chemical analysis sheet

Hodeidah Green Belt survey - Profile no. HUE 026 - Date collected 25-09-96

Lab. No.	Depth (cm)	pH H_2O 1 : 1	pH KCl 1 : 1	pH paste	EC (mS/cm)	$CaCO_3$ (g/ kg)	Org. C (g/ kg)	Total N (g/ kg)	C/N ratio	Avail. P (mg/kg)
783	0-30			6.8	3.8	27.2	5.3	0.42	13	4.0
784	30-85			7.5	3.4	8.8	1.8	0.0	0	4.0
785	85-140			7.5	1.9	18.7				

Lab.	Depth	CEC(cmol/kg)		Exch. bases (cmol/kg)				BS	$CaSO_4$
No.	(cm)	soil	clay	Na	K	Ca	Mg	(%)	(g/kg)
783	0-30	16		3.2	0.7	2.1			
784	30-85	13		2.9	1.0	9.1			
785	85-140	14		3.4	1.3	9.3			

Lab.	Depth	Soluble Cations & Anions (cmol/1 sat. extract)								ESP	SAR
No.	(cm)	Na	K	Ca	Mg	Cl	CO_3	HCO_3	SO_4	(%)	
783	0-30	27.5	0.4	9.2	4.4	27.6	0.0	2.2	11.7	20	11
784	30-85	31.5	0.5	6.8	5.3	23.8	0.0	1.4	18.9	10	13
785	85-140										

Profile code	: HUE027	Date	: 30/9/1996
Author(s)	: M.H. Al-Mashreki and L.K. Al-Asbahi	Toposheet	: 1442 B4
Location	: see soil map	Elevation	: 15 m
Soil classification	: coarse loamy, mixed, isohyperthermic, typic Haplocalcid (Soil Taxonomy)		
	: haplic Calcisol (FAO/Unesco 1988)		
Soil moisture regime	: aridic	Soil temp. regime	: isohyperthermic
Topography	: almost flat	Micro topography	: low hummocks
Land use	: nil	Vegetation	: dwarf shrubland
Crops	: nil	Slope	: 0.5 - 2%
Parent material	: alluvium	Surface stones	: nil
Sealing/crusting	: moderate sealing	Erosion	: nil
Drainage	: moderately well drained	Effective soil depth	: >150 cm deep

AB 0 - 15 cm dark brown (10YR 3/3, moist), brown (10YR 4/3, dry) sandy loam; weak and moderate, medium and coarse, subangular blocky; hard (dry), very friable (moist); many fine and medium pores; very few fine roots; slightly calcareous; clear, smooth boundary.

Bk 15 - 45 cm brown (10YR 4/3, moist), pale brown (10YR 6/3, dry) sandy clay loam; moderate medium and coarse subangular blocky; soft (dry), very friable (moist); many fine and medium pores; very few very fine and fine roots; common fine, spherical, soft, carbonate nodules; moderately calcareous; gradual, wavy boundary.

Ck 45 - 75 cm dark yellowish brown (10YR 3/4, moist), pale brown (10YR 6/3, dry) sandy loam; very weak, medium, subangular blocky; soft (dry), loose (moist); many very fine to fine pores; very few very fine roots; common fine, irregular, soft, carbonate nodules; extremely calcareous; clear, smooth boundary.

C 75 - 120 cm brown (10YR 5/4, moist), very pale brown (10YR 7/4 dry) loamy sand; massive structure; soft (dry), loose (moist); many very fine pores; no roots; very few fine, spherical, soft, carbonate nodules; extremely calcareous.

Soil physical analysis sheet

Hodeidah Green Belt survey - Profile no. HUE 027 - Date collected 30-09-96

Lab. No.	Depth (cm)	Particle size distribution (%)								Texture class
		>2 mm	VCS	CS	MS	FS	VFS	silt	clay	
786	0-15		0.0	3	13	20	23	33	8	sand loam
787	15-45		0.0	2	9	23	28	36	2	sand loam
788	45-75		0.0	2	5	24	33	34	2	sand loam
789	75-120		0.0	2	5	15	27	51	0	silt loam

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Soil chemical analysis sheet

