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Soil Survey and Land Classification

REPUBLIC OF YEMEN

LAND SUITABILITY FOR IRRIGATED SORGHUM (SEIFI) IN WADI MAWR (TIHAMA)

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The conclusions given in this report are considered appropriate at the time of its preparation. They may be modified in the light of further knowledge gained at subsequent stages of this project.

INTRODUCTION

The purpose of this evaluation is to determine the land suitability of the Wadi Mawr area for the cultivation of (spate) irrigated sorghum under improved traditional management, and to determine the yield response to additional water gifts on various soil types.

The evaluation was carried out for the alluvial plain, i.e. hills, dunes and wadi beds were excluded, and takes into account the following soil qualities and characteristics:
Drainage, salinity of the rootzone, surface sealing and the occurrence of crusts, effective soil depth and the available water holding capacity of the rootzone.

The results are expressed as expected yields under two irrigation schedules, and in qualitative land limitation classes which indicate the type and degree of limiting factors.
The final results are presented in maps on basis of the soil map of Wadi Mawr (Van Waveren etal, 1990), as well as in tables which shows the basic results for each of the observation sites and the aggregated results for the soil units.

CROP MANAGEMENT DATA

The potential grain yield of Seifi sorghum is 1.7 - 2 ton/ha under improved tradional management (Williams, 1979). The planting date is mid-April; length of growing season is 100 days consisting of four crop stages of respectively 15, 40, 30 and 15 days. The total water requirement of the crop is 567 mm (FAO, 1988). Fertilizer is not applied.

The irrigation schedules are as follows:

1. Sub-optimal schedule consisting of a preplanting irrigation to field capacity, or upto 300mm in case the field capacity exceeds 300mm. In addition an irrigation of 200mm is given after 60 days.
2. High water deficient schedule consisting of a single preplanting irrigation to field capacity with a maximum of 300mm.

The rainfall is considered additional to both schedules. The average rainfall during the growing season is approximately 40mm (see under climatic conditions).

Both irrigation schedules are typical for spate irrigation. however, the same schedules can also used to indicate the potential of the pump irrigated areas adjacent to the spate areas:

(a) The results of the sub-optimal schedule (1) are comparable with, or slightly lower than, those of a sub-optimal pump irrigation schedule, which comprises two additional water gifts of 100mm rather than a single one of 200mm.

(b) Schedule 2 (high water deficiency) is also valid for a pump irrigated area, as it simply assumes the crop to grow on the soil at field capacity without any further water gifts.

Note that this evaluation is not yet validated with actual yield data from the Wadi Mawr area. However, the potential grain yield of spate irrigated Seifi sorghum under traditional management in the Tihama has been established by Williams (1979) on basis of measurements and locally collected data. However, the expected yields which result from this evaluation are expressed in relative terms (as percentage of potential yield) rather than in absolute terms (tons/ha) to allow for useful interpretations even with local deviations of the potential yield.

EDAPHIC REQUIREMENTS AND PROPORTIONAL YIELD REDUCTIONS

The edaphic requirements and related proportional yield reductions are summarized below following Rhebergen (1989) and Williams (1979).

Drainage:
Poorly and very poorly drained soils are considered unsuitable.

Surface sealing:
Surface crusts and slight to moderate sealing do not significantly influence the sorghum yield. However strong sealing (extremely hard 5-25cm thick soil surface) is prohibitive for cultivation of sorghum.

Effective soil depth:
The depth to an impenetrable layer should be at least 50cm. Impenetrable layers may be layers with a very high carbonate, salt or stone content. Also the effective soil depth can be limited by an abrupt textural change.

Salinity of the rootzone:
Sorghum is moderately tolerant to salts. The relation between salinity of the rootzone and proportional yield reduction is as follows:

ECe (mS/cm)	Yield reduction (%)	
0 - 5	0	- non limiting
5 - 7	10	- slightly limiting
7 - 9	25	- limiting
9 - 12	50	- strongly limiting
> 12	90	- prohibitive

Available waterholding capacity (AWHC):

The AWHC can be defined as the amount of water that can be stored in the soil between wilting point and field capacity, i.e. roughly the amount of water that is available to the plant. The AWHC depends mainly on texture, amount of

coarse fragments and effective soil depth.

