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Determination of Land Suitability for Irrigated Agriculture Using Some of Soil Properties and Aided by RS & GIS in Sahra Bayuada area, Northern State, Sudan

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Abstract: This study was conducted in Sahra Bayuada, (agricultural investment project), located 45 Km northwest Karima city, the area is about 10000 feddens. The aim of this research is determine the most soil growth limiting factors that obstructed the establishment of irrigated agriculture in the study area beside to classify the study area into suitability classes by using the framework of the land suitability (FAO, 1990 and 2006). Objectives achieved by using some of soil properties (soil moisture, soil texture, pH, ECe, and SAR) and aided by Remote Sensing (RS) and Geographic Information System (GIS). The results revealed that the physiochemical of soil indicators namely: pH, Ece and SAR, their levels increases from surface soil to sub-soil accounted about, 8.3-9.3, 0.41-1.13 and 1.35-2.07, respectively. These findings may be attributed to the increases in clay content with depth leading to capture and raise the values of physiochemical of soil indicators. Regarding to the result of soil moisture content increased with depth and this finding coinciding with soil texture where clay content increases and texture classes from surface soil to sub-soil ranged between sandy loam-sandy and sandy clay –loam, respectively. The land suitability classification revealed that, land class S2 (moderately suitable lands), include the following sub-classes S2m covered an area about (565feddans), S2ma covered an area about (4299 feddans) and S3ma (marginal suitable lands), covered an area about (5068 feddans). In general, the most soil growth limiting factors in the study area are pH, Ece, SAR and soil texture as well as the soil topography.

Key words: Sahra Bayuada Land suitability, soil properties, soil topography, RS &GIS.

I. INTRODUCTION:

Desertification is land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors including climatic variations and human activities (Lean, 1995). Land in this context includes: soil, land surface, vegetation and local water resources. Degradation refers to reduction of the current and the potential of the land to produce (quantitatively/qualitatively) goods or service by various degradation processes: including soil erosion, reduction in amount or diversity of natural vegetation, salinization, sodication and compaction (Abdelwahab, 2013). Wind erosion, soil salinization and chemical deterioration are is a predominant process of desertification in Sudan, particularly in the northern part of the country and thus, it was given priority in research.

Mustafa (2007) defined it as: " the soil physical process by which dry, loose and fine surface soil particles are picked up or moved on the ground surface and transported by wind and the soil surface material is abraded by wind-born particles." Wind erosion occurs, naturally, in all lands wherever the surface soil is loose and dry and blown by erosive winds. However, it is predominant and has serious adverse impacts on agricultural lands in the arid and semi-arid lands characterized by low, variable, erratic, and unpredictable rainfall, and high temperature, high wind velocity and consequent high rates of evapotranspiration (Abdelwahab, 2013).

In Sudan comprehensive reviews on wind erosion were presented by several research workers (Abdelwahab and Mustafa, 2013; Abdelwahab et al., 2014; Abuzeid et al., 2017; Rizgalla et al. (1999); Farah, 2003; and Haikal, 2005). Salt-affected soils are widely spread and have adverse impact on reduction the productive capacity of all agricultural lands. Salt- affected soils are covers vast areas at latitudes 14-22o N, including some states namely, the White Nile, North Gezira, Khartoum, crossing the River Nile and the Northern states, falling under three soil orders: Vertisols, Aridisols and Entisols (USDA, 1999).

Salt-affected soils in Sudan are dominated by arid and semi-arid climatic zones that favor the formation of salt-affected soils. In general, salt-affected soils in Sudan have a relatively low status of nutrient and organic nitrogen. Sodicity represents the relative predominance of exchangeable sodium compared to other exchangeable cations, chiefly calcium, magnesium, potassium, hydrogen and aluminum and is expressed as ESP (Exchangeable Sodium Percentage).

The sodium adsorption ratio (SAR), is another expression of sodicity that refers to the ratio of adsorbed sodium and the sum of calcium and magnesium. Soil salinity refers to the content of water-soluble salts in the soil and expressed mostly as ECe (electrical conductivity of paste extract) and is measured as dS m^{-1} (Charman and Murphy, 2000). The inter-relation of all these soil parameters is important for the interpretation of their measures (Van de Graaff and Patterson, 2001). Salt-affected soils studied from many ways such as physiochemical properties e.g., (Mohammed and Mustafa, 2001; Ishaq and Mustafa, 2005; Saeed and Aissa, 2002; Mustafa and Abdelmajid, 1981, 1982; Dahab, et al. 1988); some research conducted to evaluate the impact of Farm Yard Manure (FYM) and chemical fertilizers on some crop production (Alaagib, 1999; Alaagib, 2003; Alaagib and Babiker, 2004; Elkhazin and Khalid, 2013; Elmahi et. al., 2002) and other researches has been conducted by (Mustafa and Hamid, 1977; Elmahi and Mustafa, 1980; Malik et. al., 1992; Awad Elkarim et. al.,1995).

