FOOD AND AGRICULTURAL ORGANIZATION OF THE UNITED NATIONS
ENVIRONMENTAL RESOURCE ASSESSMENT FOR RURAL LAND USE PLANNING
GCP/YEM/021/NET *Technical Note 7*

THE SOILS OF AL-MAHAWIB

(DHAMAR GOVERNORATE)

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

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بسم الله الرحمن الرحيم

ABSTRACT

This study was undertaken at the request of the FAO (Dutch funded) "Watershed and peri-urban wastewater reuse" project of the General Directorate of Forestry and Desertification Control. The study area, measuring about 5 by 5 km and located north of Dhamar town (see soil map), is downstream of the wastewater treatment plant, and can make use of treated wastewater for agricultural production. Three dominant landscapes are found in the area, viz. the plateau, wadis dissecting the plateau, and piedmont. The main objective of this Al-Mawahib study is to characterize the soil resources for proper agriculture use, amongst other with agro-forestry.

The information collected from the field on soil physiography, morphology and distribution are supported by existing data on chemical and physical properties from previous studies (Acres, 1982). Apart from field information this report includes a soil map and related data on some climatic parameters. The suitability of the different soils is indicated. The report concludes by making recommendations on the use and management of the soils for locally adapted crops. Growing of certain species of woodland trees is also being recommended for some selected sites.

The study was started at the beginning of November 1998 by the author, under the direction of Dr. El-Abbas Doka, FAO Land Resource Expert. Since the area had already been surveyed before (Acres, 1980), it was decided to carry out this study mainly through doing field verification of the soil units on the existing soil map. Six days of fieldwork was undertaken, which included the digging of three additional soil pits. However, the analytical data for the soil series was obtained from the previous study, and this was formatted in a table to show the difference between the series occurring in the study area.

خلاصـــــة:

هذه الدراسة تـــم تنفيذهـــا بطلـــب مـــن منظمـــة الأغذيـــة والزراعـــة (FAO)
(مشروع إعادة إستخدام المياه العادمة في الأدارة العامة للغابـــات ومكافحـــة التصحـــر)
ويتمويل من حكومة المملكة الهولندية الصديقة

تقدر المساحة الكلية لمنطقة الدراسة بحوالي ٥ كيلومترات طولا إلى خمسة كيلومتر
عرضا وذلك شمال مدينة ذمار كما هي موضحة في خارطة التربة وكما هو ملاحظ أنها تقع

أسفل منطقة مياه المجاري المعالجة وذلك لإستخدام تلك المياه في الإنتاج الزراعي ، ثلاثة أنماط فيزوغرافية للآراضي وجدت في منطقة الدراسة وهي الهضبة Platue ، السهل Plin ، الوادي Wadi . بالإضافة إلى المنحدرات السهلية المتكونة في بطون الجبال Piedmont

إن الهدف الرئيسي لهذه الدراسة (دراسة منطقة المواهب) هو تشخيصي والتعرف على أنواع الترب السائدة لإستخدامها الأستخدام الأفضل لفرض الأنتاج الزراعي وزراعة أشجار الغابات .

إن المعلومات المجمعة حقليا على السطح وشكل الأرض Physiography وخواص التربة الداخلية Morphology وتوزيعات التربة مدعمة بالمعلومات الكيمائية الموجودة عن التربة وكذلك خواصها الفيزوياويه المأخوذة من تقرير تربة سابق Acres1983 كما أن هذا التقرير يحتوي على خارطة تربة بالإضافة إلى معلومات مناخية عن منطقة الدراسة .

هذا التقرير تم إختتامه بعمل توصيات على إستخدام وإدارة الترب للمحاصيل المنزرعة محليا فيما يخص أماكن زراعتها وأماكن زراعة الأشجار الخشبية .

هذه الدراسة أبتدأت في بداية أكتوبر ١٩٩٨م بواسطة م / عبدالله البوراني – كبير مساحين التربة وحصر الآراضي في الهيئة تحت إشراف وتوجيه د/ عباس دوكا محمد علي – خبير موارد الآراضي FAO . ولكون المنطقة قد درست مقدما ACRES83 تم التوجيه بشأن إستخراج تلك الدراسة بعمل تأكيد حقلي لخارطة التربة الموجودة بحيث أخذ العمل الحقلي ٦ أيام وتم حفر ٣ قطاعات بالأضافة إلى عدة ملاحظات بواسطة Auger ومع ذلك نظرا لدقة التحاليل الكيميائية في الدراسة السابقة تم أخذ تلك البيانات وإخراجها في جدول يوضح كل سلاسل التربة في المنطقة .

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Chapter 1 Environment

1.1 BACKGROUND

This study was initiated in November 1998, at the request of the "Watershed Management and Wastewater Reuse in Peri-urban Areas of Yemen" project of the General Directorate of Forestry and Desertification Control, Ministry of Agriculture and Irrigation. The main purpose of the study was to assess the suitability of the area for irrigated agriculture and agro-forestry, using treated wastewater from the Dhamar urban wastewater treatment plant as source of water. Since the area had already been included in the semi-detailed Soils and Land Suitability of the Montane Plains survey (Acres, 1980), it was decided to carry out the study mainly through field verification of the soil mapping units. Six days of fieldwork were undertaken during which auger observations were made and three profile pits were opened up. As far as analytical data are concerned, this report relies completely on the information contained in the Montane Plains report.

1.2 CLIMATE

Generally the climate in the north of Yemen is controlled by the air circulation resulting from large-scale pressure systems of the Arabian deserts to the north and the Indian ocean to the south. In winter, from November to February, north-easterly winds from the high pressure system over the deserts bring very dry settled weather with little cloud, high radiation and a large diurnal range of temperature. In early summer, between March and May, south-westerly winds resulting from the weakening of this high pressure zone bring some rain, followed by heavier rain in mid-summer (between July and September), associated with the northward movement of the intertropical convergence zone.

According to a recent study (Bruggeman, 1997) the survey area is located in agro-climatic zone 6a, which has two representative rainfall stations, viz. Dhamar at 2100 m and Risaba at 2300 m altitude. A summary of climatic data for the Dhamar station is shown in appendix 2. The following details pertain to zone 6a :

a) *Rainfall*

In this zone the first rainy period starts around mid March - beginning of April. The second rainy period begins mid July - beginning of August and stops abruptly at the end of August. The months September through to February are generally dry, although occasional thunderstorms may bring some rain during these months. The number of rainy days with precipitation amounts above 5 mm/day varies between 15 and 25. The average amount of rainfall per rain day is about 16 mm.

b) *Potential evapotranspiration*

The potential evapotranspiration (PET) for an average year varies depending on altitude and wind exposure. The PET is 3-4 mm/day during the dry, cold period and around 5 mm/day during the months May and June. The average annual evapotranspiration is about 1500 mm.

c) *Temperature*

The mean monthly maximum temperature varies between 22-25°C during the cold months of November through February, and 28-30°C during the warm months of June to September, while the mean monthly minimum temperature varies between 0-3°C during the cold months of November through January, and 10-14°C during the wet month of July. Night frost may occur between October and February.

d) *Relative humidity*

The mean daily relative humidity in zone 6 varies according to the seasons. The mean daily relative humidity ranges between 40 and 50% during the cool and dry period, between 50 and 65% during the wet months of July and August, and between 25 and 40% during the hot, dry months of May and June.

e) *Length of growing period*

The length of growing period in agro-climatic zone 6a is about 60 days for the first rainy period, and 40 days for the 2nd rainy season, with a dry interval of about 50 days. The first growing season is intermediate, i.e. fairly reliable (occurring roughly in about 7 out of 10 years), while the 2nd is normal (9 out of 10 years). But these growing periods are obviously too short to cultivate cereals, and hence additional water has to be provided to extend the growing seasons, or bridge the dry interval. Traditionally this is done through rainwater harvesting, or with the aid of spring waters for areas falling under the command of springs. Providing water from underground water reservoirs and/or perennial wadis is a more modern method to ensure that crops can complete their growing cycle.

f) *Soil temperature and soil moisture regime*

According to Bruggeman (1997) the soil temperature regime is thermic (mean annual soil temperature at 50 cm depth between 15 and 22°C, with a difference between summer and winter of more than 5°C), while the soil moisture regime has been classified as aridic (moist in some or all parts of the soil for <90 consecutive days, and dry for >180 cumulative days). However, many areas receive, apart from rainfall, water from runoff over adjoining area, through which additional water is made available to the soil. This modifies the soil moisture regime in such areas to weak aridic, bordering on an ustic (dry for >90 but <180 cumulative days) soil moisture regime.

1.3 WATER

Springs and wells are the most reliable source of surface water. They commonly occur at the interface between different volcanic strata in the study area. There is also a perennial stream coming from the Dhamar wastewater treatment plant, which passes from the south down to the north through the area. Inhabitants are sometimes using this wastewater to irrigate their field crops.

1.4 GEOLOGY AND LANDFORM

In the study area alluvium is the most important parent material for soil formation. Of the various rock types two stand out above all others, the dark basalts and the pale lithified pyroclastic ash deposits. The geology in the survey area is essential to an understanding of the soils, their origin, parent material and distribution. Table 1 shows in brief landforms, their geological formation and lithology for the study area.

fig. 1 Relationship landorm - geology

Landform	Formation	Lithology
Plateau and lava flows Valley Plateau	Tertiary Yemen volcanic Quaternary alluvium	Basalt Alluvium Ash-tuff

1.5 LAND USE

Agriculture in the survey area is dominantly based on field crops (sorghum, maize, barley and vegetables) along Al-Mawahib valley, while the plateau and the rocky pediment are used for grazing. All land is used for cultivation, grazing or water harvesting.

Chapter 2 Soil characteristics

2.1 PHYSICAL CHARACTERISTICS

a) *Soil depth*

Three features limit the depth of root penetration :

i Rock
ii Dominant stones and gravel
iii Soil horizon cemented by lime.