Hodeidah Green Belt survey - Profile no. HUE 027 - Date collected 30-09-96

Lab. No.	Depth (cm)	pH H_2O 1 : 1	pH KCl 1 : 1	pH paste	EC (mS/cm)	$CaCO_3$ (g/ kg)	Org. C (g/ kg)	Total N (g/ kg)	C/N ratio	Avail. P (mg/kg)
786	0-15			7.1	80.7	10.0	7.0	0.14	50	5
787	15-45			6.7	61.3	37.5	6.2	0	0	2
788	45-75			6.7	55.8	40.8				
789	75-120			6.9	37.6	25.0				

Lab.	Depth	CEC(cmol/kg)		Exch. bases (cmol/kg)				BS	$CaSO_4$
No.	(cm)	soil	clay	Na	K	Ca	Mg	(%)	(g/kg)
786	0-15	26		16	0.6	9.4			
787	15-45	19		4.4	0.2	14.4			
788	45-75	17		5.1	0.1	11.8			
789	75-120	21		8.9	0.0	12.1			

Lab.	Depth	Soluble Cations & Anions (cmol/1 sat. extract)								ESP	SAR
No.	(cm)	Na	K	Ca	Mg	Cl	CO_3	HCO_3	SO_4	(%)	
786	0-15	960	1.1	134	18.0	8.6	0.0	1.0	1103.4	57	110
787	15-45	620	0.4	296	42.0	11.6	0.0	1.0	945.8	13	48
788	45-75	540	0.2	262	68.0	10.6	0.0	1.0	858.7	14	42
789	75-120	370	0.1	168	28.0	10.6	0.0	1.2	554	32	37

Profile code	: HUE028	Date	: 30/9/1996
Author(s)	: M.H. Al-Mashreki and L.K. Al-Asbahi	Toposheet	: 1442 B4
Location	: see soil map	Elevation	: 10 m
Soil classification	: coarse loamy, mixed, isohyperthermic, typic Haplocalcid (Soil Taxonomy)		
	: haplic Calcisol (FAO/Unesco 1988)		
Soil moisture regime	: aridic	Soil temp. regime	: isohyperthermic
Topography	: almost flat	Micro topography	: high hummocks
Land use	: mixed dryland and irrigated agriculture	Vegetation	: dwarf shrubland
Crops	: cereal crops	Slope	: 0.5 - 2%
Parent material	: marine deposit	Surface stones	: nil
Sealing/crusting	: nil	Erosion	: nil
Drainage	: moderately well drained	Effective soil depth	: >150 cm deep

A 0 - 10 cm — brown (10YR 4/3, moist), pale brown (10YR 6/3, dry) coarse loamy sand; massive structure; loose (dry), very friable (moist); many very fine pores; few very fine roots; moderately calcareous; clear, smooth boundary.

B 10 - 30 cm — dark yellowish brown (10YR 4/4, moist), brown (10YR 5/3, dry) fine sandy loam; moderate and strong, medium and coarse, subangular blocky; hard (dry), friable (moist); common fine and medium pores; few very fine roots; strongly calcareous; clear, smooth boundary.

C1 30 - 80 cm — dark grayish brown (10YR 4/2, moist), brown (10YR 5/3, dry) coarse sandy loam; very weak, fine, subangular blocky; soft (dry), loose (moist); common fine and medium pores; very few very fine roots; many, fine and medium, spherical and irregular, soft carbonate segregations; moderately calcareous; gradual, wavy boundary.

C2 80 - 150 cm — brown (10YR 5/3, moist), light gray (10YR 7/3, dry) coarse sandy loam; massive structure; soft (dry), loose (moist); few very fine and fine pores; no roots; few, fine, spherical and irregular, soft, carbonate segregations; extremely calcareous.

Soil physical analysis sheet

Hodeidah Green Belt survey - Profile no. HUE 028 - Date collected 30-09-96

Lab. No.	Depth (cm)	Particle size distribution (%)								Texture class
		>2 mm	VCS	CS	MS	FS	VFS	silt	clay	
790	0-10		0	1	23	34	23	19	0	loamy sand
791	10-30		1	3	21	21	14	34	6	sandy loam
792	30-80		0	3	31	31	14	21	0	loamy sand
793	80-150		0	2	26	41	13	16	2	loamy sand

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Soil chemical analysis sheet