Remote sensing is a powerful modern technique for assessing, mapping, and monitoring of terrestrial natural resources worldwide. Numerous research were conducted on the spatio-temporal of degraded natural resources in Sudan e.g., (Ali et al. 2012; Biro et al. 2013; Adam et al. 2014; Abdelwahab, et al. 2014; Fadl et al. 2014; Mohammedzain, et al. 2015; Elhaja, et al. 2017;Abuzied, et al. 2017). The cost of remote sensing is effective compared to old field survey methods, particularly for large areas 3,600 to 324,000 km^2 (Abdelwahab et al., 2014). The technique is mainly based on the physical interaction between solar radiation, atmosphere and the main features of the land surface, so this technique can be used for assessing and monitoring all types of degradation processes by estimation biophysical soil properties such as salinity and sodicity problems because of take place among the major factors which limit crop production.Basic research on assessment and mapping of salt-affected soils, wind erosion, and chemical deterioration are an essential prerequisite for discovering practical methods for combating salinization troubles, advancing biological productivity and determine the inherent risk in the affected areas by desertification a aspects; they will result in sustainable development of both plant and animal sectors reflected automatically in natural resources sustainability and provide food supplies for future needs. The present study was undertaken to achieve the following objectives:

- To generate data on land degradation that may help in designing soil reclamation projects in study area.
- To determine the most soil growth limiting factors that obstructed the establishment of irrigated agriculture in the study area.
- To classify the study area into suitability classes by using the framework of the land suitability (FAO, 1990 and 2006).

2. MATERIALS AND METHODS:

2.1 Materials:

2.1.1 STUDY AREA.

In general the Northern State located between 17˚ 45 - 19˚ 15’ N and longitude 30˚ 15’-32˚ 00’ E, in the desert ecological zone (75–300 mm), occupied an area about 348697km2 and is severely affected by desertification processes in general and salt-affected soils in particular. Depends on the climatology normal’s,1941-2003 (Table 1), of Dongola, showed that the differences between mean summer (June, July and August) air temperature and mean winter (December, January and February) air temperature is more than 15 Co. The mean annual soil temperature is estimated more than 22 Co and the survey area has a hyper-thermic soil temperature regime (USDA, Soil Taxonomy 1999). Since the area falls within the desert climatic zone, the expected soil moisture regime is Aridic (Torric), (Wambeke, 1982). The mean daily temperature is 29.9 Co and mean daily maximum reaches 41.9 Co in May while the minimum is 15.6 Co in January. The average total annual rainfalls are 3, 18 and 37.7mm in Wadi Halfa, Dongolla and Karima respectively. The annual potential evapo-transpiration is 2065 mm and the annual water deficit is about 1944 mm. The mean relative humidity is 28 % and ranges from 15 % in April to 48 % in August. The sunshine duration ranges from 63 % in July to 91 % in November. In the dry season the prevailing wind blowing from the northeast direction and its speed reaches 4.6 m /s, in the rainy season; the winds originate from the southwest direction and their speed reach 4.5 m/s. Salt-affected soils adversely affects the productive capacity of the arable lands in the State by reducing their fertility (Dregne et. al.,1991; Mustafa 2007). According to Whiteman (1971) and the Geological map of Sudan (1981), the main geological formations in the survey area consist of Basement Complex, Nubian sandstone and superficial deposits (alluvium and Aeolian materials). Basement Complex is assumed to be of the Precambrian age and comprises gneiss, granitic gneiss and quartzite. The Nubian Formation of Cretaceous age lies on the Basement Complex and includes subordinate conglomerates, siltstones and mudstones. Ridges of gravelly material and small outcrops of thinly bedded Nubian sandstones were also found in the area. The superficial deposits are transported and deposited during the Quaternary period (Pleistocene and Holocene ages). The survey area lies within the semi- desert zone according to Harrison and Jackson (1958) which is characterized by semi- desert grasses such as ***Aristida spp.*** and scattered Acacia ***ehrenbergiana*** **(**salam trees)**.**Sahra Bayuada Project is an agricultural investment located 45 Km north-west Karima city, lies about 7km south west Karima–Dongola Street, the area is about 10000 feddens (Fig.1). The area is approximately bounded by longitudes and latitudes given below, table (2).