Very shallow soils (<30cm) and shallow soils (30-50 cm) over rock or gravel are widespread on the level or gently sloping surfaces of the central plateau. Minor depressions associated with stony ridges on the plains, alluvial fans and to a lesser extent some terraced hillsides have moderately deep soils. Deep soils are confined to the valleys and plains.

b) *Texture and drainage*

Texture is broadly related to parent material. Coarser textures are associated with metamorphic rocks, sandstones, tuffaceous ash and alluvium derived from these rocks, whereas more clayey soils can be linked to more basic rocks. Texture is also closely related to the process of erosion and deposition, with medium textured soils occurring in minor valleys and on hillsides, while moderately fine to fine textured soils can be found in major valleys and on plains. The majority of soils are well drained. Soils affected by groundwater occur only in areas where the wastewater passes through, and where springs debouch, mainly in wadi Al-Mawahib.

c) *Colour*

With the exception of recent sand deposits, soils are dominantly yellowish brown with a 10YR hue. Horizons containing more than 1% organic matter are very dark brown to black in colour, and gley horizons (i.e. horizons subjected to regular water logging) are greyish or have brown and yellowish mottles. Calcic horizons have pale or white colours. Strong red colours attract attention because of their rarity, they are either buried beneath lava flows or below basalt caps.

d) *Soil structure, porosity and bulk density*

Moderately fine to fine textured soils show moderate to strong angular or subangular blocky structures, while some dark buried layers show prismatic features. Some clay soils display strong vertic properties, developing cracks 1 cm or more wide to a depth of 50-100 cm with slickenside development in the subsoil. Otherwise the soils are porous and well drained, while in coarse and medium textured soils porosity is depending on texture and bulk density.

e) *Soil-water relationship*

Measurements of available moisture were carried out by the Montane Plains and Wadi Rima' project (Acres, 1980) using a neutron probe at 6 infiltration measurement sites. As there is little textural variation between the sites, they show a rather similar moisture availability of 11-21% for medium textured soils. The results are included in table 2. Soil moisture is of supreme importance for plant growth in this semi-arid environment, both in terms of providing the plant with moisture and in ensuring a proper uptake of nutrients, including those provided by inorganic fertilizers.

In broad terms soils can be divided into those soils where moisture is reliably adequate in :

i) Most years during the growing season. These are deep medium to fine textured soils with a good infiltration and high moisture availability, situated in depressions, valleys and the lower parts of plains, or on terraced footslopes of hillsides, all receiving runoff water which supplements annual rainfall.

ii) Wet years only, due to either a coarse texture, shallow depth, low infiltration rate, and sites which do not receive additional runoff water.

Table 2 shows the infiltration rates and available moisture for the different soil series in the study area.

table 2 Infiltration rate and available water for soil series in the study area*

Series name	Pit no.	Texture	Depth (cm)	Infiltration rate (cm/hr)		Class	Available water (%)
				1 hr	5 hr		
Rakhamah	98	SiC	0-100	26	9	very high	nd
Bani Falah	103	SiL	0-50	4.4	4.1	high	nd
Jahran	57	SiL SiC	0-25 25-100	2.2	1.9	medium	12
Atalaba	40	L SiL	0-55 55-80	4.8	3.9	high	14
Yefa	55	CL L rock	0-20 20-40 40+	3.5	3	high	nd
Maris	39	SiL SiC	0-30 30-70	1.8	1.5	medium	21

* data derived from Acres (1980); nd=notdetermined
SiC=siltyclay, SiL=siltyloam, L=loam,CL=clayloam

2.2 CHEMICAL CHARACTERISTICS

a) *Soil reaction (pH)*

All soils in the study area are alkaline and the majority of soils have pH values in the range of 8-8.5. pH values of 8.6 or higher are usually associated with high contents of exchangeable sodium. Soils with pH values of less than 8 are rare in the study area. There is little or no change in pH with depth even between different textures.

b) *Organic matter*

Levels of organic matter calculated from the determination of organic carbon are low to very low, being less than 1% in most soils. Exceptions are the cambic soils, in which organic matter in the topsoil and upper subsoil exceeds 1%. However, since the colour of the topsoil is too light to qualify as a mollic A (topsoil) horizon, there might be an analytical overestimation of the organic carbon content. Another possibility is that the upper layer of the soil has been mixed with (part of) a buried topsoil, which according to Acres (1983) is a relic from a period when the Dhamar plain was much more wetter than at present. Profile 9, representing the Jahran series, is an example of this kind of situation.

c) *Cation exchange capacity*

Most soils have a cation exchange capacity (CEC) that lies in the range 15-30 cmol/kg per 100 g soil. The CEC is clearly related to clay, lime and organic matter contents. The CEC ranges from less than 6 to more than 40 cmol/kg in relatively heavy soils. Coarse textured soils have a CEC of around 6 cmol/kg, although with a high lime content the CEC may increase to 10-20 cmol/kg. The CEC of medium textured soils ranges around 15-30 cmol/kg, while the CEC of most moderately fine to fine textured soils, and dark horizons, are often greater than 30 cmol/kg.

In general, a high CEC value is indicative of a high capacity to retain nutrients. In calcareous soils, such as in the study area, this effect is negated by the fixation of nutrients, in particular P, through the formation of Ca complexes.

d) *Major nutrients*

Total N is low to very low, less than 1%, and decreases with depth. Available phosphorous is invariably very low in all soils, less than 5 ppm (Bray no. 2 method), and usually nil near the surface. Exchangeable potassium is medium to high at the surface (0.4-1.0cmol/kg), decreasing with depth to about 1 cmol/kg in almost all soils.

e) *Calcium carbonate (lime)*

All soils in the study area are calcareous, and almost all have free lime which is usually visible in the soil profile. It takes the form of pseudomycelia, pore linings, coatings on pebbles, discrete nodules or cemented layers.

f) *Salinity and alkalinity*

Saline soils occur in areas of poor drainage or where groundwater tables were formerly near the surface (e.g. wadi Al-Mawahib).

2.3 FERTILITY

As indicated above, the chemical fertility of all soils is low. This can be overcome through the application of inorganic and organic fertilizers. However, the major management action to be recommended is to raise the organic matter content of the topsoil. This will not only increase the number of sites to which nutrients can be attached, without fixing them permanently, it will also enhance the N status of the soil, and will moreover drastically improve the physical fertility of the soil. The latter will have a positive affect on soil tilth, on its infiltration rate, and will reduce sealing and capping of the surface layer, a phenomenon especially prevalent in silty soils such as found in the study area. Through providing the topsoil with a better structure, organic matter also contributes to strengthening soil resistance to erosion.

Increases in organic matter can be achieved through the application of farmyard manure, the incorporation into the soil of stover, and the ploughing under of a green crop such as alfalfa or clover. It is realized that in Yemen virtually all the crop organic matter not suitable for human consumption is used as stockfeed. Nevertheless, it is strongly recommended that the project advocates measures to increase the organic matter content of the soil as this is the single-most, and most economic, manner to improve the quality of the soil.

Chapter 3 Soils and their distribution

3.1 SOIL CLASSIFICATION

The main properties used in the study area to differentiate soils are texture, depth, drainage and presence of a calcic horizon, salinity and/or alkalinity. Subsidiary properties are cracking and slickenside (very smooth sub-horizontal ped faces) development. The presence of a dark horizon at shallow depth is ignored.

The soils are differentiated in terms of series on the assumption that:

- Each series has it own particular management requirements
- Each series can be mapped as a separate unit (see chapter on soil map) in more detailed surveys

The main characteristics of each series are described below (partly after Acres, 1980). The series names, as used by Acres (1980), have been maintained. It should be noted, however, that a national register of established series in Yemen is under development. Through merger with other series, redefinition etc, the series names may in future change. A conversion table will, however, be available to link old series names with new names.

The international classification, according to the World Reference Base for Soil Resources (FAO, 1998) and Soil Taxonomy (USDA, 1994), which is based on the profile descriptions given in Appendix 3, is summarized in table 3, together with some general characteristics. The correlation with the international classification systems is not similar to Acres' correlations (see profile descriptions in Appendix 3,) as more recent versions of the respective systems have been used. Although some of the soils, according to their analytical data, have a low lime content, their profile descriptions indicate the presence of secondary lime accumulations, which is in keeping with the general conditions of the soils in the area. They have therefore been considered as "calcaric" subunits.

3.2 SOIL SERIES

a) *Rakamah series*

This is a deep, moderately well drained alluvial clay soil with an uniform texture to at least 100 cm depth. It is distinguished by its vertic properties, i.e. when dry it forms cracks at least 1 cm wide at the surface, sometimes creating a polygonal surface pattern. These cracks continue to at least 50 cm below the surface with slickenside development on structural faces. The cracks close when the soil is thoroughly wetted. This movement, brought about by the shrinking and swelling of clay minerals, can cause root damage. Its great advantage is in allowing rain to percolate rapidly into the soil after a dry period. Due to the high clay content, often greater than 50% (a clayey textural class), these soils tend to release moisture for a prolonged period so that crops grown on these soil can bridge a dry interval more easily than crops on other soils. CEC values are high, averaging 37 cmol/kg, while exchangeable magnesium is high to very high. There is little variation in these properities with depth. A buried dark horizon may occur.

Correlation : Chromic Vertisol (WRB, 1998)
Chromo Haplotorrert (USDA)
Representative profile : 63

b) *Maris series*

This is a deep, well-drained alluvial soil distinguished by its uniform texture below the plough layer, ranging from clay, silty clay loam to silty clay, sometimes clay loam or clay to at least 100 cm depth. The surface texture of the plough layer is silty clay loam or silt loam. Soils with textures intermediate between Maris series and Atalabah series are included in the Maris series if there is more than 50 cm of silty clay loam or silty clay below the plough layer as a continuous layer. Thus the dominant texture is silty clay, and the family textural class is coarse loamy. Some soils show slickenside development below 50 cm, but no deep cracking. Soils with moderately high ESP between 50-100 cm occur where groundwater tables have fallen, e.g. near Milla, and saline-alkali conditions have developed near the fringe of Al-Mawahib village.