Hodeidah Green Belt survey - Profile no. HUE 028 - Date collected 30-09-96

Lab. No.	Depth (cm)	pH H_2O 1 : 1	pH KCl 1 : 1	pH paste	EC (mS/cm)	$CaCO_3$ (g/ kg)	Org. C (g/ kg)	Total N (g/ kg)	C/N ratio	Avail. P (mg/kg)
790	0-10			7.0	20.4	55.0	13.2	0.42	31	2
791	10-30			7.1	37.2	75.0	1.8	0.70	3	10
792	30-80			7.0	38.4	18.8	6.2			
793	80-150			6.9	46.3	25.0	7.0			

Lab.	Depth	CEC(cmol/kg)		Exch. bases (cmol/kg)				BS	$CaSO_4$
No.	(cm)	soil	clay	Na	K	Ca	Mg	(%)	(g/kg)
790	0-10	9		3.0	1.0	5			
791	10-30	18		6.9	1.5	9.6			
792	30-80	16		8.6	0.9	6.5			
793	80-150	17		15.5	0.2	1.3			

Lab.	Depth	Soluble Cations & Anions (cmol/1 sat. extract)								ESP	SAR
No.	(cm)	Na	K	Ca	Mg	Cl	CO_3	HCO_3	SO_4	(%)	
790	0-10	180	3.3	70	24	6.4	0	1.8	269	10	26
791	10-30	380	4.5	140	38	11.6	0	1.0	550	30	40
792	30-80	470	2.0	96	36	12.8	0	1.0	590	32	68
793	80-150	490	0.7	166	74	9.6	0	1.6	791.5	60	45

Profile code	: HUE029	Date	: 30/9/1996
Author(s)	: M.H. Al-Mashreki and L.K. Al-Asbahi	Toposheet	: 1442 B4
Location	: see soil map	Elevation	: 10 m
Soil classification	: coarse loamy, mixed, isohyperthermic, typic Torriorthent (Soil Taxonomy)		
	: calcaric Regosol (FAO/Unesco 1988)		
Soil moisture regime	: aridic	Soil temp. regime	: isohyperthermic
Topography	: almost flat	Micro topography	: high hummocks
Land use	: dryland farming	Vegetation	: dwarf shrubland
Crops	: nil	Slope	: 0.5 - 2%
Parent material	: marine deposits	Surface stones	: nil
Sealing/crusting	: nil	Erosion	: moderate
Drainage	: moderately well drained	Effective soil depth	: >150 cm deep

A 0 - 10 cm yellowish brown (10YR 5/4, moist), very pale brown (10YR 7/4, dry) fine sandy loam: weak, medium, subangular blocky; soft (dry), very friable (moist); common very fine and fine pores; very few very fine roots; strongly calcareous; clear, smooth boundary.

AC 10 - 30 cm yellowish brown (10YR 5/4, moist), very pale brown (10YR 7/4, dry) sandy loam; weak, medium, subangular blocky; hard (dry), very friable (moist); common fine and medium pores; few fine roots; slightly calcareous; clear, smooth boundary.

C1 30 - 65 cm dark yellowish brown (10YR 4/4, moist), yellowish brown (10YR 5/4, dry) sandy loam; porous massive; soft (dry), very friable (moist); common very fine pores; few very fine roots; very few, fine, irregular, soft carbonate segregations; non calcareous; clear smooth boundary.

C2 65 - 120 cm yellowish brown (10YR 5/4, moist), light yellowish brown (10YR 6/4, dry) sandy loam; porous massive structure; soft (dry), very friable (moist); common very fine pores; no roots; moderately calcareous.

Soil physical analysis sheet

Hodeidah Green Belt survey - Profile no. HUE 029 - Date collected 30-09-96

Lab. No.	Depth (cm)	Particle size distribution (%)								Texture class
		>2 mm	VCS	CS	MS	FS	VFS	silt	clay	
794	0-10		0	2	26	41	13	16	2	loamy sand
795	10-30		0	1	13	42	18	26	0	loamy sand
796	30-65		0	1	12	47	20	18	2	loamy sand
797	65-120		0	1	12	48	19	14	4	sand

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Soil chemical analysis sheet

Hodeidah Green Belt survey - Profile no. HUE 029 - Date collected 30-09-96

Lab. No.	Depth (cm)	pH H_2O 1 : 1	pH KCl 1 : 1	pH paste	EC (mS/cm)	$CaCO_3$ (g/ kg)	Org. C (g/ kg)	Total N (g/ kg)	C/N ratio	Avail. P (mg/kg)
794	0-10			6.7	17.8	50.0	4.4			7
795	10-30			6.5	27.4	12.5	2.6	0.56	5	2
796	30-65			6.6	23.2	50.0	5.3			
797	65-120			6.7	31.8	113.8	3.5			