Table 1. Dongola climatology normal's, 1941-2003

Month	Elements					
	Mean relative Humidity (%)	**Total rainfall (mm)**	**Potential Evapo-transpiration ETo (mm/day)**	**Mean wind speed (m/s)**	**Mean daily temp. (ºC)**	**Daily sunshine hours**
January	34	0.0	5.9	4.7	18.1	10.1
February	30	0.0	7.0	4.8	19.8	10.5
March	26	0.0	8.7	4.8	23.9	10.3
April	24	0.5	10.3	5.0	28.6	10.7
May	19	3.9	11.5	4.9	32.5	10.8
June	19	4.2	10.6	4.8	34.0	11.2
July	22	29.6	12.1	3.7	33.9	10.6
August	24	48,3	10.3	4.3	34.0	10.2
September	23	26.7	10.7	4.3	33.3	9.7
October	25	7.8	11.3	4.7	30.2	10.1
November	31	0.7	10.1	4.8	23.8	10.4
December	36	0.0	7.5	4.6	19.5	10.2
Year	26	121.4	9.3	4.6	27.6	10.4

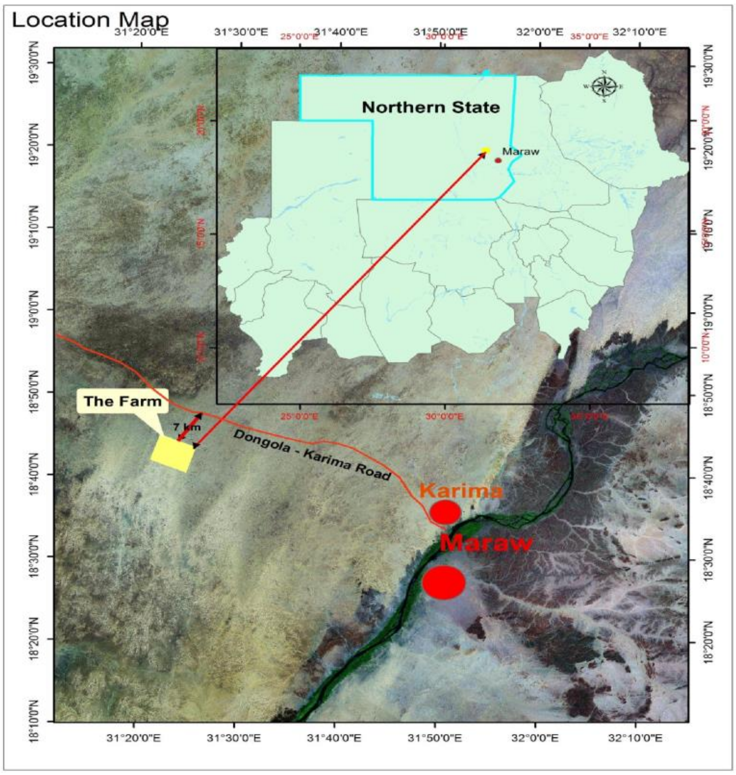


Fig.1. Location map of the study area Based on Land-sat image 2018.

Table (2). Shows longitudes & latitudes bounded the project area by UTM system.

Corner	Longitude (X)	Latitude (Y)
1	328327	2073967
2	334663	2070991
3	332884	2065260
4	326548	2068237

2.2. Methodology:

A. Office methods this method includes the following steps:

i. Collection of previous studies in the area that covers the target area.
ii. Preparation of location map and other topographic map.
iii. Preparation and interpretation of satellite images.

B. Field work:

Satellite Image (land sat 8, 2018), Global Positioning System (GPS) and Geographic Information System (GIS) were used to locate and determine the coordination of soil observations and designing soil map. Depending on the variability that observed from satellite image analysis samples of soil were collected (by auger and profile methods) from different selected locations in the study area. The selection of soil samples depending on satellite image interpretation, morphological features and differences physical properties (color, texture, structure…etc.). The intensity of observations will be one auger for (54.3 feddans) about to have = 169 auger sites from two soil depths (0-30cm, 30-60cm) and vertical and horizontal distance between the Auger sites is 500 meters (Fig.2). Digging and description of soil profiles for the soil unites (indicated by the interpretation of satellite images and Sudan Land Cover maps, about 15 profile sites and 169 auger points covering all the soil unites, (Fig.2). Soil analysis information (Evaluation Classification & Land Suitability) based on USDA (2010) system of classification and photos of the area showing some soil profile, Landscape and Geographic Feature.