Correlation : Vertic Cambisol (WRB, 1998)
Vertic Halocambid (USDA, 1994)
Representative profile : 58, DHE079

c) *Atalabah Series*

This is a deep well drained alluvial soil distinguished by layers of different texture below 30 cm. The contrast is between layers of loam or silt loam intercalated with clay loam, silty clay loam, silty clay or clay. It includes sites that are intermediate in texture between the Maris series (coarse silty) and Bani Falah series (coarse loamy). Despite the variation in texture, there is no marked change in most chemical properties. The main feature is higher CEC values in the clayey layers, as compared to the more loamy soils (30-40 cmol/100 g soil versus 20-30 cmol/100 g soil).

Correlation : Calcaric Cambisol (WRB, 1998)
Typic Haplocambid (USDA, 1994)
Representative profile : 66, DHE080

d) *Bani Falah Series*

This series is deep, well drained alluvial soil characterised by its uniform loam or silt loam texture from the surface to at least 100 cm depth. In most soils the silt content is above 40% and the sand content less than 50% (fine and coarse loamy family texture). The buried dark horizon is rare. CEC values are moderate (mostly in the range 20-30 cmol/100 g soil), but lower values (around 15 cmol/100 g soil) occur as well in some valleys.

Correlation : Calcic Cambisol (WRB, 1998)
Typic Haplocambid (USDA, 1994)
Representative profile : 79

e) *Jahran Series*

This is a deep, well drained alluvial soil distinguished by a calcic horizon extending from close to the surface to 100 cm or deeper. The calcic horizon shows variations in lime content, with a maximum in the "Grey calcic horizon" (lime content ranging from 30 to 70%) between 50 and 100 cm depth. This is overlain by layers of different colour ranging from brown to very dark greyish brown, all with a lime content in excess of 15%. In the grey calcic horizon the CEC value is rather low, about 9-20 cmol/100 g soil. Surface textures are silty loam, even silty clay over silty clay loam. The family class texture is clayey. Shells are often prominent features of the grey horizon. Organic matter content varies sometimes irregularly with depth and may be greater than 1%, suggesting an alluvial origin. Unusual chemical characteristics are a high to very high content of exchangeable and total magnesium. Some parts are slightly alkaline below 50 cm.

Correlation : Haplic Calcisol (WRB, 1998)
Typic Haplocalcid (USDA, 1994)
Representative profile : 9

f) *Balasan Series*

This is a deep, well drained alluvial soil with texture below the plough layer of clay loam, silty clay loam, silty clay or clay, usually to a depth of at least 100 cm, similar to Maris series, and sometimes with textural changes similar to Atalaba and Shirah series. It is distinguished from these other series by a high content of lime nodules which usually do not form a discrete layer but are scattered throughout the soil. So much lime is present that the calcium carbonate content is greater than 15% and CEC values of the soil are affected, being lower than normal for soils with an equivalent texture. Frequently the lime nodules are present within 50 cm of the surface where CEC values range from 12 to 20 cmol per 100 g soil, and then increase with depth. Organic matter content is low, though a dark horizon may occur.

Correlation : Haplic Calcisol (WRB, 1998)
Typic Haplocalcid (USDA, 1994)
Representative profile : 54

g) *Yafa Series*

This is a well-drained soil developed over basalt rock parent material. It is distinguished by depth, texture and the occurrence of a calcic horizon. Yafa Series is a shallow or very shallow soil with rock at 50 cm or less. The texture of the plough layer is loam which lies over clay loam. The clay loam (fine loamy texture at family level) is usually also a buried dark horizon with higher organic matter content than at the surface. The calcic horizon has developed within weathering basalt at the base of the profile and is discontinuous. Some soils are very stony. This soil forms on level or gently sloping plateau surfaces and on lava flows in association with many roack outcrops. It is widespread in the central hills and lava flows, and on the eastern lava flows in assoication with the Mahannashah series. The soils of this series have better moisture holding properties and fertility than the shallow soils of the Qamah series. Like them they are used mainly for wheat and barley. Deep ploughing should be avoided on these soils.

Table 3 Soil series, their classification and characteristic

Soil series	WRB classification	USDA classification	Parent material	Depth (cm)	Drainage	Family texture	$CaCO_3$ (%)	O.M. (%)	EC (dS/m)	pH	CEC soil	Repr. profile
Rakhamah	chromic vertisol	chromic haplotorrert	alluvium	>100	well	clayey	7	0.4	1		46	63
Maris	vertic cambisol	vertic haplocambid	alluvium	>100	well	clayey	7	0.1	1		35	61
Atalaba	calcaric cambisol	typic haplocambid	alluvium	>100	well	fine loamy	5	0.5	<1		26	66
Bani Falah	calcaric cambisol	typic haplocambid	alluvium	>100	well	coarse loamy	6	0.7	<1		20	79
Jahran	haplic calcisol	typic haplocalcid	alluvium	>100	well	clayey	>20	0.9	1		24	9
Balasan	haplic calcisol	typic haplocalcid	alluvium	>100	well	fine loamy	>17	0.5	0		15-25	54
Yafa	epilepti-calcaric regosol	lithic haplocambid	basic rock	30-50	well	fine loamy	6-25	0.5	<1		20-35	77
Qamah	epileptic cambisol	litic haplocambid	volcanic ash	0-30	excessive	coarse loamy	3	0.9	<1		15	47
Sawad	sodi-calcari endogleyic fluvisol	sodic tropofluvent	alluvium	>100	moderate to poor	fine loamy	16-22	1.1	6-25		18-25	64

Correlation : Epilepti-calcaric Regosol (WRB, 1998)
Lithic Haplocambid (USDA, 1994)
Representative profile : 77

h) *Qamah Series*

This is an excessively drained soil distinguished by its texture and depth to rock. It is very shallow to shallow, 30-50 cm deep, of loamy texture (coarse loamy family class) over lithified pyroclastic ash. Organic matter content is low, varying with depth. This indicates that colluvial processes have been involved in the formation of this soil. CEC values are also low (about 15 cmol per 100 g soil). It is formed on gentle slopes or ash platueaus associated with rock outcrops at the surface. It is most extensive on the plateau slopes and in parts of the southwestern and northeastern plateau. This soil is sensitive to drought and only suited to shallow-rooting crops. This series includes all soils formed on stratified gravelly deposits in which (a) horizons with dominant gravel and stones occur within 50 cm of the surface, and (b) gravel and stone content are described as common throuhout most of the profile to 100 cm. Texture is usually loam or silt loam but layers of clay or sandy loam can occur (texture at family level is fine loamy).

Correlation : Epileptic Cambisol (WRB, 1998)
Lithic Haplocambid (USDA,1994)
Representative profile : 47

j) *Sawad Series*

These soils have developed in alluvium, and are imperfectly to poorly drained due to a seasonable high groundwater table or the presence of springs. They are thus wet for certain periods of the year, but are distinguished from Nimijah series in that they can be cultivated. This has been achieved by draining the fields, although maintenance of drains has lapsed in places and some of these sites are now too wet for cultivation. In addition to drainage problems these soils are saline and sodic, at the surface if caused by springs, at depth if due to groundwater. Grey colours are common in some soils but in others brown mottles are in evidence. pH values are usually higher than 8.5 in some parts of the profile. Lime content may be greater than 15%, mainly in the form of nodules. In the valleys where springs issue, soils of Sawad series occur in very localised areas, associated with Maris series.

Correlation : Sodi-calcaric endogleyic Fluvisol (WRB, 1998)
Sodic Tropofluvent (USDA,1994)
Representative profile : 64, DHE081

3.3 SOIL MAPPING UNITS

The distribution of the different soils throughout the study area is shown on attached soil map, scale 1:20,000 (after Acres, 1980). The mapping units are described as soil series where a single series is dominant. Where there is an association, the map legend indicates for each mapping unit the dominant soils (occupying >50%), associated soils (>20%) and included soils (< 20%).

A number of soil series have been mapped together as associations. In associations a more detailed survey would be required to map soils separately. There are two kind of assocations. Firstly, associations where an assemblage of soils occurs, with no one series being dominant. The Thamar association is such an association, as it occurs in valleys where springs issue, and where soils of the Sawad series occur in association with the Maris series. The other type of association has a dominant soil, with pockets of other soils. The Yizlah series is such an association, as it consists mostly of steeply sloping rocks with shallow soils (Yizlah series), but contains small dispersed areas where Yafa, Qamal and Bani Falah series can be expected.

Mapping units bear the name of dominant soil series. For example, Maris series (MS), which occurs in valley floors and plains, merges upslope into Atalaba series, while downslope the lower parts change into Rakhamah series. The Maris series, however, is dominant in this unit and hence provides it with its name. Table 4 gives a brief description of all the mapping units.

Table 4 Soil mapping units

Map unit symbol	Physiography	Soil Characteristics	Associated Soil Series (20-50%)	Included Soil Series (< 20%)
RM	Plain	Deep slightly calcareous soil, well drained, clayey, alluvium; this soil has cracks as limiting factor	MS	
MS	Plain/Large valleys	Deep calcareous soil, well drained, silty clay loam, silty clay, clay loam and clay texture; alluvium	AB	RM,TV,SH
AB	Plains/valleys	Deep calcareous soil, well drained, loam over silty loam; alluvium	MS BH	NH
BH	Minor valleys and footslope	Deep soil, well drained, loam over silty loam, with stony and sandy layers; alluvium; saline phase.	AB	SH
UN	Lower parts of plain	Deep soil, well drained, silty clay loam and silty clay, with grey calcic horizon between 50-100 cm; alluvium	MS TN	KF
BN	Plateau/plain	Deep soil, well drained, silty clay loam and silty clay, contains weathered rock with nodules, calcic horizon within 100 cm, stony layers may occur; alluvium/colluvium	MS AB	WH YF
YF	Plateau and lava flows	Shallow soil, well drained, silty clay loam with nodules; calcic horizon between 30-50 cm	MH	AB,MS,YF, rock
QH	Plateau	Very shallow soil, excessive drainage, loam to silty loam texture, stony phase; volcanic parent material	YF	AB MS
SW	Valley with stream	Deep soil, moderately well to poorly drained, silty clay loam to silty clay texture; alluvium with an EC of >4 dS/m and an ESP of >15	NJ MS	JB RM

CHAPTER 4 LAND SUITABILITY

4.1 LAND SUITABILITY CLASSES

In this chapter a more detailed appraisal is given of soil limitations and land suitability for rainfed crops and trees. Suitable land is divided into three classes according to the severtiy of the limitations. These are defined in the table below. Suitability class N1 (Provisionally not suitable) can only be applied to areas where drainage improvement is possible.