Lab.	Depth	CEC(cmol/kg)		Exch. bases (cmol/kg)				BS	$CaSO_4$
No.	(cm)	soil	clay	Na	K	Ca	Mg	(%)	(g/kg)
794	0-10	15	0	5.4	2.7	6.9			
795	10-30	17	0	7.1	2.5	7.4			
796	30-65	17	12	9.6	1.5	7.9			
797	65-120	14	29	10.9	1.2	1.9			

Lab.	Depth	Soluble Cations & Anions (cmol/1 sat. extract)								ESP	SAR
No.	(cm)	Na	K	Ca	Mg	Cl	CO_3	HCO_3	SO_4	(%)	
794	0-10	240	3.1	20	6	260	0.0	0.5	8.6	36	67
795	10-30	310	2.7	72		300	0.0	0.8	83.9	42	52
796	30-65	300	1.7	46	4	262	0.0	1.4	88.3	45	60
797	65-120	360	1.6	92	14	370	0.0	2.2	95.4	79	49

Profile code	: HUE030	Date	: 12/9/1996
Author(s)	: M.H. Al-Mashreki and L.K. Al-Asbahi	Toposheet	: 1443 A3
Location	: see soil map	Elevation	: 20 m
Soil classification	: fine loamy, mixed, isohyperthermic, typic Torriorthent (Soil Taxonomy)		
	: calcaric Regosol (FAO/Unesco 1988)		
Soil moisture regime	: aridic	Soil temp. regime	: isohyperthermic
Topography	: almost flat	Micro topography	: even
Land use	: mixed dryland and irrigated agriculture	Vegetation	: shrubland
Crops	: cereal crops and cotton	Slope	: 0.5 - 2%
Parent material	: aeolian deposit	Surface stones	: nil
Sealing/crusting	: nil	Erosion	: nil
Drainage	: well drained	Effective soil depth	: >150 cm deep

A	0 - 30 cm	brown (10YR 5/3, moist and dry) sandy loam; very weak, coarse and very coarse subangular blocky; loose (dry), very friable (moist); common very fine and fine pores; few very fine roots; moderately calcareous; clear, smooth boundary.
C1	30 - 60 cm	light yellowish brown (10YR 6/4, moist), dark yellowish brown (10YR 4/4, dry) sandy loam; massive structure; loose (dry), very friable (moist); many very fine and fine pores; few very fine roots; strongly calcareous; clear, smooth boundary.
C2	60 -100 cm	yellowish brown (10YR 5/4, moist), brown (10YR 4/3, dry) sandy loam; massive structure; loose (dry), very friable (moist); many very fine and fine pores; no roots; common, medium, irregular soft carbonate segregations; extremely calcareous

APPENDIX 2

ANALYTICAL WATER DATA

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WATER ANALYSIS RESULTS

W.S .NO	E.C.m S/cm at 25C	pH	Na	K	Ca	Mg	SUM OF CATION S cml/L	Co3	HCO3	CL	S04	SUM OF ANION cml/L	SAR	RSC	ESP	USDA CLASS
1	4.19	7.8	42	0.1	3.2	5.4	50.7	0.0	2.0	2.8	45.9	50.7	20	0.0	82.8	C4-S4
2	4.55	7.6	37	0.1	7.2	12.3	56.6	0.0	2.4	26	28.2	56.6	12	0.0	65	C4-S3
3	2.6	7.6	26	0.1	3.4	6.4	35.9	0.0	3.4	9.0	23.5	35.9	12	0.0	72	C4-S4
4	4.6	7.7	28	0.2	10	11	49.2	0.0	2.8	2.5	43.9	49.2	9	0.0	57	C4-S3
5	3.9	8	26	0.2	9.1	9.4	44.7	0.0	3.4	1.4	39.9	44.7	9	0.0	58	C4-S3
6	7.1	7.7	47	0.2	15	23.8	86	0.0	3.4	3.8	78.8	86	11	0.0	55	C4-S3
7	7.7	8.8	63	0.2	8.6	20.4	86	0.0	1.4	50.4	40.8	92.2	4	0.0	6.8	C4-S2
8	9.1	7.4	67	0.2	14.1	25.1	107.2	0.0	2.0	60.0	45.2	107.2	15	0.0	63	C4-S4
9	10.1	7.4	62	0.2	19.5	36.5	118.2	0.0	2.0	70.0	48.0	118.2	12	0.0	52	C4-S4
10	2.6	7.9	24	0.1	3	6.2	33.3	0.0	2.4	10.0	20.9	33.3	11	0.0	68	C4-S3
11	4.3	7.7	41	1.1	4.3	9.7	591	0.0	11	26	19.1	56.1	15	0.0	73	C4-S4