The yield reductions due to the AWHC were calculated for both above defined irrigation schedules with the Cropwat program (FAO, 1988) using the following crop data:

		Initial	Development	Mid - Late Season		Total
Crop Stage	[days]	15	40	30	15	100
Crop Coefficient	[coeff.]	0.40	->	1.05	0.50	
Rooting Depth	[meter]	0.40	->	2.50	2.50	
Depletion level	[fract.]	0.50	->	0.55	0.90	
Yield-response F.	[coeff.]	0.40	0.40	0.55	0.40	0.90

The calculated yield reductions due to moisture stress are as follows:

AWHC of rootzone	Schedule #1 high deficiency	Schedule #2 low deficiency
< 75 mm	90 %	90 %
75 - 150 mm	70 %	40 %
150 - 225 mm	60 %	10 %
225 - 300 mm	30 %	0 %
> 300 mm	10 %	0 %

If the AWHC is not determined analytically it is estimated from soil texture, soil depth and content of coarse fragments.

The relation between soil texture class and AWHC is as follows based on the results of various studies carried out in the Tihama and Central highlands (Halcrow & Partners, 1978; Tipton & Kalmbach, 1979; Williams, 1979; Acres, 1980).

Sands	= 50mm/m
Loamy sands	= 70mm/m
Sandy loams, sandy clayloam	= 120mm/m
Clayloam, loam, sandy clay, clay	= 170mm/m
Silts	= 220mm/m

The available waterholding capacity is considered for three different soil layers: the topsoil from 0 - 25cm, and two subsurface layers respectively from 25 - 75cm and from 75 -125cm.

First the AWHC for each of the layers is determined on the basis of texture and, if necessary, corrected for the amount of coarse fragments. Subsequently the total AWHC for the rootzone is calculated taking into account the effective soil depth.

LAND RESOURCES DATA

Physiography and soils:

The physiographic information and soils data are derived from the physiographic soil map of Wadi Mawr at scale 1: 100,000 and the covering report (Van Waveren, 1990). The soil map was used as basis for the land suitability maps, whereas the soil profile data were used for the actual evaluation procedures.

Climatic Conditions

The climatic station of As Zuhra is located in the center of the study area. Daily rainfall data are available from 1973, 77, 80-88. The reference crop evapotranspiration (ETo) was calculated using monthly data from 80-88 (Rhebergen, Van Waveren & Bafadel, 1990).

The average annual ETo is 2228mm. The maximum average evapotranspiration is 7.5mm/day (May) and the minimum evapotranspiration is 4.3mm/day (January).

The average annual rainfall is 164mm. Average rainfall per decade is given in figure 2. It shows that most of the rainfall occurs in three periods: April-May, August-October, and December-January.
However the rainfall pattern is extremely erratic and the distribution pattern and amounts vary considerably from year to year. This is illustrated in figure 3, which shows the probability of the occurrence of rains amounting more than 10mm/decade. Note that on average this probability is very low (less than 20%), only in April and October a 50% probability is reached.

The geographical variation of the rainfall is also considerable as it increases from west to east over a distance of 40km from less than 100mm annually in the coastal area to more than 300mm at the footslopes of the escarpment.

Air temperature during the growing period is optimal, with mean daily temperatures > 25 °C.

RESULTS

Map 1. Land Limitation Classes

This map gives the physical suitability of the land for irrigated sorghum cultivation by indicating the kind and degree of limitations that can be expected in the various mapping units.
The map shows that the available water holding capacity of the soil is the main differentiating characteristic. Salinity and strong surface sealing are less important limiting factors.

The available water holding capacity is a function of soil texture, stoniness and effective soil depth. On the alluvium low available water holding capacities are mainly caused by sandy textures, on the pediment the limited effective soil depth and stoniness negatively influence the available water holding capacity.

Salinity of the rootzone is largely related to land use and irrigation management and may occur in places, especially in the pump irrigated areas where saline water is used for irrigation (see Van Waveren, 1990).