Table 5 Land suitability classes

Code	Class	Limitation
S1	Highly suitable	Land with no limitations
S2	Moderately suitable	Land with moderate limitations
S3	Marginally suitable	Land with severe limitations
N	Not suitable	Land with very severe limitations
N1	Provisionally not suitable	Land which could be suitable ifimprovements were made

a) *Limitations*

The limitations on land suitability for rainfed crops and trees are mainly physical, climate, site, and some factors of depth, texture and drainage. All of these affect the available soil moisture which, in a (semi-) arid environment is considered to be the chief limitation to plant growth. Other important limitations can be soil salinity and alkalinity, while a calcic horizon is of lesser importance and is not considered in the assessment of suitability. The limitations affect crops in varying degrees depending on the crop requirements for good growth.

b) *Rooting requirements*

Rainfed crops have been divided into two groups, based on their moisture requirements, shallow rooting and deep rooting crops. Shallow rooting crops (abbreviation SR) include wheat, barley and legumes for which 50 cm of soil is assumed to be adequate for good growth. Deep rooting crops (abbreviation DR) include sorghum, maize (grown only under irrigation, however), alfalfa and potatoes. Although red sorghum is far more hardy than either yellow or white sorghum, all three crops are treated as equal in terms of rooting depth. Crops vary in their tolerance to salinity and poor drainage.

Whether grown for fruit, browse or timber, tree crops are classified as very deep rooting plants requiring more than 100 cm soil for good growth. They differ from rainfed crops in being perennial and thus have time to put roots down to great depth in search of moisture.

c) Climatic limitations

Since rainfall is marginal (see section 1.2), high valued cash crops such as vegetables and fruits can only be grown under (supplementary) irrigation. This is already being practised in study

area. Provision of treated sewage water to the area would contribute to increasing the acreage and quality of these crops, provided the better soils (S1) are being used for their cultivation.

Table 6 Soil limitation for the growth of rainfed crops and trees

Characteristic	Class	limitation for rainfed crops		limitation for trees
		Shallow rooting	Deep rooting	
Depth (d)	< 10 cm 10-30 cm 30-50 cm 50-100 cm >100 cm	very severe moderate nil nil nil	very severe severe moderate nil nil	very severe severe severe moderate nil
Drainage (w)	Poor Imperfect Moderately well Well Excessive	very severe moderate nil nil severe	very severe severe moderate nil moderate	very severe severe moderate nil moderate
Texture (t)	gravelly (0-50 cm) S, LS SL, SiL, clay L,SCL, SiCL,CL,SiC	very severe severe moderate nil	very severe severe nil nil	severe moderate nil nil
Calcic horizon (c)	cemented (0-50 cm) cemented (50-100 cm) nodules (0-50 cm) grey (50-100 cm)	severe nil moderate n/a	severe moderate moderate nil	severe moderate moderate nil
Salinity/ alkalinity (n)	EC>15 dS/m (0-50 cm) ESP>15% (50-100 cm)	very serve	very severe	very severe
	EC 4-15 dS/m (0-50 cm) EC>15 dS/m (50-100 cm) and/or ESP>15% (50-100cm)	moderate	severe	severe
	EC 4-15dS/m (0-100 cm) and/or ESP 6-15% (50-100 cm)	moderate	moderate	moderate
	EC<4 dS/m (0-50 cm) and ESP<6% (0-100 cm)	nil	nil	nil

d) *Site limitation*

The landform on which soils occur are considered as either "receiving" or "shedding" sites. Receiving sites are supplied with runoff water from elsewhere which supplements rainfall, and in the study are in most years ensures an adequate moisture for good crop growth. These are mainly walled terraces on or at the foot hill and mountain slopes, in valleys, minor depressions, and the middle and lower parts of most plains. Shedding sites are those which do not receive supplementary water, but rather supply runoff to other sites. They include all uncultivated slopes, minor ridges in gently undulating terrain and on plains, plateau and lava surfaces and wash fans. For the purpose of land suitability it is assumed that rainfall is adequate in most years on these sites unless soil factors are limitations.

4.2 SOIL SERIES AND LAND SUITABILITY

Soil series has been given a suitability rating based on its properties (see tables 4 and 6). For example Yafa series has depth limitations, which are severe for deep-rooted rainfed crops and trees but are moderate for shallow-rooted crops. Usually this classification is rather general and should be used as a guide to the most suitable soils and where they occur. Further investigations should test out its validity for both rainfed and tree crops.

Table 7 Suitability classes for the soil mapping units

Mapping Unit Symbol	Rainfed arable crops SR	DR	Tree
RM	S2W	S1	S1
AB	S1	S1	S1
BH	S1	S1	S1
JN	S2c	S2c	S2c
BN	S2c	S2c	S2c
YF	S2d	S3d	S3d
QH	S2d	S3d	S3d
SW	S3wn	S3wn	S3wn
MS	S1	S1	S1

Limitations : d =depth, c =calcareous, w =drainage, n =salinty

Chapter 5 Recommendations

1. The main area where drainage needs to be improved is the part of the valley between Al-Mawahib and Mankadhah, particularly in and below the gorge. The present system comprises a central channel to carry the main stream and flood flows, and two diversion canals that lead water along either side of the gorge. Several fields in the gorge have been abandoned due to water pounding on their surface, and severe gleying (development of phenomena that are related to long periods of ponding) has developed in the soil. Wells along the side of the gorge are old, without pumps, and look neglected or abandoned.

   Below the gorge, the depth of the groundwater table varies over short distances with consequent variations in soil drainage. Near very shallow wells, some of which orginally probably were spring sites, land is often left as grass, just one or two fields, and soils are soils are poorly to imperfectly drained, with water between 40-80 cm below the surface. Greyish ghley soil colours are dominant and orange mottling prominent. On cultivated land, away from the centre of the valley, groundwater is between about 80-120 cm below the surface, and soils are imperfectly to moderately well drained. Towards the sides of the valley, where terraces are well developed, there is no evidence of impeded drainage. In order to make this land (more) suitable for crop production, the drainage conditions will have to be drastically improved.

2. It is suggested that the highest priority for land development should be given to rainfed land without limitations or with moderate limitations, i.e. suitability classes S1 and S2, which are at the same time extensive and accessible. These soils include Bani Falah and Maris series which represent the main textural differences between soils, together with associated soils of Atalaba and Rakahmah series, the latter requiring special management attention because of heavy texture.

3. Lowest priority should be given to marginal land of suitability class S3, among these first consideration should be given to soils of greater extent, namely Yafa and Qamah series. The least attention can be given to problem series such as the Sawad series.

4. Apart from the crop-water management issues, through an improved flow of wadi Mawahib, particular attention should be paid to improving soil conditions to make them more suitable for crop production. In particular increasing the organic matter content in the topsoil should be high on the agenda.

5. Other problems specifically related to the soil that should be investigated are :
   a) The effect of the calcic horizon in its different forms on moisture availability and crop growth,
   b) The effect of different drainage conditions on crop performance,
   c) Mointoring of soil salinity and its effects on crop growth and yields.

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station: Dhamar (agro-)metecrological
latitude: 14°21' average 1987-1992
longitude: 44°20'
altitude: 2400 m

