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Annex 3: Soils, Land Suitability and Land use

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ANNEX 3

Soils, Land Suitability and Land use

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1. INTRODUCTION

1.1 SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

This report describes the soils, the land suitability and the land use of a 9,600 ha area south of the railway line and east of Hawata town. It is located between latitudes 1,472,500-1,478,000 m and longitudes 678,000-695,000 m in zone 36P- WGS-84. The report is part of the feasibility study of the area. It is based primarily on the Land and Water Research Centre soil survey report of the area (LWRC, 2009).

The area falls within the semi-arid climatic zone where the average annual rainfall is 581 mm and the mean annual temperature is 28.7°C. The soils were developed on the Blue Nile and its tributaries alluvial deposits being transported from the Ethiopian Plateau. The indigenous vegetation consists mainly of *Acacia seyal* (talh), *Acacia mellifera* (kitr) and *Balanites aegyptiaca* (heglig) with thick grass understory. The existing land uses are rainfed and pump irrigated agriculture in addition to grazing.

According to the U.S. Soil Taxonomy, the recognized soil mapping units in the area belong mainly to the Vertisols Usterts suborder i.e. Vertisols with an Ustic soil moisture regime.

The land suitability evaluation has shown that at current conditions 72 % of the soils of the area (6,912 ha) are rated as Class S2 (moderately suitable land for irrigated agriculture), 27.1 % (2,603 ha) are rated as Class S3 (marginally suitable for irrigated agriculture). These can be made more productive and their suitability class upgraded if land amelioration measures, including land levelling, soil drainage and fertilizer application are adopted. The remaining 0.9 % of the soils of the area (85 ha) are rated as Class N2 (permanently unsuitable land for irrigated agriculture).

The main current soil constraints to agricultural production in the area consist of:

a- Vertisolic (v) or high clay content which retards water movement through the soil and also creates poor soil aeration conditions.

b- Moderate chemical fertility (f)

c- Hazard of inundation (i) in parts of the area close to the river

d- Topography (t) at the low lying and depressional sites

If certain measures are adopted including, proper levelling, good drainage system, use of farm machinery at optimum soil moisture, addition of nitrogen and phosphorous fertilizers the expected potential land suitability class of the bulk of the area soils will be upgraded to the moderately suitable land Class S2 with only one inherent constraint i.e. the vertisolic limitation (v) due to the high content of swelling clay. The table below summarizes the area current and potential land suitability classes and subclasses. The table also gives the recommendations for each soil unit for agricultural development based on the land suitability classification and the suggested remedies for land management.

Table 1: Summary Table

Map unit	Current land suitability classes and subclasses	Potential land suitability classes and subclasses	Area (ha)	% of total area	Recommendations for development based on land suitability classification
VT 10	S2 vf	S2 v	6,624	69	Recommended
VC 20	S2 vf	S2 v	288	3	Recommended
VTd 30	S3 wvf	S3 v	2,315	24.1	Recommended for paddy rice production
VTg 40	S3 tvf	S3 v	288	3	Recommended
D 50	N2	-	86	0.9	Not recommended
Total			9,600	100.0	

Finally, the land use is defined as gravity irrigated agriculture based on the physical, economic and social factors prevailing in the area. The land utilization types are defined. The importance of soil and water managements is stressed for sustainable land uses. This entails need to adopt certain measures in the area including, proper levelling, efficient drainage system, crop rotation and adoption of recommended cultural practices.

2. THE ENVIRONMENT OF THE STUDY AREA

2.1 LOCATION AND EXTENT

The area is located on the eastern bank of Rahad River, between latitudes 1,472,500 -1,478,000 m, and longitudes 678,000 – 695,000 m, in zone 36 P – WGS – 84. It extends southeast of the railway line at Hawata town. Total extent is 9,600 ha.

2.2 CLIMATE

According to Kevie (1976) the area lies within the semi-arid climatic zone of Sudan. Its average annual rainfall lies between 600 mm and 700 mm isohyets (Coyne et al, 1977). Table 1 summarizes the climatic data for Abu Naama town at the south western part of the area, for the period 1971-2000.

The table shows that the average annual rainfall is 581 mm. Its distribution is however erratic throughout the rainy season. The average annual relative humidity is 45% and is often above the average during the rainy season (July-October). The yearly average potential Evapotranspiration is 12.3 mm. When compared with rainfall there is always a water deficit during the dry period (November-April). Evapotranspiration is enhanced by temperature and wind speed which reaches 16 km/hr (during June). The wind direction is northerly during the dry period and southerly and south-westerly during the rest of the year. The bright sunshine duration is highest during the dry period and ranges from 9 hrs to 10.4 hours.