Surface sealing may occur on homogeneous alluvial silts, especially on the fringes of the spate irrigated areas where well sorted silty deposits are found. These soils are extremely liable to compaction and surface sealing because they tend to resort themselves into denser structures due to over-irrigation in the irrigation basins (See Williams, 1979; Van Waveren, 1990).

The map gives generalized information for the mapping units. The generalized results per soil unit are given in table 1. The variability within the units and results for the individual soil profiles (as indicated on the map) in are given in table 2.

Map 2 and 3. Expected yield reductions under sub-optimal and high water deficient irrigation schedules.

The maps show the expected yield reductions for each of the soil profiles and the aggregated results for the mapping units. The reductions are given as percentage of the potential yield, i.e. the yield under optimum conditions (no limiting soil conditions and no water stress). They are given in relative terms (%) rather than absolute terms (tons/ha) to allow for useful interpretations even if the potential yield in the Wadi Mawr area differs from that determined by Williams (1979).
The generalized results per soil unit are given in table 1. The variability within the soil units is also given in table 2.

Map 2. shows that under a sub-optimal irrigation schedule expected yields are close to the potential yield on most of the alluvium. The yield response does not vary much between the units, because the additional gift of water after 60 days prevents depletion of the soil, also if those soils have low water holding capacities.

Map 3. The yield response to the high water deficient irrigation schedule depends strongly on the available water holding capacity of the soils. The total amount of available water to the crop equals the available water holding capacity (upto 300mm), because the irrigation schedule comprises a single preplanting water gift only.
Soils with high waterholding capacities have expected yields comparable to the yields under the sub-optimal irrigation schedule. However, the expected yields on soils with low water holding capacities are significantly lower as compared to the expected yields under the sub-optimal irrigation schedule.

Figure 2

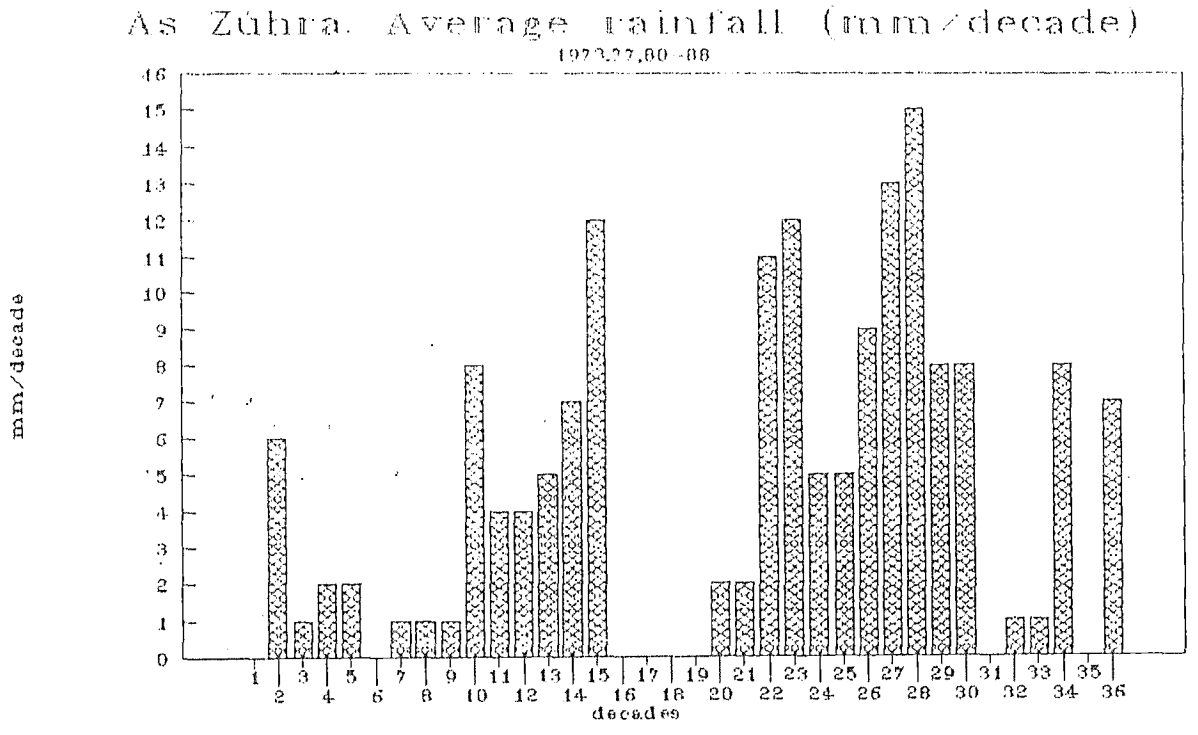

Figure 3.