C. Laboratory work:

The physical and chemical analysis carried out to investigate the following parameters;

1- Electrical conductivity (Ec) to investigate the soil salinity.
2- Soil reaction (pH) to investigate soil alkalinity and acidity.
3- Sodium Adsorption Ratio (SAR) to investigate the soil sodicity.
4- Percentage of the calcium carbonates (%CaCo3), to investigate the soil calcareousness.
5-Mechanical analysis & the textural class, to investigate the percentage of the relative proportions of the soil particle size (sand, silt and clay). The results were expressed as percentages on oven dry weight basis. The fractions are: Coarse sand: 2-0.2 mm, Fine sand: 0.2-0.05 mm, Silt: 0.05-0.002 mm, Clay: less than 0.002 mm
6- Cations Exchange Capacity (CEC), to evaluate the ability of the soil for holding capacity of water and nutrients
7- Fertility status by measuring the N, P and K levels.
8- Determination of Organic Carbon (O.C %).

D. GIS analysis and mapping:

Geographical Information System (GIS) was used for data capture, manipulation, visualization, combination, query, and output; an intersection was performed between the classified image and the soil map of the study area in order to improve the classification results.

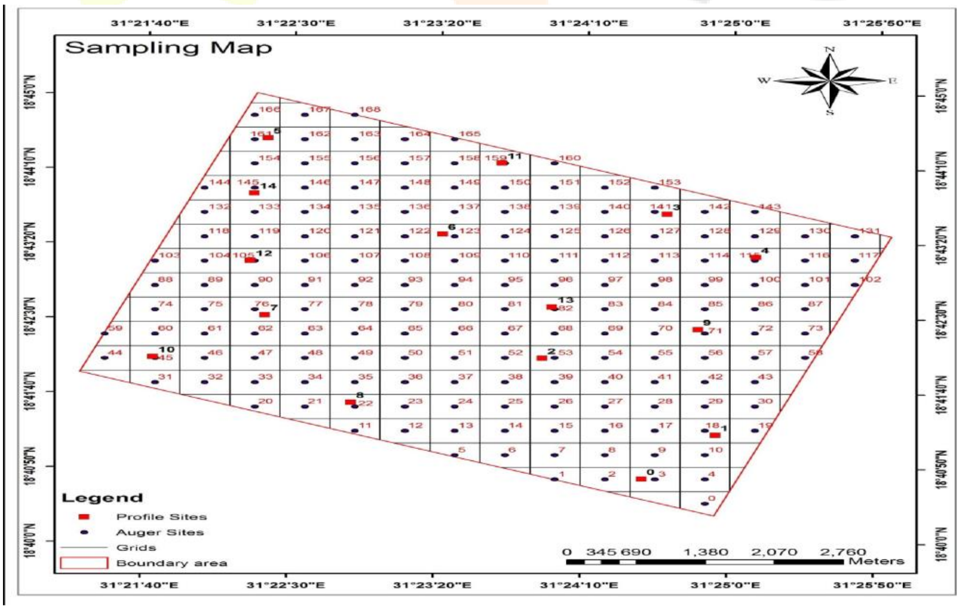


Fig.2. Soil Sampling map

3. Results and Discussion:

3.1. Results:

The soil has to be a physical support for the plant roots and above ground parts, but it also need to act as a supporting store and supply air, nutrients and water for growth. As a result the paper aim to explain the most soil growth limiting factors and their influence in production of different crops in the study area. Although there is no such thing as an ideal soil, but there is aplenty that the agronomist and farmer can do to improve this basic growing media, there for we aim to interpreting the analytical data obtained to overcome the most problematic growth factors.

3. 1.1 Soil pH:

Table. (3) shows the average values of pH for all samples. The soil guideline (6.5-7.5) relates to the pH at which the soil chemistry is such that the optimum amount of all soil held nutrients are available to the crop. At pH values more or less the reference value (guideline) nutrients, phosphorus, iron, manganese, boron, copper and zinc are reduced in availability. The results of soil pH in the surface and sub surface soils are moderately and highly alkaline. Fig.3&4; are presented pH in the study area.

Table.(3). Values of pH for different soil depths in the study area.