Table 2 also shows that the annual mean temperature is 28.7°C, with a mean maximum of 36.7°C and a mean minimum of 20.8°C. This indicates that the mean annual soil temperature of the soil is more than 22°C and the difference between mean air summer temperature (June, July and August) and mean air winter temperature (December, January and February) is less than 5°C. Accordingly it can be logically deducible that the study area has an isohyperthermic soil temperature regime (Soil Survey Staff, 1999).

Finally, since the study area lies within the semi-arid climatic zone, the occurrence of the ustic soil moisture regime is highly probable (Wambeke, 1982).

Table 2: Abu Naama climatological normals for the period 1971-2000.

Lat. 12o44'N and Long. 34o08'E (Source: Sudan Meteorological Authority)

Month	Element				Air temperature			Bright sunshine duration	
	Mean relative humidity (%)	Total rainfall (mm0	Potential evapotrans-piration (mm)	Mean wind speed (km/hr) direction	Mean daily max. temp. (°C)	Mean daily min. temp. (°C)	Mean daily temp. (°C)	(hrs)	(%)
Jan.	32	0.2	13.5	12.8 N	35.2	16.0	25.6	10.3	90
Feb.	25	0.0	16.0	12.8 N	37.2	17.5	27.3	9.9	87
Mar.	21	1.8	19.0	12.8 N	39.9	20.7	30.3	9.6	80
Apr.	24	2.7	19.2	12.8 N	41.6	23.7	32.6	9.7	78
May	38	41.9	15.6	14.4 SW	39.9	25.1	30.3	8.7	69
June	53	91.6	11.9	16.0 SW	36.9	23.7	30.3	7.5	59
July	68	159.8	7.0	14.4 S	33.3	22.1	27.7	5.9	47
Aug.	75	155.3	4.7	11.2 S	32.1	21.7	26.9	6.4	49
Sep.	71	96.1	4.6	9.6 SW	33.6	21.6	27.6	7.3	60
Oct.	58	29.6	10.4	9.6 S	36.8	21.3	29.0	8.6	73
Nov.	36	2.2	12.5	11.2 N	37.9	19.4	28.6	10.4	91
Dec.	33	0.0	12.9	11.2 N	35.8	16.9	26.4	10.2	90
Year	45	581	12.3	12.3	36.7	20.8	28.7	9.0	73

2.3 GEOLOGY AND PHYSIOGRAPHY

According to Whiteman (1970) the main geological formation in the study area consists of Precambrian Basement Complex rocks overlain by superficial deposits including the clayey alluvium of the Sudan central clay plain. The superficial deposits are believed to be deposited during the pluvial period.

Inselbergs of Basement Complex granites and gneisses outcrop through the plain at far distance east of the area. Thus the area is limited on its eastern side by rising ground.

The clay plain south of El Hawata town railway line is believed to be derived from the basic rocks of the Ethiopian plateau and deposited by the Blue Nile and its tributaries. This is confirmed by the existence of several cut-off meanders and ox-bow lakes.

Physiographically the area is gently sloping from south east to north west, in the direction of the Rahad River, and from east to west towards the river.

2.4 VEGETATION

Harrison and Jackson (1958) describes vegetation in Sudan as a function of rainfall and soil types. The study area with its clayey soils retains large amounts of water during the rainy season and therefore promotes dense growth of grasses and tree flora in the uncultivated lands. The dominant tree species are *Acacia seyal* (talh), *Acacia mellifera* (kitr) and *Blanites aegyptiaca* (heglig) with thick grass understory.

Natural as well as reserved forests mainly *Acacia Senegal* (hashab) and *Acacia nilotica* (sunt) also exist in the area, under the supervision of the Forestry Department.

3. THE SOILS

3.1 INTRODUCTION

The soil information in this report is based on the available data furnished by the soil surveys conducted by the Sudan Land and Water Research Centre (LWRC, 2009; A. /Karim, 1993). Detailed information including methodology of field verification and soil analysis can be found in the LWRC (2009) report.

3.2 GENERAL PROPERTIES OF THE SOILS

The soils of the study area are believed to be developed on parent material derived from the weathering products of the Ethiopian basaltic high lands (Buraymah, 2005; 1976; A/Karim, 1993; Commissaris et al, 1970).