		Temperature (°C)			RH	sun	radiation	winds	PET		rainfall (mm)					
		max	min	mean	%	h/d	MJ/m²/d	m/s	mm/d	mm/dec	average	1987	1988	1990	1991	1992
	dec-1	22.3	2.9	12.6	46	9.4	15.0	1.3	3.1	31	0.0	0.0	0.0	0.0	0.0	0.0
Jan	dec-2	22.3	2.9	12.6	51	9.6	15.3	1.3	3.1	31	0.0	0.0	0.0	0.0	0.0	0.0
	dec-3	22.3	4.0	13.1	46	9.2	15.4	1.4	3.3	33	0.0	0.0	0.0	0.0	0.0	0.0
	dec-4	22.3	5.4	13.8	44	8.8	15.5	1.7	3.6	36	3.6	0.0	0.0	16.0	0.0	0.0
Feb	dec-5	22.3	6.1	14.2	43	8.7	15.8	1.8	3.8	38	1.0	0.0	0.0	3.0	2.0	0.0
	dec-6	23.1	6.8	15.0	44	8.8	16.5	1.7	4.0	40	10.0	13.2	0.0	18.0	19.0	0.0
	dec-7	24.1	7.8	16.0	45	9.1	17.1	1.6	4.2	42	25.2	69.2	9.0	9.0	39.0	0.0
Mar	dec-8	24.6	8.3	16.5	46	9.2	17.7	1.6	4.3	43	10.0	23.0	0.0	3.0	18.0	8.0
	dec-9	24.6	8.8	16.7	47	9.1	17.8	1.6	4.4	44	39.0	24.8	0.0	96.0	32.0	42.0
	dec-10	24.5	9.3	16.9	47	9.0	17.9	1.7	4.5	45	23.6	65.0	0.0	13.0	28.0	12.0
Apr	dec-11	24.6	9.6	17.0	46	8.9	17.9	1.7	4.5	45	13.7	21.5	42.0	0.0	5.0	0.0
	dec-12	25.2	9.9	17.6	46	9.1	18.2	1.7	4.7	47	7.3	0.0	8.4	16.0	0.0	12.0
	dec-13	26.2	10.4	18.3	43	9.3	18.4	1.8	4.9	49	16.6	18.2	0.0	6.0	27.0	32.0
May	dec-14	26.7	10.6	18.6	42	9.5	18.5	1.8	5.0	50	8.4	1.0	5.8	6.0	0.0	29.0
	dec-15	27.1	10.9	19.0	41	9.4	18.3	1.8	5.0	50	1.2	5.0	0.0	1.0	0.0	0.0
	dec-16	27.7	11.3	19.5	39	9.4	18.1	1.8	5.1	51	0.5	2.4	0.0	0.0	0.0	0.0
Jun	dec-17	28.0	11.5	19.7	38	9.3	18.1	1.8	5.1	51	9.7	2.5	32.0	0.0	4.0	0.0
	dec-18	27.7	11.6	19.7	40	8.9	17.5	1.9	5.0	50	1.8	0.0	0.0	0.0	4.0	5.0
	dec-19	27.4	11.7	19.6	42	8.3	16.9	2.0	4.9	49	1.8	0.0	0.0	1.0	2.0	6.0
Jul	dec-20	27.3	11.7	19.5	43	8.0	16.6	2.0	4.9	49	9.0	4.1	19.8	3.0	3.0	15.0
	dec-21	27.0	11.7	19.4	45	7.9	16.5	1.9	4.8	48	43.6	10.8	111.3	35.0	2.0	59.0
	dec-22	26.8	11.7	19.2	46	7.8	16.3	1.8	4.6	46	26.4	7.0	39.0	40.0	2.0	44.0
Aug	dec-23	26.4	11.7	19.1	49	7.5	16.2	1.8	4.5	45	43.9	35.7	61.8	20.0	30.0	72.0
	dec-24	26.2	11.1	18.7	48	7.9	16.5	1.7	4.5	45	26.6	0.0	49.1	2.0	16.0	66.0
	dec-25	26.0	10.4	18.2	46	8.4	17.0	1.7	4.5	45	17.7	22.0	32.4	8.0	10.0	16.0
Sep	dec-26	25.8	10.0	17.9	46	8.6	17.1	1.7	4.5	45	2.1	0.0	3.4	3.0	0.0	4.0
	dec-27	25.2	9.1	17.2	44	9.0	17.3	1.7	4.4	44	0.2	0.0	0.0	0.0	0.0	1.0
	dec-28	24.5	7.9	16.2	42	9.6	17.6	1.6	4.2	42	8.4	0.0	0.0	0.0	2.0	30.0
Oct	dec-29	24.1	7.3	15.7	41	9.9	17.4	1.6	4.1	41	0.0	0.0	0.0	0.0	0.0	0.0
	dec-30	23.6	6.2	14.9	41	9.9	17.0	1.6	3.9	39	0.0	0.0	0.0	0.0	0.0	0.0
	dec-31	23.0	4.8	13.9	41	9.9	16.4	1.6	3.8	38	1.4	0.0	0.0	0.0	0.0	7.0
Nov	dec-32	22.7	4.1	13.4	41	9.9	16.0	1.4	3.4	34	0.0	0.0	0.0	0.0	0.0	0.0
	dec-33	22.6	3.7	13.1	42	9.7	15.6	1.4	3.3	33	4.8	0.0	0.0	0.0	0.0	24.0
	dec-34	22.4	3.1	12.8	43	9.5	15.0	1.4	3.2	32	0.8	0.0	0.0	0.0	4.0	0.0
Dec	dec-35	22.4	2.8	12.6	43	9.4	14.8	1.4	3.1	31	0.0	0.0	0.0	0.0	0.0	0.0
	dec-36	22.4	2.9	12.6	46	9.4	14.8	1.4	3.1	31	3.4	17.0	0.0	0.0	0.0	0.0
Year		24.8	8.1	16.4	44	9.0	6039	1.7	4.2	1507	380	352	414	301	249	432
										P/PET	0.2	0.2	0.3	0.2	0.2	0.3

Appendix 3

Soil profile descriptions and analytical data

SOIL PROFILE 1

GENERAL DESCRIPTION

Profile code :	DHE079	Date :	13/10/98
Author :	Abdullah Al-Borani		
Soil classification :	Typic Haplocambid (USDA 1994) Calcaric Cambisol (WRB, 1998)		
Location :	Al-Mawahib area, wadi Al-Dhahr, N of Dhamar		
Map sheet :	1444 A4 (UTM grid 04391-016131)		
Elevation :	2320 m	Slope :	1 - 2% straight
Landform :	highland plain	Land element :	valley
Topography :	flat	Micro-topography :	even
Land use :	small scale irrigated agriculture	Human influence :	-
Crops :	cereals		
Vegetation :	nil		
Parent material :	alluvium		
Effective soil depth :	>150 cm	Groundwater depth :	not observed
Erosion :	slight	Sealing/crusting :	nil
Rock outcrops :	nil	Surface stones :	nil
Drainage :	moderately well		
Permeability	moderately rapid		
Moisture conditions :	0 - 25 cm dry, 25 - 100 cm moist		
Remarks :	- nature of cutans not clear - soil classifications tentative		

SOIL DESCRIPTION

Ap	0 - 25 cm	yellowish brown (10YR 5/4, dry) clay loam; moderate fine and medium subangular blocky; soft (dry), friable (moist), sticky and plastic (wet); common fine pores; common medium roots; slightly calcareous; clear and wavy boundary.
Bw1	25 - 40 cm	dark brown (10YR 3.5/4, moist) clay loam; moderate fine and medium subangular blocky; soft (dry), friable (moist), sticky and plastic (wet); common fine pores; common medium roots; slightly calcareous; clear and wavy boundary.
Bw2	40 - 75 cm	dark brown (10YR 3/3, moist) clay loam; moderate fine and medium subangular blocky; soft (dry), friable (moist), sticky and plastic (wet); common fine pores; common medium roots; slightly calcareous; clear and wavy boundary.
Bt	75 - 100 cm	dark brown (10YR 3/3, moist) clay; weak to moderate medium subangular and angular blocky; soft (dry), friable (moist), sticky and plastic (wet); common fine pores; many faint cutans on pedfaces; common medium roots; slightly calcareous.

SOIL PROFILE 2

GENERAL DESCRIPTION

Profile code :	DHE080	Date :	13/10/98
Author :	Abdullah Al-Borani		
Soil classification :	Typic Haplocalcid (USDA 1994) Typic Calcisol (WRB, 1998)		
Location :	Al-Mawahib area, wadi Manqadah, N. of Dhamar		
Map sheet :	1444A4 (UTM grid 04362-016158)		
Elevation :	2350 m	Slope :	1 - 2% straight
Landform :	highland plain	Land element :	fluvial terrace
Topography :	flat	Micro-topography :	even
Land use :	small scale irrigated agriculture	Human influence :	none
Crops :	cereals		
Vegetation :	nil		
Parent material :	alluvium		
Effective soil depth :	>150 cm	Groundwater depth :	not observed
Erosion :	slight	Sealing/crusting :	nil
Rock outcrops :	nil	Surface stones :	nil
Drainage :	moderately well		
Permeability	moderate		
Moisture conditions :	0 - 30 cm dry, 30 - 120 cm moist		
Remarks :	- inclusion in mapping unit MS - soil classifications tentative - nature of cutans not known		

SOIL DESCRIPTION

Ap 0 - 30 cm brown (10YR 5/3, moist) and pale brown (10YR 6/3, dry) silty clay; weak to moderate medium and coarse subangular and angular blocky; soft (dry), friable (moist), sticky and plastic (wet); common fine pores; common fine and medium roots; strongly calcareous; clear and smooth boundary.

Bwk1 30 - 50 cm brown (10YR 4/3, moist) silty clay; weak to moderate fine and medium subangular and angular blocky; soft (dry), friable (moist), sticky and plastic (wet); common fine pores; discontinuous weakly cemented by carbonates; common spherical soft white calcareous segregations; common fine and medium roots; strongly calcareous; clear and smooth boundary.

Bwk2 50 - 70 cm brown (10YR 4/3, moist) silty clay; moderate to strong medium subangular and angular blocky; hard (dry), firm (moist), sticky and plastic (wet); common fine pores; common faint cutans on pedfaces; common medium spherical soft white calcareous segregations; nil roots; strongly calcareous; clear and smooth boundary.

2Bw 70 - 100 cm dark brown (10YR 3/3, moist) silty clay loam; moderate to strong medium subangular and angular blocky; hard (dry), firm (moist), sticky and plastic (wet); common fine pores; common faint cutans on pedfaces; strongly calcareous; clear and smooth boundary.

SOIL PROFILE 3

GENERAL DESCRIPTION

Profile code :	DHE081	Date :	14/10/98
Authors :	Abdullah Al-Borani		
Soil classification :	Aquic Ustrochrept (saline phase) (USDA 1994) Gleyic Cambisol (WRB, 1998)		
Location :	Al-Mawahib area, wadi Al-Makalem, N. of Dhamar		
Map sheet :	(UTM grid 04353-016180)		
Elevation :	2350 m	Slope :	1 - 2% straight
Landform :	highland plain	Land element :	wadi floor
Topography :	flat	Micro-topography :	even
Land use :	small scale irrigated agriculture	Human influence :	none
Crops :	cereals		
Vegetation :	nil		
Parent material :	alluvium		
Effective soil depth :	>150 cm	Groundwater depth :	90 cm
Erosion :	nil	Sealing/crusting :	nil
Rock outcrops :	nil	Surface stones :	nil
Drainage :	poor		
Permeability :	-		
Moisture conditions :	0 - 90 cm moist		
Remarks :	- EC groundwater (direct measurement) at 90 cm depth is 2.6 dS/m - Soil classifications tentative - salts observed at the surface - nature of cutans in Bwg horizon not known		

SOIL DESCRIPTION

Ap 0 - 45 cm dark yellowish brown (10YR 3.5/3, moist) silty clay; weak to moderate medium and coarse subangular and angular blocky; soft (dry), friable (moist), sticky and plastic (wet); common fine pores; few fine roots; moderately calcareous; clear and smooth boundary.