Soil depth	Ranges	Average	Guideline	Comments
Surface soil (0-30 cm)	7.4-9.3	8.35	6.5-7.5	Moderately alkaline
Sub-soil (30-60 cm)	7.1-9.2	9.3	6.5-7.5	Highly alkaline

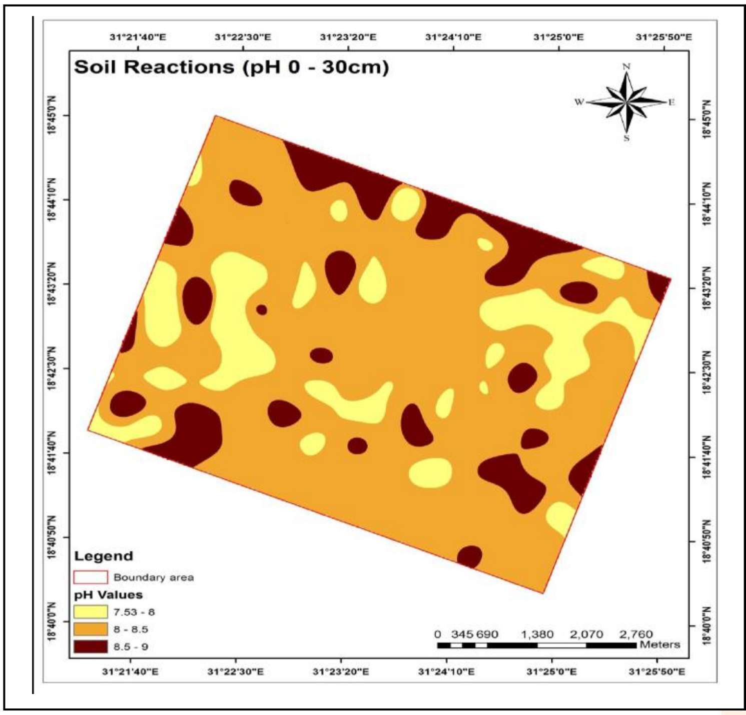


Fig.3. Soil reactions (pH 0-30cm)

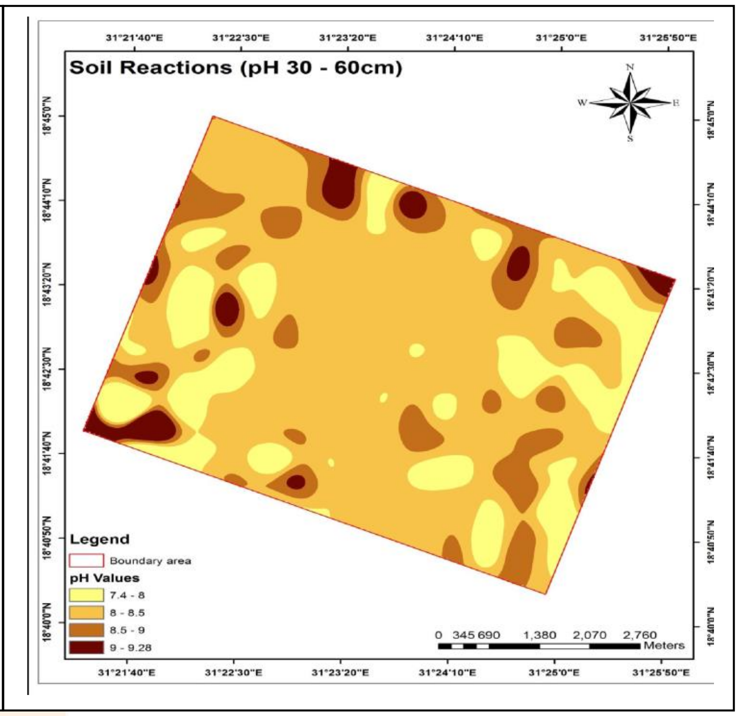


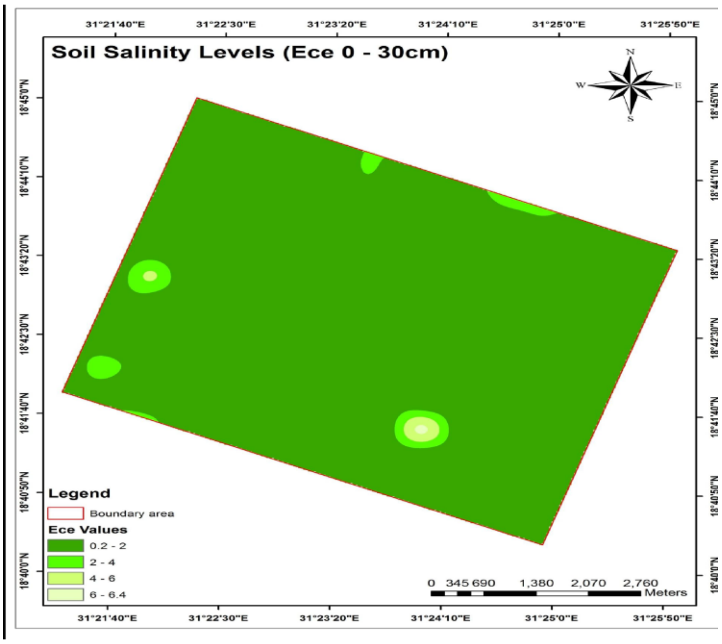
Fig.4. Soil reactions (pH 30-60cm)

3.1.2 Soil salinity levels (Ece).

Soil salinity is the accumulation of soluble salts in the plant root zone. Accumulation of salts either leads to changes in the osmotic pressure of the soil solution, restricting the flow of water into the plant and/or build up of elements at toxic levels (particularly problems of sodium and chlorine). Table.4 and Fig.5 & 6; below depicted the status of salinity levels in the study area.