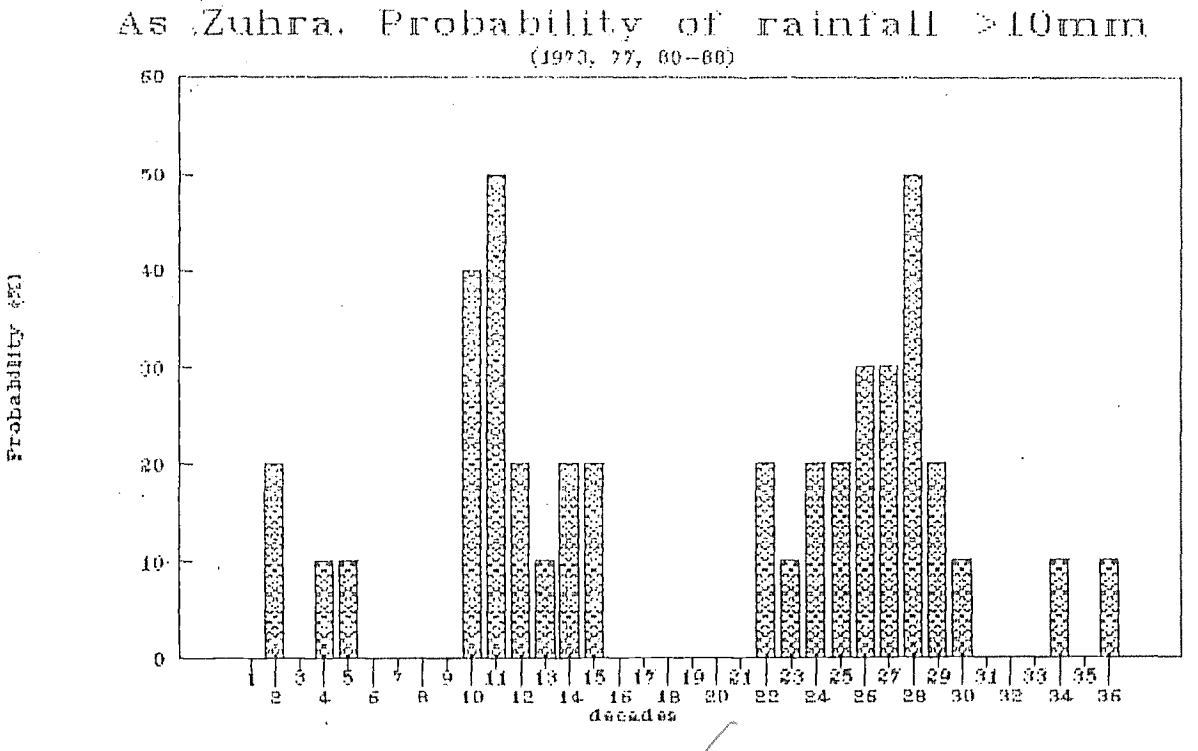

Table 1. Aggregated results per soil unit

Soil Unit	Yield 1 (in % of pot. yield)	Yield 2	Limit. Class	Remarks
CA01	90-70	100	1-2wc	Sandy profiles slightly limited AWHC
CA02	90	100	1	
Ca02a	40	50	3sa	
CA10	90	100	1	
CA11	30	60	3wc	
CA13	40	90	3wc	
CA20	30	60	3wc	
CA20a	90	100	1	
CA20b	35	75	3wc	
CA21	-	-	4	
CD01	-	-	4	
CE00	40	90	3wc	
CE10	-	-	4	
CE20	-	-	4	
CT00	30	60	3wc	
CI01	90	100	1	
CI01a	70	75	2sa	
CW01	-	-	4	
CW01a	-	-	4	
CW02	30	60	3wc	
CW03	70	100	2wc	
CW03a	60	90	2sa/wc	
CW10	40	90	2wc	
CW10a	30	60	3wc	
CW11	80	90	1-2sa	locally saline
CW20	70	90	2wc	
CW20a	30	60	3wc	
CL01	40	60	3wc	