Bwg 45 - 90 cm dark brown (10YR 3/3, moist), with common medium distinct grey mottles, silty clay loam; moderate to strong medium subangular and angular blocky; soft (dry), friable (moist), sticky and plastic (wet); common fine pores; common faint cutans on pedfaces; few fine roots; moderately calcareous; clear and smooth boundary

Soil Series JAHRAN

Pit number: 9

Location Land unit: 23 1:50 000 map: A2 . Grid reference: 254E 389N

1.5 km west of Al Kharbah beside road to Wasitah at the junction with the Ma'bar-Al Madarah road

Physiographic position: intermontane plain

Rainfall mm: <350

Elevation m: 2 330

Slope % : level

Groundwater depth m: 10-15

Land use: cultivation - alfalfa

Soil drainage: well

Soil correlation:

FAO : Calcic Cambisol

USDA: Typic/Fluventic Ustochrept

Parent material: stratified, fine textured alluvial and lacustrine deposits

Horizon	Depth cm	
Akp	0-25	Dark yellowish brown (10YR 3/4); silt loam; moderate to strong, coarse subangular blocky structure with massive appearance; dry, slightly hard; very few stones; calcareous; clear smooth boundary
ABk	25-45	Dark brown (10YR 3/3); silty clay; moderate, fine and medium subangular blocky structure; dry, slightly hard; very few stones; calcareous; common, faint carbonate mycelia round roots; clear, smooth boundary
Bk1	45-65	Very dark greyish brown (10YR 3/2); silty clay; moderate to strong, medium angular blocky structure; dry, slightly hard; very few stones; calcareous; common mycelia as above; clear, smooth boundary
Bk2	65-110	Dark greyish brown (10YR 4/2); silty clay loam; moderate, medium and coarse prismatic structure; dry, hard; very few stones; calcareous; common shelly; common mycelia around roots; abrupt, smooth boundary
A	100-120	Black (2.5Y 2/0) becoming mottled with depth, common medium distinct yellowish brown (10YR 5/6) and strong brown (7.5YR 5/8); clay; strong, fine prismatic structure; dry, very hard; few carbonate mycelia at top of horizon; very few stones; non-calcereous; clear smooth boundary
	120-145	Very dark greyish brown (2.5Y 3/2) with many, fine, faint yellowish brown (10YR 5/8) mottles; silty clay; strong, medium prismatic structure; dry, very hard; very few stones; continuous thin cutans; non-calcareous; clear, smooth boundary
C	145-160	Olive (5Y 5/3); silty clay loam; moderate to strong, medium and coarse prismatic structure; dry, very hard; very few stones; broken, moderately thick cutans; non-calcareous patches on ped faces as very coarse mottles; abrupt, smooth boundary
	160-	Olive brown (2.5Y 4/4); sandy loam; structureless; dry, slightly hard; many subangular and round gravel often as lenses; non-calcareous

Depth cm	Lab no	Particle size class, mm				pH 1:5 H_2O	EC mmhos 1:5 H_2O	% $CaCO_3$ ads	Org C % ods	Total N % ods	Exchangeable cations meq/100g ads				CEC soil meq/ 100g	Av P Olsen	Total content ppm			Trace elements ppm			ESP
		Sand		Silt	Clay						Na	K	Mg	Ca			P	K	Mg	Cu	Mn	Zn	
		2 - 0.25	0.25- 0.05	0.05- 0.002	< 0.002																		
0-25	7193	2	19	53	26	8.5	0.13	20	0.64	0.08	0.5	0.4	8.0	>50.0	19.3	1	1 020	6 500	22 400	30	810	90	3
25-45	7194	2	10	46	42	8.5	0.13	28	0.54	0.06	0.5	0.4	11.5	>50.0	23.8	1	1 060	5 650	27 500	30	840	80	2
45-66	7195	1	5	40	54	8.4	0.17	52	0.92	0.08	0.5	0.3	12.7	>50.0	19.8	3	540	3 400	30 550	20	930	80	2
66-110	7196	1	8	55	36	8.6	0.12	72	0.84	0.05	0.3	0.1	7.9	>50.0	9.8	5	600	19 000	14 550	20	2 180	40	3
110-120	7197	1	6	36	57	8.5	0.16	1	1.23	0.06	1.6	0.6	23.0	41.2	59.6	1	420	6 250	22 400	40	1 580	80	3
120-145	7983	1	12	41	46	8.8	0.21	0	0.20	0.03	5.0	0.6	14.4	18.2	32.0	1	560	7 100	18 800	30	390	70	16
145-160	7198	3	13	53	31	9.0	0.17	0.5	0.06	0.01	4.5	0.4	10.6	14.5	28.2	<1	730	5 150	17 550	30	340	90	16
160-	7199	35	38	20	7	9.0	0.10	0	0.05	0.01	3.4	0.2	6.5	10.2	20.3	<1	710	2 450	10 200	20	340	120	17

Soil Series QAMAH

Pit number: 47

Location Land unit: 14 1:50 000 map: A1 Grid reference: 307E 167N

100 m east of Dhamar-Sana'a road at Km post 89

Physiographic position: upper convex slope (2%) of gently dissected plateau; rock outcrop class 1.

Parent material: ash

Rainfall mm: 350-550

Elevation m: 2 385

Slope % : level

Groundwater depth m: NA

Land use: cultivation - wheat

Soil drainage: somewhat excessive

Soil correlation:

FAO : Calcic Cambisol

USDA: Lithic Ustochrept

Horizon	Depth cm	
		Platy surface 1 cm thick.
A p	0-15	Brown to dark brown: (10YR 4/3); gritty loam; weak fine and medium subangular blocky; dry, soft; few, fine, irregular gravel of ash; abrupt, smooth boundary
Bw	15-30	Dark brown (10YR 3/3); loam; moderate, fine, medium and coarse subangular blocky structure; dry, soft; few, fine gravel of ash; very few, very fine, thin mycelia around roots; abrupt, smooth boundary
C	30+	Weathering rock with soil forming in crevices and cracks - calcareous coatings and mycelia on rock faces.

Depth cm	Lab no	Particle size class, mm: Sand 2 - 0.25	Sand 0.25 - 0.05	Silt 0.05 - 0.002	Clay < 0.002	pH 1:5 H_2O	EC mmhos 1:5 H_2O	% $CaCO_3$ ads	Org C % ods	Total N % ods	Exchangeable cations meq/100g ads: Na	K	Mg	Ca	CEC soil meq/100g	Av P Olsen	Total content ppm: P	K	Mg	Trace elements ppm: Cu	Mn	Zn	ESP
0-15	7890	9	32	47	12	8.3	0.08	3	0.53	0.09	0.1	0.5	1.9	42.4	13.8	2	480	4 500	11 500	20	690	70	
15-30	7891	6	28	44	18	8.3	0.09	3	0.51	0.08	0.2	0.3	2.6	49.4	15.7	1	380	4 150	10 250	20	660	70	

Soil Series BALASAN

Pit number: 54

Location Land unit: 15 1:50 000 map: A4 Grid reference: 316E 116N

25 m west of track from Dhamar to Ad Darb, 4.5 km from Dhamar

Physiographic position: Lower middle part of long gentle (2%) slope on very gently undulating plateau surface

Parent material: Moderately fine textured alluvium

Rainfall mm: 350-550

Elevation m: 2 430

Slope %: level

Groundwater depth m: NA

Land use: cultivation - old fallow

Soil drainage: well

Soil correlation:

FAO : Calcic Cambisol

USDA: Typic Ustochrept

Horizon	Depth cm	
Ap	0-20	Dark yellowish brown (10YR 4/4); loam; moderately weak fine and medium subangular blocky structure; dry, slightly hard; few, medium, hard, irregular lime nodules; abrupt, smooth boundary
A	20-30	Brown to dark brown (10YR 4/3); loam; moderate, medium, fine and coarse subangular blocky structure; slightly moist, friable; very few gravel of rock from Jabal Yefar to west; very few, medium, hard lime nodules; few mycelia; abrupt, smooth boundary
Bck1	30-50	Brown to dark brown (10YR 4/3); silty clay loam; moderate, medium subangular blocky structure; moist, friable; very few round gravel from Jabal; many, medium, very hard, irregular lime nodules; many mycelia, abrupt, smooth boundary
Bck2	50-110	Brown to dark brown (10YR 4/3) with common, distinct dark yellowish brown (10YR 4/4) and dark brown (10YR 3/3) patches; clay loam; moderate, fine and medium subangular blocky structure; slightly moist, friable; few rounded gravel; many medium and large, very hard, irregular lime nodules; common mycelia; abrupt, wavy boundary
2C	110-120	Dark yellowish brown (10YR 4/4) with dark brown patches; clay loam; weak, subangular blocky structure; moist, very friable; weakly developed, moderately thick cutans in pores; very few, medium, hard lime nodules; abrupt, wavy boundary
3Cck	120-140	Dark yellowish brown (10YR 4/4); gravelly clay loam; structureless; moist, very friable; dominant rounded gravel and stones of basalt, obsidian and jabal; many, hard, irregular lime nodules