Table.4. Salinity level for different soil depths in the study area.

Soil depth	Ranges	Average	Guideline	Salinity classes
Surface soil (0-30 cm)	0.12-6.37	0.41	<4.0 ds/m	Non-saline
Sub-soil (30-60 cm)	0.8-14.8	1.13	<4.0 ds/m	Non-saline



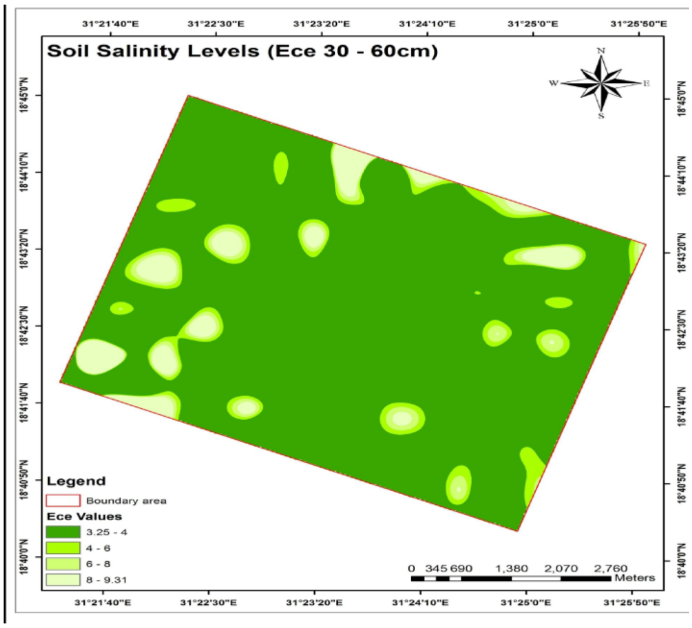


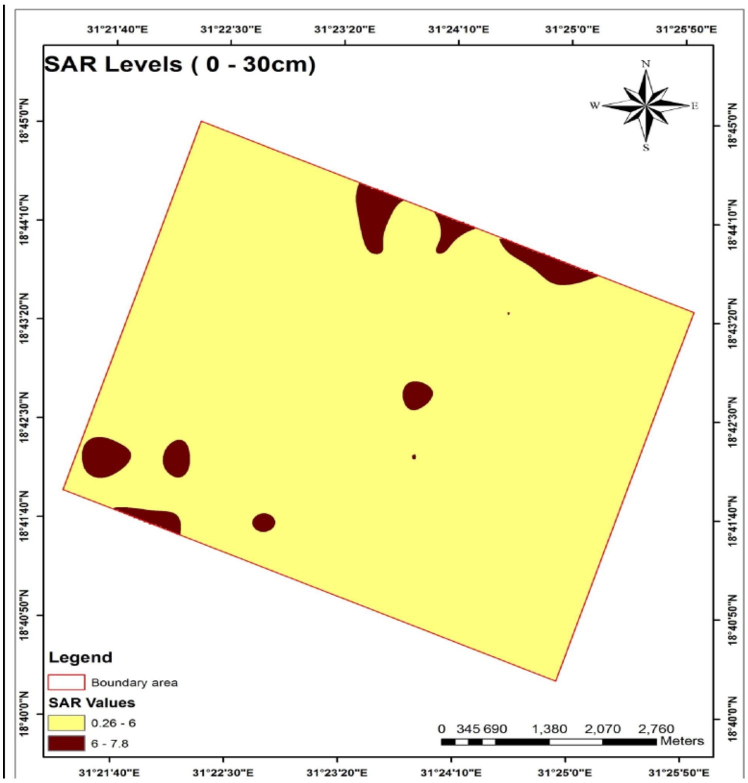
Fig.5. Soil salinity levels (Ece 0-30cm) **Fig.6. Soil salinity Leveles (Ece 30-60cm).**

3.1.3 Sodicity (SAR):

Sodicity is expressed in terms of Sodium Adsorption Ratio (SAR), or defined by the values of Exchangeable Sodium Percentage (ESP %). However Sodicity is particularly problematic in alkaline soils conditions. When the sodic problem is at surface; crusts are formed which inhibit seed germination and when the Sodicity occurs at depths; hardpans formed restricting roots development. SAR values are indicated by table.5 and Fig.7&8.