SAR: Sodium Adsorption Ratio **RSC:** Residual Sodium Carbonate **ESP:** Exchangeable Sodium Percentage

Classification (U.S. Salinity Lab.):

S4-C4 = Very high salinity, very high sodium. Not suitable for irrigation except under very special circumstances of excellent drainage and for very tolerant crops.

S4-C3 = Very high salinity to high sodium water. This water is not suitable for irrigation under ordinary conditions and may produce harmful levels of both salts and alkali in most soil except under very special soil and crop management.

S4-C2 = Very high salinity medium sodium water. Not suitable for irrigation but can be used for reclamation of highly saline soils provided that the E.C. of the soil at saturation is grater than E.C. of this water.

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Water samples were taken from sites as indicated below:

Water sample NO.	Location	Well Depth (M)	Nearest Opservation
1	Al- oga Village	60	Profile no. HUD053
2	Biot Al- Offa Village	100	Profile no. HUD054
3	Deer Hassan	50	Profile no. HUE020
4	Mahal Al- Shaikg		Profile no. HUE021
5	Al-Sharaf Al- A'ala V		Augering. no. 12
6	Al- Zafaran Village	40	Augering. no. 13
7	Al- Guraiba Village	50	Profile no. HUE024
8	Al- Sela'a Village	50	Profile no. HUE028
9	N. Quzat Al-Dubal V.	50	Profile no. HUE026
10	AL-Bayda Water station		
11	Sewage Water		

HUDEIDA GREEN BELT SOIL SURVEY_COMMENT ON RESULTS OF ANALYSIS "REQUESTED BY MR. AL-MASHREKI"

A.E. FADL (SOIL CHEMIST)

The soil of the surveyed area are coarse to moderately coarse textured soils. Textural classes are dominantly loamy sand, sand and sandy loam. This may critically increase the downward movement of water to undesirable rate, and gravity irrigation may present some difficulties, particularly at the sand textured sites where contents of both silt and clay are very low. However, other characteristics are involved in the movement and percolation of water such as condition of the soil surface, sodicity status and quantity and quality of soluble salts. It is strongly recommended that special water management practices, that consider the above mentioned criteria be followed in this area.

The area is variably affected by soluble salts. 9 of the 16 sampled sites are non-saline with an average E.C. at saturation less than 4 mS/cm. However at all other sites salinity levels are sufficiently high to affect adversely the growth of most plants. Sulfate and chloride are the principal soluble anions present in these soils, the bicarbonate content is relatively low and carbonate is absent. Soluble sodium content exceeds those of calcium plus magnesium, and thus the high SAR values. Saline areas are generally sodic. Accordingly both leaching and replacement of exchangeable sodium are required for reclamation, and irrigation agriculture would have doubtful success at areas represented by profiles HUED23, 25, 27, 28, 29 and HUC003 unless reclamation measures are carried out.

$CaCO_3$ is a common constituent of all sampled sites. Its content varies between 2-8%. Presence of gypsum is also evidenced by high concentration of both soluble calcium and sulfate in saturation extract, and by a relatively low pH (commonly less than 8.2) in presence of high sodicity levels. The two constituents together with soluble salt determine the suitability of different amendments and process of leaching this area.

Conclusion : The soils of Green-Belt area are regarded as problem soils that require very special remedial measures and management practices. It is unfortunate that all sources of water available in the area as represented by 11 water sample analysed in our laboratory are of very high salt content and their use may result in further salinization. (See lab report an analysis of water samples collected from Green Belt area).

LABORATORY ANALYSIS METHODS

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

1. Soil Reaction (pH) is determined by pH meter.
   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 mS/cm at 25°C.

3. Concentration of soluble Na and K are measured by flame photometry

4. Soluble Ca and Mg are titrated against EDTA.

5. Soluble CO_3 and HCO_3 are obtained by titration against standard sulphuric acid using phenolphthalein and methyl orange indicators.