Depth cm	Lab no	Particle size class. mm				pH 1:5 H_2O	EC mmhos 1:5 H_2O	% $CaCO_3$ ads	Org C % ods	Total N % ods	Exchangeable cations meq/100g ads				CEC soil meq/ 100g	Av P Olsen	Total content ppm			Trace elements ppm			ESP
		Sand		Silt	Clay																		
		2 - 0.25	0.25- 0.05	0.05- 0.002	< 0.002						Na	K	Mg	Ca			P	K	Mg	Cu	Mn	Zn	
0-20	7913	5	30	50	15	8.4	0.08	8	0.44	0.07	0.1	0.4	2.0	>50.0	15.1	2	530	4 900	12 600	20	850	70	
20-30	7914	8	29	45	18	8.4	0.09	9	0.40	0.06	0.1	0.3	2.4	>50.0	15.8	1	480	4 350	11 550	20	820	50	
30-50	7915	2	12	56	30	8.3	0.10	29	0.45	0.05	0.1	0.2	3.6	>50.0	19.2	1	440	4 750	12 200	20	570	70	
50-110	7916	7	18	39	36	8.5	0.10	17	0.23	0.04	0.3	0.3	3.0	>50.0	25.5	1	360	5 600	12 600	30	820	70	
110-120	7917	3	34	31	32	8.4	0.10	1	0.12	0.03	0.4	0.4	6.5	30.0	25.5	<1	230	5 650	12 600	30	1 040	90	
120-140	7918	35	7	28	30	8.6	0.12	24	0.09	0.02	0.5	0.3	5.4	48.5	22.4	<1	240	3 550	11 900	20	750	70	

Soil Series MARIS

Pit number: 58

Location Land unit: 16 1:50 000 map: C2 Grid reference: 248E 999N

5.3 km along road from Al Qaidah to Al Hadan, beside the road

Physiographic position: Middle of shallow narrow valley: receiving site

Parent material: Fine textured alluvium

Rainfall mm: 350–550

Elevation m: 2 530

Slope % : level

Groundwater depth m: NA

Land use: cultivation – ploughed

Soil drainage: well/moderately well

Soil correlation:

FAO : Calcic Cambisol

USDA: Udic Ustochrept

Horizon	Depth cm	
Ap	0–10	Yellowish brown to dark yellowish brown (10YR 4.5/4); silty loam; moderate, fine medium and coarse subangular blocky structure, (cloddy); dry hard; very few, round basalt gravel; abrupt, smooth boundary
A	10–25	Yellowish brown to dark yellowish brown (10YR 4.5/4); silty clay loam; weak, coarse subangular blocky structure; moist, very friable; very few, round basalt gravel; abrupt, smooth boundary
AB	25–50	Brown to dark brown(10YR 4/3); clay loam; moderate, medium subangular blocky structure; moist, friable; very few round basalt gravel; patchy thin cutans; clear, smooth boundary
Bca(c)1	50–90	Brown to dark brown(10YR 4/3); silty clay loam; moderate, medium angular blocky structure with a tendency to slickensides; moist, firm; very few, round basalt gravel and quartz grains; moderately thick continuous cutans; common, large (1–2 cm), moderately hard, irregular lime nodules; diffuse, smooth boundary through a mottled zone to
Bca(c)2	90–150	Dark brown(10YR 3/3)with common, fine, faint brown to dark brown mottles; gritty clay loam; strong, medium angular blocky structure and strongly developed slickensides; very moist, firm; very few round basalt gravel and quartz grains; thick continuous cutans; common, large (1–2 cm), moderately hard, irregular lime nodules

Augering shows a dark brown to very dark greyish brown horizon to nearly 200 cm with rust mottling evident.

Thin sections taken 70–80 cm and 117–127 cm.

Depth cm	Lab no	Particle size class, mm: Sand 2 – 0.25	Sand 0.25 – 0.05	Silt 0.05 – 0.002	Clay < 0.002	pH 1:5 H_2O	EC mmhos 1:5 H_2O	% $CaCO_3$ ads	Org C % ods	Total N % ods	Exchangeable cations meq/100g ads: Na	K	Mg	Ca	CEC soil meq/100g	Av P Olsen	Total content ppm: P	K	Mg	Trace elements ppm: Cu	Mn	Zn	ESP
0–10	1 454	8	13	34	25	8.4	0.24	4.0	0.39	0.05	0.5	0.8	5.3	48.5	23.8	2	550	7 500	15 450	30	770	100	
10–25	1 455	0	14	47	39	8.7	0.26	2.0	0.24	0.03	1.5	0.3	6.3	39.0	29.7	0	250	7 900	15 450	40	370	100	
25–50	1 456	10	13	47	30	8.4	0.16	4.0	0.29	0.04	0.8	0.4	5.7	47.6	22.0	0	240	3 200	12 900	20	530	150	
50–90	1 447	7	10	46	37	8.4	0.24	4.5	0.23	0.04	1.1	0.4	7.8	>50	26.9	0	440	6 500	14 400	30	730	100	
90–150	1 458	10	10	46	34	8.4	0.22	4.5	0.22	0.04	0.8	0.3	7.8	>50	25.4	0	350	5 000	11 450	20	620	90	

Soil Series RAKHAMAH

Pit number: 63

Location a. Land unit: 13 b. 1:50 000 map: A4 c. Grid reference: 403E 105N

2 km south west of Rakhama near newly dug well

Physiographic position: Centre of broad valley floor : receiving site

Parent material: Fine textured alluvium over coarse gravelly alluvium

Rainfall mm: 350-550

Elevation m: 2 415

Slope % : level

Groundwater depth m: 5

Land use: cultivation - stubble

Soil drainage: well

Soil correlation:

FAO : Chromic Vertisol

USDA: Entic/Udorthentic Chromustert

Horizon	Depth cm	
		Strong surface cracking 2-3 cm wide in polygonal pattern, 25-40 cm across.
Ap	0-15	Brown to dark brown (7.5YR 4/4); clay; moderate medium and coarse subangular blocky structure; dry, hard; few gravel and stones, mainly basalt with some ash; common, small and medium, hard, black centred lime nodules; calcareous; many fine and medium pores with faunal channels and faecal pellets ; when wetted becomes flaky; abrupt, smooth boundary
AB	15 30/35	Brown to dark brown (7.5YR 4/4); clay; strong, medium and coarse, platy structure each plate with smooth face like horizontal slickensides; dry, very hard; very few gravel and stones as above; common rounded small and medium hard lime nodules as above; calcareous; clear; wavy boundary
Bw1	30/35-110	Dark brown to dark reddish brown (5YR 3/4-7.5YR 4/4) with few, distinct, medium and coarse, very dark grey (10YR 3/1) mottles; clay; strong slickenside development with moderate, medium, subangular blocky structure within; moist, friable; few basalt gravel; few rounded, small, black, hard lime nodules; calcareous; diffuse boundary
Bw2	110-160	Dark brown to dark reddish brown (5YR 3/4-7.5YR 4/4) with many medium and coarse, distinct, very dark grey (10YR 3/1) mottles; clay; slickensides dominant giving wedge-shaped structural units and breaking to subangular and angular faces; moist, friable; few basalt gravel; few small lime nodules as above; calcareous
		Below 180 cm black mottles become dominant and include soft, black manganese concretions: below 270 cm red (2.5YR 4/6) gritty clay with common basalt gravel and few lime nodules.

Depth cm	Lab no	Particle size class, mm				pH 1:5 H_2O	EC mmhos 1:5 H_2O	% $CaCO_3$ ads	Org C % ods	Total N % ods	Exchangeable cations meq/100g ads				CEC soil meq/ 100g	Av P Olsen	Total content ppm			Trace elements ppm			ESP
		Sand		Silt	Clay																		
		2 - 0.25	0.25- 0.05	0.05- 0.002	< 0.002						Na	K	Mg	Ca			P	K	Mg	Cu	Mn	Zn	
0-15	9 540	1	7	42	50	8.5	0.13	7	0.23	0.04	0.4	1.0	10.9	>50	46.0	2	1 250	5 600	22 250	-	-	-	
15-30	9 541	2	6	38	54	8.8	0.13	7	0.22	0.05	0.5	0.8	11.6	>50	46.4	0	1 240	5 350	22 600	-	-	-	
30-65	9 542	1	6	36	57	8.2	0.18	7	0.22	0.05	0.7	0.7	13.2	>50	46.4	0	1 440	5 350	22 050	-	-	-	
65-110	9 543	1	5	34	60	8.3	0.20	7	0.24	0.04	0.8	0.7	15.0	>50	46.4	0	1 190	5 200	22 250	-	-	-	
110-160	9 544	1	4	33	62	8.3	0.20	7	0.27	0.05	0.9	0.6	17.4	>50	46.9	0	1 190	4 450	21 750	-	-	-	

Soil Series SAWAD

Pit number: 64

Location Land unit: 12/15 1:50 000 map: A4 Grid reference: 365E 091N

About 300 m north of the track Dhamar to Tinnan near the main spring draining the Dhamar Plain

Physiographic position: Narrow, shallow valley floor, at edge of plateau below spring seepage: receiving site

Parent material: Fine textured alluvium

Rainfall mm: 350-550 Soil drainage: Poor

Elevation m: 2 400 Soil correlation:

Slope % : Level FAO : Gleyic Solonchak

Groundwater depth m: 0.2 m USDA: Typic Halaquept

Land use: Cultivation - very poor wheat/barley

Horizon	Depth cm	
		Surface coated with patches of white efflorescence
Ap2k	0-10	Dark greyish brown (10YR 4/2); loam to silt loam; moderately weak, coarse subangular blocky structure; wet, sticky and slightly plastic; very few irregular gravel; abrupt, smooth boundary
Agnk	10-20	Dark greyish brown (10YR 4/2); with common medium, faint dark reddish brown (5YR 3/3), and few, medium and coarse, distinct very dark grey (2.5Y 3/0) mottles; silt loam to loam; weak, fine and medium subangular blocky structure; wet, slightly sticky and slightly plastic; very few, angular basalt gravel; abrupt, smooth boundary
Bgnk	20-45	Very dark greyish brown (2.5Y 3/2) with few, medium and coarse, distinct mottles; loam;moderate, fine and medium subangular blocky structure; wet, slightly sticky and plastic; very few, angular basalt gravel; abrupt, smooth boundary
Cgnk	45-100	Greyish brown (10YR 5/2); silty clay; moderate, fine angular blocky structure within a weak prismatic; wet, slightly sticky and plastic; very few, round gravel; common, medium and large, soft and moderately hard irregular lime nodules