Physically, the soils are deep and moderately well drained to poorly drained. They are dark cracking fine textural clays with the clay content exceeding 60%.The soils also have high available water holding capacity, thus they can be irrigated at longer intervals like in the other parts of the irrigated clay plain.

Because they are fine textured water movement through and down these soils is quite slow (infiltrate values vary from 0.9 – 2.0 cm/hr). However the cracks in these soils (resulting from the shrink-swell phenomena due to the high content of montmorillonitic clay minerals) allow large amounts of irrigation water to enter and move down the soil before they swell and close. The average air dry bulk densities of the top soil vary from 1.72 to 1.93 g/cc indicating that these soils are hard and compact particularly during the dry season. However, values as low as 1.58 g/cc are depicted at lower moist depths (LWRC, 2009).

Chemically, like the rest of Sudan, the soils of the area are low in organic matter and nitrogen. In the main soil units (VT and VTd) total nitrogen (%N) is very low varying between 0.04% to 0.07%. However the soils have high cation exchange capacity (CEC) varying from 73-81 cmol(+)/kg, indicating that they have high potential to supply plants with nutrients when added as a fertilizer, particularly nitrogen. The available phosphorous is low for all soils in the area. This is expected in these high pH clays (pH> 7.0) because at high pH the ions of Ca and Mg and their carbonates tend to precipitate phosphorous and render it less available as a plant nutrient.

Finally, the soils are calcareous ($CaCO_3$ range from 5-5.8 %) and are non saline (EC ranges from 0.2-0.5 dS/m) and non sodic (ESP ranges from 3-5 %). The chemistry of the main soils of the area is given in Tables 4.1 and 4.2 in the LWRC (2009) soil report.

The results of the trace elements analysis for the soils of the area (LWRC, 2009), using DTPA method, have shown that Cupper (Cu) and Zinc (Zn) are below the critical levels while Manganese (Mn) and Iron (Fe) are above the critical levels that are tabulated in table 3 below. Mn is very high reaching the toxic levels (100 – 600 ppm) in some cases.

Table 3: Trace elements availability

Element	Mn	Zn	Cu	Fe
Critical level (ppm)	5.00	0.75	1.50	2.50

3.2.1 Soil mapping units

Four mapping units and one miscellaneous land type have been recognized in the study area (LWRC 2009). The mapping legend has been based mainly on the variations of the moist soil, colour values and chromas of the top 30 cm soil layers and on micro-topographic differences. Soil characteristics such as texture, calcareousness, soil reaction and thickness of surface mulch have also been given considerable weight as well. All mapping units belong to the Vertisol order. Table 4 shows brief description of these units together with their classification and total extent. The table can also serve as a legend for mapping the soils in the field.

Table 4: Soil mapping units

Mapping unit symbol	Classification USDA (1999)	Description	Area (ha)	%
VT (10)	Typic Haplustert	Deep, very dark greyish brown (10YR3/2) moist, moderately well drained, non- saline, non-sodic cracking clay occupying flat sites on the clay plain.	6,624	69.0
VC (20)	Chromic Haplustert	Deep, dark greyish brown (2.5Y4/2) moist, moderate to poorly drained cracking soils occupying receiving sites on the clay plain.	288	3.0
VTd (30)	Typic Haplustert	Deep very dark greyish brown (10YR3/2) moist, moderately well drained non-saline, non-sodic cracking clay occupying seasonally flooded or receiving sites on the clay plain.	2,315	24.1
VTg (40)	Typic Haplustert	Deep, very dark greyish brown (10YR3/2) moist; moderately well drained non-saline, non-sodic soils occupying gently undulating sites on the clay plain.	288	3.0
D (50)	Miscellaneous land type (maya)	Low lying sites used as water reservoirs during the dry season for human and animal use.	85	0.9

4. Land Evaluation of the Soils of the Area

4.1.1 The land suitability classification system

The system of land suitability classification is based on the FAO Framework for Land Evaluation (FAO, 1974) as adopted by Kevie and El Tom (2004) to suit the local conditions of Sudan. The purpose of the system is to provide comparative and qualitative assessments of soils suitability potentials for irrigated agriculture according to their limitations. The system is composed of four categories, in a decreasing level of generalization, including orders (reflecting kinds of suitability), classes (reflecting degrees of suitability within orders), subclasses (reflecting kinds of major limitations within classes) and units (reflecting minor differences in production capacities, such as management requirements within the subclass). These categories are described below:

Order S: Suitable land.