Table.(5). Sodicity level for different soil depths in the study area.

Soil depth	Ranges	Average	Guideline	Comment
Surface soil (0-30 cm)	0.26-7.79	1.35	<13.0	Non-sodic
Sub-soil (30-60 cm)	0.36-16.6	2.07	<13.0	Non-sodic



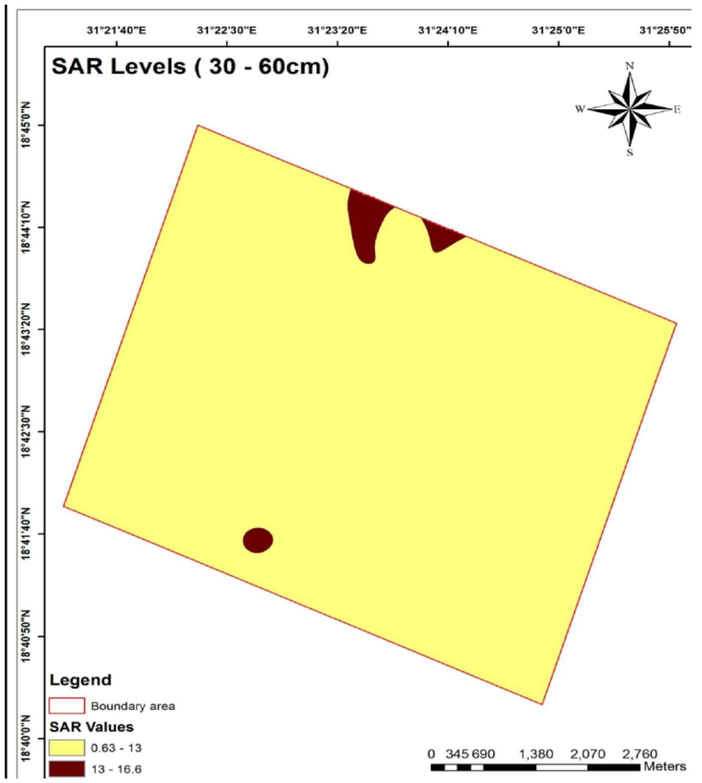


Fig.6. SAR level (30-60cm) **Fig.7. SAR level (30-60cm)**

3.1.4 Soil Moisture Content (M.C).

In general soil moisture content in the study area is low but, the moisture increased with depth. The values of soil moisture content are presented in table.7 and Fig.9 & 10.

Table.7. Moisture content for different soil depths in the study area.

Soil depth	Ranges	Average	Guideline	Comment
Surface soil (0-30 cm)	19-40.3	24.7	>40%	Low moisture content
Sub-soil (30-60 cm)	19-45.6	26.7	>60%	Low moisture content .

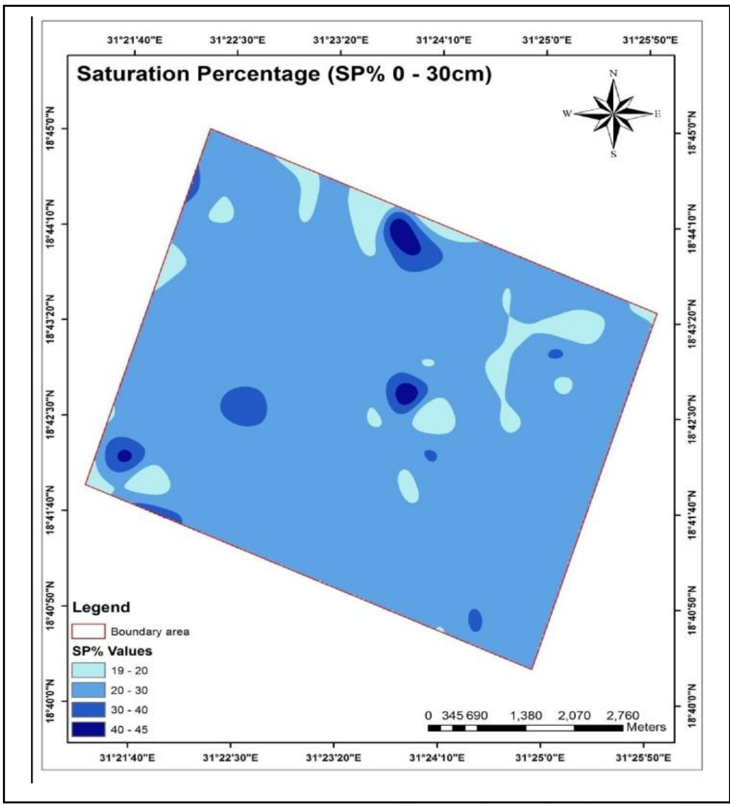


Fig.9. Soil moisture content (0-30cm)