Land Limitation Classes:

1 ... No limitation
2 ... Soil conditions slightly limiting
  2wc .. AWHC rootzone 225-300mm
  2sa .. ECe rootzone 5-9 mS/cm
3 ... Soil conditions limiting
  3wc .. AWHC rootzone 75-225mm
  3sa .. ECe rootzone 9-12mS/cm
4 ... Soil conditions prohibitive

Table 2. Evaluation results of individual soil profiles per soil unit (yields in percentage of potential yield)

UNIT	PROFILE	LAND LIMITATION CLASS	YIELD (%) 1	2	REMARKS
CA01: very deep, well drained, strongly calcareous stratified sandy loams to siltloam. Liable to strong sealing and compaction. Calcaric Fluvisol/Typic Torrifluvent. 6372 ha.					
	HUA013	1	90	100	silts throughout
	HUA014	1	90	100	silts throughout
	HUA042	1	90	100	silts throughout
	HUA029	2wc	70	100	sandy loam over silts
	HUA033	2wc	70	100	sandy loam over silts
	HUA054	4se	-	-	strong sealing
CA02: Very deep, moderately well drained, strongly calcareous, stratified silty clayloam to silty clay. Typic Torrifluvent/Calcaric Fluvisol. 6359ha					
	HUA032	1	90	100	
	HUA037	1	90	100	
	HUA043	1	90	100	
	HUA044	1	90	100	
	HUA045	1	90	100	
	HUA039	3wc	40	90	silts overlying sandy subsoil
CA02a: As CA02, but saline. 728ha					
	HUA036	3sa	45	50	
CA10: Very deep, moderately well to well drained, moderately calcareous, siltloam to silty clay. Calcaric Cambisol/Fluventic Camborthid. 8104ha					
	HUA009	1	90	100	
	HUA038	1	90	100	
	HUA040	1	90	100	
	HUB012	1	90	100	
	HUB014	1	90	100	
	HUB018	1	90	100	
	HUA041	2wc	70	100	silt over sand
	HUA056	2wc	70	100	transitional to unit CA11
	HUA005	2wc	70	100	sandy loam over silts
	HUB010	3wc	40	90	transitional to CA11
CA10a: As CA10, but with salic and/or sodic phase. 724ha					
	HUA010	3wc/sa	35	80	on map minor inclusion CA10

UNIT	PROFILE	LAND LIMITATION CLASS	YIELD (%) 1	2	REMARKS
CA11: Very deep, well drained, moderately calcareous, sandy loam to loam. Calcaric Cambisol/Fluventic Camborthid. 5134ha					
	HUA003	3wc	30	60	
	HUA027	3wc	30	60	
	HUB015	3wc	30	60	
	HUA047	4se	-	-	transitional to CA03
CA13: Very deep, moderately well drained, noncalcareous, siltoam to silty clayloam Eutric Cambisol/Fluventic Camborthid. 1449ha					
	HUB023	3wc	40	90	
CA20: Very deep, moderately well to well drained, strongly calcareous, silt loam to silty clayloam. Haplic Calcisol/Typic Calciorthid. 1224ha					
	HUA026	3wc	30	60	partly sandy clayloam
	HUB013	3wc	30	60	partly sandy loam
CA20a: as CA20, but with sandy topsoil (overblown material). 4621ha ,					
	HUA001	1	90	100	
	HUA004	1	90	100	
	HUA006	1	90	100	
	HUA008	2wc	70	100	silts overlying sandy loam
CA20b: as CA20, but silts abruptly overlying sands within 1m. Well sorted silts are liable to compaction and sealing. 1254ha.					
	HUA007	3wc	30	60	
	HUA052	3wc	40	90	
	HUA053	3wc	40	90	
CD01: Very deep, (somewhat) excessively drained sands. Calcaric Arenosol/Typic torripsamment. 8854ha					
	HUA058	4wc	-	-	
CE00: Moderately deep, moderately well drained, strongly calcareous silty clayloam to loam, stony. Overlying petrocalcic horizon. Haplic calcisol/Typic Calciorthid. 3688ha					
	HUA012	3wc	40	90	
	HUB007	3wc	40	90	