Class S1: Highly suitable land

Land having no significant or only minor limitations to sustained applications of specific use that will not significantly reduce productivity or benefits and will not raise inputs above an acceptable level.

Class S2: Moderately suitable land

Land having limitations that, in aggregate, are moderately severe for sustained given use. The limitations will reduce productivity or benefits and increase required inputs to the extent that the overall advantage to be gained from the use, though still attractive, will be appreciably inferior to that expected on Class S1 land.

Class S3: Marginally suitable land

Land having limitations which, in aggregate, are severe for sustained specific use and thus will reduce productivity or benefits, or increase required inputs, that this expenditure will be only marginally justified.

Order N: Not suitable land

Class N1: Currently not suitable land

Land having limitation(s) which, which although possibly surmountable in time, cannot be corrected at currently acceptable cost.

Class N2: Permanently not suitable land

Land having limitations that are so severe as to preclude any possibilities of successful sustained use of the land in the given manner.

The application method comprises rating of the physical characteristics of the land (land qualities) relevant to the specific land use into good, moderate, poor or very poor in terms of measurable land characteristics. The number and severity of limitations determine the land suitability classes whereas the kinds of limitations determine the land suitability subclasses. Units at the tail of the system reflect minor differences in production capacity and/or management requirements within the subclasses. There are two kinds of land suitability classification for a defined use, current (classification of the land as it is) and potential (classification of the land after major improvements have been made).

4.2 Land suitability classification of the study area

The defined use is high capital irrigated agriculture. The land qualities relevant to the area and specified use are moisture availability, chemical soil fertility, conditions for seedling establishment, drainage condition in the growing season, soil workability, adequacy of topography for gravity irrigation, soil drainability, salinity, and sodicity and erosion hazard.

Based on the above described system each land quality is rated either 1 (good) or 2 (moderate) or 3 (marginal) or 4 (severe) and the derived classes and subclasses are shown in Table 3. The soil main limitations are indicated by small case letters and are defined below:

v: Vertisolic; limitation due to high content of swelling clay

f: fertility; limitation due to low chemical fertility

t: topography; limitation due to unfavourable relief limiting the use of the land

i: inundation; limitation caused by inundation (flooding) of the land from rivers

w: wetness; limitation due to water logging caused by slow permeability or slow surface drainage or combination of these

s: salinity; limitation due to high contents of soluble salts

a: sodicity; limitation due to high contents of exchangeable sodium

4.3 The current land suitability classification of the area

The current suitability classes and subclasses of the area as derived from rating the land qualities are shown in Table 5 and are defined below:

4.3.1 Land Class S2: moderately suitable land for irrigated agriculture

- Subclass S2vf (6,912 ha)

This soil has moderate limitations of Vertisolic characteristics due to high swelling clay content in addition to some fertility limitations that can be corrected by addition of nitrogen and phosphorous fertilizers. Also need for potassium fertilizers may arise. This subclass comprises mapping units VT and VC (72 % of the area).

4.3.2 Land Class S3: Marginally suitable land for irrigated agriculture

-Subclass S3ivf (2,315 ha)

This soil has severe limitations including, high swelling clay, low fertility and seasonal inundations. Its productivity can be upgraded by proper levelling and drainage in addition to fertilizer applications. The subclass comprises mapping unit VTd (24.1 % of the area).

-Subclass S3tvf (288 ha)

This soil has severe limitations including, high swelling clay, low fertility and topographic limitation. Its potential can be improved by proper levelling and fertilizer applications. The subclass includes mapping unit VTg (3 % of the area).

4.3.3 Land Class N2: permanently not suitable land

- Subclass N2 (85 ha)

This subclass comprises mapping unit D, the miscellaneous land type of ponds and mayas (0.9 % of the area). The soils have very severe limitations that make the land permanently non-suitable for gravity irrigation.