6. Soluble chloride by titration with silver nitrate.

7. Soluble sulphate is obtained by one of the following three methods :

   7.1 Gravimetrically by precipitation as barium sulphate.
   7.2 A modified versenate method.
   7.3 Colorimetrically, by barium chromate method.

8. Calcium carbonate : Acid neutralization method is used.

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

10. Total Nitrogen : Measured according to the standard Kjeldahl method using convenient digestion, distillation and titration units supplied by Tecator, Sweden.

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

12. 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.

13. <u>Exchangeable cations</u> : Exchangeable Na and K are determined in 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.

14. The following parameters are obtained by direct calculation.

1. C/N ratio
2. CEC/Clay
3. ESP
4. SAR

15. 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.

Soils rich in $CaCO_3$ and organic matter are carried out through special treatment. The fine earth fraction (less than 2 millimetres) is used for the test, and USDA system of the particle size grade is adopted to express results of the different fractions i.e.

	M. M
very coarse sand	2.0 - 1.0
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	Less than 0.002

16. Water Retention at 0.033 and 1.5 MPa
Saturated soil is placed in closed chamber, subjected to required pressure and allowed to stand while water is forced out until equilbrrium is reached. The moisture content is then determined by oven drying and moisture percentages at field capacity (1.5 MPa) and wilting point (0.03 MPa) are recorded. Complete set of equipment supplied by Soil Moisture Equipment Corp. USA are used for the test.

17. Non-routine determinations include bulk density, particle density, porosity, liquid limit, plastics limit plasticity index and hydraulic conductivity.

Table 4 Soil mapping description

Soil maping units		Components of main and association soils	Topography	Slope (%)	Main characteristics
Sympol	Type of maping unit				
C111	Undiffrentiated group	Typic Torripsaments Typic Torriorthents inclusions	Undulating	5-10	Very deep, well drained, slightly to moderately calcareous, sand to loamy sand texture, massive to subangular blocky structure, parent material is reworked aeolian sediments, with surface sealing.
C122	Undiffrentiated group	Typic Torripsaments Typic Torriorthent Inclusion	Gently undulating	2-5	Very deep, well drained, slightly calcareous, fine sandy loam to loamy sand texture,massive structure.
C133	Complex	Typic Torriorthents Typic Torripssaments Typic Haplargids Typic Haplocambids Inclusions	Flat	0-0.5	Very deep, well to excessively drained, slightly calcareous,stratifide very fine sandy loam to coarse sand loam and gravely layers below 12(cmdepth,massive and subangularblocky structı
C144	Consociasion	Typic Torripssaments Typic Torriorthents Inclusions	Gently sloping	2-5	Deep to very deep, well to moderately drained, moderately to strongly calcareous loamy sand to sandy loam texture,massive structure, the shale found throughout the profiles.
C211	Comlex	TypicTorripsamments Typic Torriorthents Typic Torriflufents	Gently sloping	2-5	Deep to very deep, well draind, moderately to strongly calcareous sandy loamt texture, massive strucure.
C212	Consociation	Typic haplocalcids Typic Torriorthents Inclusion	Gently level	0.5-2	Deep to very deep, moderately drained, moderately to strongly calcareous,sandy loam t loamy sand texture, subangular blocky structu
C221	Comlex	Typuic Torriorthents Typic Haplocalcids Typic Torripssamments Inclusion	Nearly Level	05-2	Very deep, well to moderately drained, moderately calcareous, sandy loam texture, massive to subangular blocky structure.
C222	Consociation	Typic Torripsamments Typic Torriorthents Inclusions	Nearly level	0.5-2	Deep to very deep, moderately drained, moderately to strongly calcareous, sandy loam texture, massive to subangular blocky structure
C223	Consociation	Typic Torriorthents Typic Torripsamments	Nearly level	0.5-2	Deep to very deep, well to moderately drained, moderately to strongly calcareous, sandy loam texture, massive structure.
W111	Complex	Typic Torrifluvents Typic Torriorthents Typic Torripsamments Fluventic Haplocambids Inclusions	Gently sloping	2-5	Very deep, well to moderately drained, strongly to extremely calcareous, sandy loam texture subangular blocy structure.
W112	Complex	Typic Torriorthents Typic Torrifluvents Typic Torripsamments	Gently sloping	2-5	Very deep, moderately well drained, strongly calcareous, silty loam texture subangular blocy structure.