Depth cm	Lab no	Particle size class, mm: Sand 2 - 0.25	Sand 0.25-0.05	Silt 0.05-0.002	Clay < 0.002	pH 1:5 H_2O	EC mmhos 1:5 H_2O	% $CaCO_3$ ads	Org C % ods	Total N % ods	Exchangeable cations meq/100g ads: Na	K	Mg	Ca	CEC soil meq/100g	Av P Olsen	Total content ppm: P	K	Mg	Trace elements ppm: Cu	Mn	Zn	ESP
0-10	9553	5	20	50	25	8.1	3.9	16	0.87	0.12	5.5	2.6	10.0	>50	18.0	6	1 780	6 100	16 750				31
10-20	9554	5	20	50	25	8.5	0.74	16	0.72	0.11	2.9	1.9	8.5	>50	17.9	4	1 850	5 850	16 250				16
20-40	9555	6	22	46	26	8.6	0.66	18	0.68	0.09	2.7	1.7	8.3	>50	17.7	3	1 880	5 500	14 900				15
40-100	9556	2	11	41	46	8.4	0.68	22	0.57	0.09	3.0	1.6	11.1	>50	24.6	2	1 360	7 100	15 450				12

Soil Series ATALABA

Profile number: 33

Location Land unit: 8 1:50 000 map: B3 Grid reference: 540E 264N

Gully exposure near the road in Wadi Atalaba, 2 Km south of Al Baradun

Physiographic position: Upper part of slope of broad valley, on dissected plateau, with moderate to severe sheet and gully erosion

Parent material: Alluvium overlying pyroclastic ash

Rainfall mm: <350

Elevation m: 2 495

Slope % : Level

Groundwater depth m: NA

Land use: Rough grazing

Soil drainage: Well

Soil correlation:

FAO : Calcic Cambisol

USDA: Udic Ustochrept

Horizon	Depth cm	
A	0-35	Yellowish brown (10YR 5/6); loam; very weak, fine and medium subangular blocky structure; moist, very friable; very few angular ash gravel
B	35-50	Dark brown (10YR 3/3); loam; weak, fine and medium subangular blocky structure; moist, friable; few angular ash gravel; moderate thin carbonate coatings on peds
Bd	50-75	Very dark greyish brown (10YR 2/1); silty clay; moderate, fine and medium angular blocky structure; moist, friable; very few, angular ash gravel: continuous thick cutans
Bca(c)	75-95	Brown to dark brown (10YR 4/3); clay loam; moderate, fine and medium angular blocky structure; moist, firm; very few, angular ash gravel; continuous thick cuta common, medium and large, soft irregular lime nodules
B	95-110	Dark yellowish brown (10YR 4/4); silty clay loam; moderate, fine and medium angular blocky structure; moist, firm; few, angular ash gravel;patchy thick cutans; few medium and large soft irregular nodules
BC	110-130	Dark yellowish brown (10YR 4/4); gravelly loam; weak, fine subangular blocky structure; many, large, angular ash stones
C	130+	Large stones and boulders dominant

Depth cm	Lab no	Particle size class. mm				pH 1:5 H_2O	EC mmhos 1:5 H_2O	% $CaCO_3$ ads	Org C % ods	Total N % ods	Exchangeable cations meq/100g ads				CEC soil meq/ 100g	Av P Olsen	Total content ppm			Trace elements ppm			ESP
		Sand		Silt	Clay																		
		2 - 0.25	0.25- 0.05	0.05- 0.002	< 0.002						Na	K	Mg	Ca			P	K	Mg	Cu	Mn	Zn	
0-35	7881	3	36	48	13	8.4	0.08	7	0.28	0.04	0.2	0.4	2.1	47.1	12.5	1	540	5 500	13 900	20	570	70	
35-50	7882	7	25	46	22	8.5	0.09	5	0.44	0.05	0.5	0.2	2.8	>50.0	17.0	1	370	4 750	10 400	20	640	70	
50-75	7883	2	13	44	41	8.4	0.12	6	1.28	0.11	0.7	0.3	4.4	>50.0	31.1	3	250	7 000	10 350	30	830	90	
75-95	7884	3	20	42	35	8.3	0.11	3	0.33	0.04	0.5	0.3	3.6	42.4	25.2	1	290	6 400	13 550	30	610	70	
95-110	7885	3	14	45	38	8.4	0.10	2	0.23	0.04	0.5	0.3	4.0	35.5	27.3	1	380	7 350	16 200	30	690	90	
110-130	7886	11	32	31	26	8.3	0.12	2	0.15	0.03	0.5	0.3	3.2	42.5	19.9	1	310	4 900	11 400	20	460	70	

Soil Series YAFA

Profile number: 71

Location Land unit: 15 1:50 000 map: A4 Grid reference: 310E 071N

4 km west of Dhamar along track to Dafinah on south side of track

Physiographic position: lower middle slope of gently sloping (3%) plateau surface, rock outcrop class 1

Parent material: Basalt

Rainfall mm: 350-550

Elevation m: 2 440

Slope % : level

Groundwater depth m: NA

Land use: cultivation - ploughed

Soil drainage: well

Soil correlation:

FAO : Calcic Cambisol

USDA: Lithic Ustochrept

Horizon	Depth cm	
A(p)	0-20	Brown to dark brown 10YR 4/3 (dry 5/4); loam; weak to moderate fine medium and coarse subangular blocky structure; dry, slightly hard; very few slightly round basalt gravel; abrupt smooth boundary
Bd	20-30	Very dark greyish brown 10YR 3/2 (dry 4/2); clay loam; moderate fine subangular blocky structure; slightly moist, slightly hard; very few basalt gravel and few basalt boulders; common mycelia; abrupt wavy boundary
R	30	Hard basalt.

Depth cm	Lab no	Particle size class, mm				pH 1:5 H_2O	EC mmhos 1:5 H_2O	% $CaCO_3$ ads	Org C % ods	Total N % ods	Exchangeable cations meq/100g ads				CEC soil meq/100g	Av P Olsen	Total content ppm			Trace elements ppm			Extr P
		Sand		Silt	Clay						Na	K	Mg	Ca			P	K	Mg	Cu	Mn	Zn	
		2 - 0.25	0.25- 0.05	0.05- 0.002	< 0.002																		
0-20	7931	3	30	48	19	8.2	0.09	6	0.39	0.05	0.1	0.4	3.1	>50	21.1	2	810	4 450	13 050	30	1 000	80	
20-30	7932	1	14	46	39	8.1	0.13	5	0.73	0.09	0.3	0.3	4.4	>50	34.6	<1	1 140	4 150	12 350	30	1 130	90	

Pit number: 79

Soil Series BANI FALAH

Location Land unit: 12 1:50 000 map: A4 . Grid reference: 376E 096N

2 Km north east of Dhamar, about 200 m south of track to Rakhamah

Physiographic position: Terraced footslopes, sloping at 7%, below basalt lava scarp bordering Interior Valleys (LU13)

Parent material: Colluvium

Rainfall mm: 350-550

Elevation m: 2 400

Slope % : Level

Groundwater depth m: NA

Land use: Cultivation - fallow

Soil drainage: Well

Soil correlation:

FAO : Calcic Cambisol

USDA: Udic Ustochrept

Horizon	Depth cm	
A	0-15	Dark yellowish brown (10YR 4/4); loam; moderately weak, fine and medium subangular blocky structure; dry, slightly hard; common slightly round and and angular basalt gravel; calcareous; clear, smooth boundary
Bca1	15-45	Brown to dark brown (10YR 4/3); loam; moderate, medium and coarse subangular blocky structure within a weak coarse prismatic; dry, hard; common, slightly round and angular basalt gravel; many, fine, soft carbonate mycelia; calcareous; diffuse, smooth boundary
Bca2	45-85	Dark brown (10YR 3/3); loam; weak, coarse subangular blocky structure; dry, hard; many slightly round and angular basalt gravel and few angular stones (2-7.5 cm); many, soft, white, fine carbonate mycelia forming continuous coatings on stone faces; calcareous; clear smooth boundary
2Cca(c)	85-135	Dark reddish brown (5YR 3/3) with many, medium, distinct dark red (2.5YR 3/6), many, fine, prominent pale yellow (2.5YR 8/4) and few, medium, distinct yellowish brown (10YR 5/6) mottles; silty clay; strong, fine and medium prismatic structure; dry, hard; many, irregular, soft and hard weathered purple basalt stones containing calcite crystals; common, medium and large soft irregular lime nodules often around calcite crystals; calcareous

Depth cm	Lab no	Particle size class. mm				pH 1:5 H_2O	EC mmhos 1:5 H_2O	% $CaCO_3$ ads	Org C % ods	Total N % ods	Exchangeable cations meq/100g ads				CEC soil meq/ 100g	Av P Olsen	Total content ppm			Trace elements ppm			SP
		Sand		Silt	Clay																		
		2 - 0.25	0.25- 0.05	0.05- 0.002	< 0.002						Na	K	Mg	Ca			P	K	Mg	Cu	Mn	Zn	
0-15	9549	13	23	48	16	8.6	0.09	3	0.20	0.04	0.1	0.4	3.6	47.8	29.0	0	2 400	2 500	10 250				
15-45	9550	12	19	50	19	8.5	0.10	3	0.16	0.04	0.2	0.3	4.0	46.2	29.3	0	2 390	2 150	10 350				
45-85	9551	28	21	38	13	8.7	0.10	3	0.13	0.02	0.4	0.1	4.9	45.4	25.1	0	1 920	11 500	8 250				
85-135	9552	6	7	43	44	8.2	0.17	3	0.09	0.02	1.0	0.1	13.4	44.8	43.2	0	2 500	550	8 500				