Table 5: Current suitability classes for high capital intensity irrigated agriculture

Mapping unit	VT (10)	VC (20)	VTd (30)	VTg (40)	D (50)
Land qualities	Rating				
Moisture availability	1	1	1	1	4
Chemical soil fertility	2	2	2	2	4
Conditions for seedling establishment	2	2	2	2	4
Drainage conditions in the growing season	2	2	2	2	4
Flooding hazard	1	2	3	1	4
Workability	2	2	2	2	4
Salinity	1	1	1	1	4
Sodicity	1	1	1	1	4
Erosion hazards (water)	1	1	1	1	4
Adequacy of topography for gravity irrigation	2	2	1	3	44
Soil drainability	2	2	2	2	4
Current suitability Classes	S2	S2	S3	S3	N2
Current Subclasses	S2vf	S2vf	S3wvf	S3tvf	
Limitations	v,f	v,f	w,v,f	t,v,f	

Rating: 1= no or slight hazard 2= Moderate hazard
3= Severe hazard 4= Very severe hazard

4.4 THE POTENTIAL LAND SUITABILITY CLASSIFICATION OF THE AREA

Land amelioration is a usual practice for removal or reduction of identified current land limitations for development. This would improve land suitability for farming and consequently upgrade its class and subclass. The followings are amelioration treatments suggested to improve the suitability classes and subclasses in the area:

A. Levelling the area to fill-in the concave and depressional sites so that irrigation water could be evenly distributed.
B. Use of farm machinery at optimum soil moisture level to avoid deformation of soil structure and/or soil compaction.

C. Installation of good drainage system (particularly in mapping unit VTd) to avoid inundation hazard and/or water logging conditions.
D. Additions of N, P, and K (if necessary) fertilizers at the required doses for the specified crops in the rotation.

If the above proposed treatments are applied the soil potential will be improved and the current suitability classes would be improved or even upgraded as can be seen in Table 6.

Table 6: The potential land suitability classification for high capital intensity irrigated agriculture in the area.

Mapping unit	Current land suitability classification	Proposed treatment	Potential land suitability classification
10	S2 vf	B + D + C	S2 V
20	S2 vf	B + D + C	S2 V
30	S3 wvf	B + D + C + A	S2 V
40	S3 tvf	B + D + C + A	S2 V

5. LAND SUITABILITY FOR SPECIFIC CROPS

5.1 ASSUMPTIONS

Each crop has specific requirements, e.g., climate soil, management … etc. Thus the rating of land for growing a specific crop (called crop suitability rating or CS) is an evaluation of the suitability of the land for the production of the crop in question. Before applying the land suitability for specific crops, the following assumptions should be considered:

1. The crop will be grown with an above average level of management.
2. The cost of management to grow the specific crop should be within economic limits of crop production based upon long-term price trends.
3. The land is rated according to its present (current) condition with infrastructure and other necessary works installed. If the limitations of crop production are removed, re-evaluation of the ratings should be made.
4. The absence of some crops from the rating list does not mean that these crops are not adapted to local conditions.
5. A low rating of a given crop does not mean that the crop cannot be produced but it indicates that some unfavourable soil characteristics should be remedied.
6. Research trials of identified soils are necessary to make reliable ratings.

Four levels of ratings are recognized as follows:

CS1: Well suited
CS2: Moderately suited
CS3: Poorly suited
CS4: Unsuited

5.2 CROPS SUITABILITY RATINGS IN THE STUDY AREA

The crops suitability ratings in the area are based on their nature and requirements for optimum growth. Table 7 shows the suitability ratings for some selected crops adapted to the area.

Table 7: The current suitability ratings for some selected crops adapted to the area.

Mapping	Current land	Crops							
Unit	Suitability subclasses	Area (ha)	Cotton	Sorghum/ maize	Groundnut/ sunflower	Vegetables	Citruses	Forages	Forest trees
VT (10)	S2vf	6,624	CS2	CS2	CS2	CS2	CS2	CS2	CS2
VC (20)	S2vf	288	CS2	CS2	CS2	CS2	CS2	CS2	CS2
VTd (30)	S3wvf	2,315	CS3	CS3	CS3	CS3	CS3	CS3	CS2
VTg (40)	S3tvf	288	CS3	CS3	CS3	CS3	CS3	CS3	CS2

6. LAND USE OF THE STUDY AREA

6.1 INTRODUCTION

The agricultural potential of the area for specific kinds of land use is determined by the physical, economic and social factors prevailing in the area. The physical factors include environmental conditions such as climate, hydrology, topography and soil conditions while the economic and social factors include price of produce, distance to markets, transport facilities, availability of capital and technology and agricultural traditions and skill of the population.