UNIT	PROFILE	LAND LIMITATION CLASS	YIELD (%) 1	2	REMARKS
CE20:	Moderately deep, moderately well drained, non calcareous stratified loam to sandy loam, very stony, Overlying stones. Eutric Cambisol/Fluventic Camborthid. 4192ha				
	HUA055	4wc	-	-	
	HUB020	4wc	-	-	
CT00:	Very deep, moderately well to well drained, slightly calcareous, stratified sandy loam to loam. Liable to compaction and surface sealing. Calcaric fluvisol/Typic Torrifluvent. 969ha				
	HUA028	3wc	30	60	
CT01:	Very deep, imperfectly drained, slightly calcareous, stratified siltloam to silty clayloam. Very liable to compaction and surface sealing. Calcaric fluvisol/Typic Torrifluvent. 1249ha				
	HUB016	1	90	100	
CT01a:	As CT01, but saline. Calcaric fluvisol/Typic Torrifluvent, salic phase. 2641ha				
	HUA011	2sa	70	75	
CL01:	Very deep, moderately well to well drained, strongly calcareous, silty clayloam to to siltloam overlying (loamy) sands. Fluventic Camborthid/Calcaric Cambisol. 2023ha.				
	HUA048	3wc	40	90	
	HUA050	3wc	40	90	
CW02:	Very deep, well drained, (strongly) calcareous, stratified sandy loam to loam. Calcaric Fluvisol/Typic Torrifluvent. 900ha				
	HUA002	3wc	30	60	
CW03:	Very deep, imperfectly to moderately well drained, (strongly) calcareous, stratified siltloam to silty clayloam. Liable to compaction Calcaric Fluvisol/Typic Torrifluvent. 1853ha				
	HUA030	2wc	70	100	
	HUA035	2wc	70	100	
	HUA046	2wc	70	100	
	HUA019	3wc	40	90	compacted subsoil

UNIT	PROFILE	LAND LIMITATION CLASS	YIELD (%) 1	2	REMARKS
CW03a: As CW03, but saline and sodic. 119ha					
	HUB009	2sa/wc	65	90	
CW10	Very deep, imperfectly to moderately well drained, noncalcareous silty clay to siltloam. Eutric Cambisol/fluventic Camborthid. 381ha				
	HUB022	2wc	40	90	
CW10a: As CW10, but overlying very stony material. 581ha					
	HUB021	3wc	30	60	
CW11:	Very deep, moderately well drained, (strongly) calcareous silty clayloam to siltloam. Locally saline. Calcaric Cambisol/Typic Camborthid. 4461ha				
	HUA015	1	90	100	silts
	HUA016	1	90	100	silts
	HUA018	1	90	100	loam
	HUA020	1	90	100	
	HUA024	1	90	100	loam/clayloam
	HUA017	2sa	70	75	saline
	HUA049	2sa	70	75	saline
	HUA057	2wc	70	100	overlying sandy loam
	HUA022	3wc	30	60	sandy loam over clayloam
	HUA051	3wc	30	60	transitional to CA03
	HUB011	3wc	40	90	mod. deep silts
CW20:	Very deep, moderately well drained, strongly calcareous, silty clayloam to sandy loam. Haplic Calcisol/Typic Calciorthid. 2076ha				
	HUA031	1	90	100	siltloam
	HUA023	2wc	40	90	sandyloam over siltloam
	HUA025	2wc	70	100	siltloam over sandy loam
	HUA021	3wc	30	60	sandy loam
	HUA034	3sa	45	50	saline
CW20a: As CW20, but overlying very stony material. 581ha					
	HUB006	3wc	30	60	

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