The proposed land use is gravity irrigated agriculture where the area will be irrigated by canals from the Blue Nile river. The crops to be irrigated (land utilization types) are those adapted to the area and according to the Agricultural Research Corporation (ARC) recommendations on crop rotations and land and water management. It is assumed that all agricultural activities are to be mechanized together with the necessary infrastructure, labour availability and proximity to markets by good paved roads.

6.2 LAND UTILIZATION TYPES

The suitability ratings for the crops adapted to the area Table 7 show that the main soil unit (VT) is moderately suitable (CS2) for all land utilization types adapted to the area including growing of, cotton, grain crops (sorghum, millet, maize), oil crops (sunflower, groundnut, sesame), vegetables, citruses, forages and forest trees. Below is a brief description of the land utilization types relevant to the area.

6.3 GRAVITY IRRIGATED COTTON

Like in all other irrigated national schemes on the central clay plain high capital intensity irrigated cotton is expected to be grown in the study area. The traditional varieties, Brakat and Acala can be grown at the beginning, and then gradually new high yielding varieties can be produced in collaboration with ARC Research Station at El Rahad town. Because the rainy season extends from July to October and the rainfall is relatively high (581 mm, Table 1) compared to the other irrigated schemes the cotton sowing date might be delayed compared to the usual sowing dates in the other national irrigated schemes. Also because the soils in the area are much finer in texture compared to the northern parts of the clay plain a good drainage system is needed particularly during the growing season. Other cultural practices required for cotton including, land preparation, irrigation, fertilizer application, weed control, pests control, harvesting and rotation should follow the ARC recommendations.

6.4 Grain crops

Irrigated grain crops include sorghum, millet and maize. Sorghum is rainfed grown on large areas around the study area. Maize is grown by the local inhabitants on the moist banks of Rahad when the river flood subsides. These crops can however be regularly irrigated when irrigation water is made available. Cultural practices to produce these crops should also follow ARC recommendations.

6.5 Oil crops

These include sunflower, groundnut and sesame. The local population probably less experienced with the management of these crops under irrigation. Sesame in particular is sensitive to water logging, thus a good drainage is expected particularly in soils of mapping unit VTd. An extension system should also be established to help. Cultural practices are according to ARC recommendations.

6.6 Vegetables and citruses

The availability of irrigation water is a good help to the people of the area who grow vegetables and citruses intensively on banks of Rahad river, using pump irrigation. With the introduction of irrigation water, these people can cultivate larger areas and diversify on these crops particularly the vegetables, within the rotation.

6.7 Forages

The area should have at least two irrigated forage crops within the rotation. Abu sabeen is suggested as a summer crop and Lablab bavarieus (luba afin) as a winter crop.

6.8 Forest trees

Irrigated forest trees should comprise mainly the shelter belt around the area as legislated by the Forestry Department (5 % of the area). The belt should be composed of the already existing indigenous trees described in section 1.4 plus two other species (*Acacia ampliceps* and *Acacia stenophylla*), recently introduced by ARC from Australia(ARC, Annual Reports, 1999- 2003). Like the indigenous species the Australian species are nitrogen fixing, drought tolerant and has better economic returns by giving larger amounts of fuel and timber. The Australian species should be planted at three to four meters apart within the indigenous trees.

7. MANAGEMENT

The soils of the area (Vertisols) are characterized by having high clay content and low organic matter and nitrogen. When they are wet their workability is difficult, therefore their tillage should be at optimum moisture contents. After harvest crop residues should be left on top of the soil and turned under to replenish organic matter losses. Fertilizers, particularly nitrogen and phosphorous should be added according to ARC recommendations. A rotation including a fallow important. The Rahad Scheme four course rotations could be applied as a start.

Water management is equally important. Enough water will enter the area through a net-work of canals coming from a Barrage constructed at Wad Miskeen village. The farm water content and the irrigation interval should be according to the ARC recommendations. A good drainage system is vital to remove excess water away from the fields.

8. CONCLUSIONS AND RECOMMENDATIONS

Based upon the above given soil information the soils can be used for gravity irrigated agriculture, to grow crops adapted to the area. However, certain measures need to be taken for sustained land use:

- Land levelling is a priority for easy even movement of irrigation water through the area.
- An efficient drainage system is necessary to drain excess water away from the fields.
- The crops should be grown in a four – course rotation including a fallow to help the soil have a resting period.
- Tillage should be at optimum soil moisture level to avoid soil structure degradation, fuel wastage or implement damage.
- Cultural practices including weeding, fertilizers application, crop protection …etc. should be according to ARC recommendations, and through the help of Extension people.

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