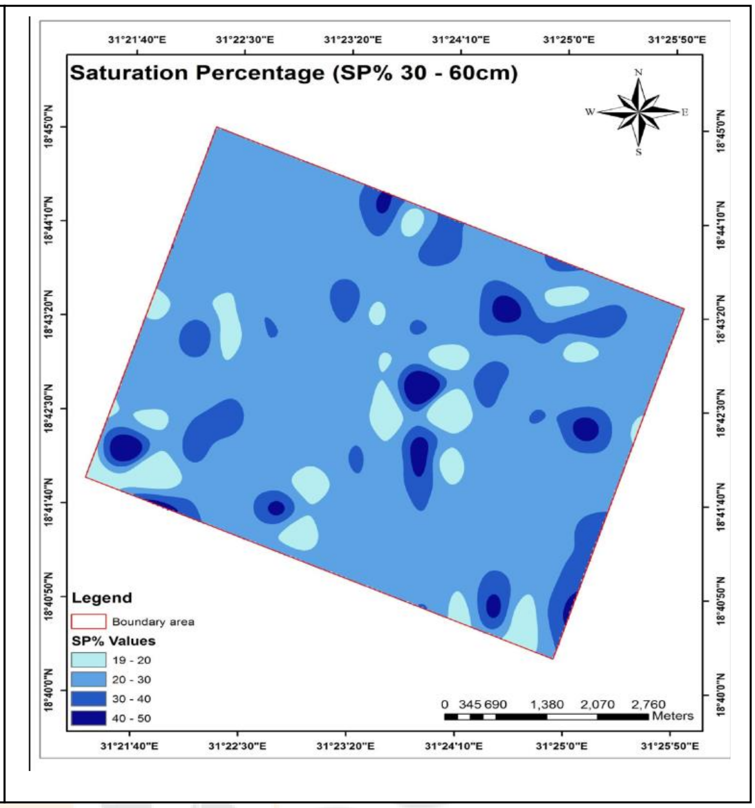


Fig.10. Soil moisture content (30-60cm).

3.1.5 Soil texture:

Soil Texture has highly significant effect on the soil air, water holding capacity and drainage properties of soil. The analytical results revealed that, the study area is characterized by light-medium texture, ranged in textural classes (sandy loam and sandy soils). Having sand (50-90) %, Silt (20-30) % and clay <20 %. Unlike the medium texture the lighter soils resulted in low Cation Exchange Capacity (CEC), so the project area suffers from low moisture content and low nutrients holding capacity.

3.2. Discussion:

The land suitability classification system now in use (Kevie and El Tom, 2004) is an approach derived from the FAO Framework for Land Evaluation, as given in (Brinkman *et al*, *1973*) to suit the local conditions of the Sudan. The purpose of the land suitability classification is to provide a comparative and qualitative assessment of the potential suitability's of the soil for irrigated agriculture according to limitations and problems. The system is composed of four categories in a decreasing level of generalization, i.e. orders, classes, subclasses and units. The soil survey was carried out to evaluate the land suitability for irrigated agriculture. The land suitability classification revealed that, land class S2 (moderately suitable lands), include the following sub-classes S2m covered an area about (565 feddans), S2ma covered an area about (4299 feddans) and S3ma (marginal suitable lands), covered an area about (5068 feddans). Where (m) means moisture content ranged from 10-40%, (s) salinity level ranged from(0-4) &(4-8) ds/m., and (a), Alkalinity levels indicated by pH values (8-8.5) & >8.5.
The physiochemical of soil indicators namely: pH, Ece and SAR, their levels increases from surface soil to sub-soil accounted about, 8.3-9.3, 0.41-1.13 and 1.35-2.07, respectively. These findings may be attributed to the soil texture class. Clay content increases with depth leading to capture and raise the values of physiochemical of soil indicators. Regarding to the result of soil moisture content increased with depth and this finding coinciding with soil texture where clay content increases and texture classes from surface soil to sub-soil ranged between sandy loam-sandy and sandy clay –loam, respectively.

4. Conclusion and recommendation:

4.1. Conclusion:

- The results of survey and analysis carried out for the study area provide general overview considering the most soil growth limiting factors (pH, Ece, SAR and soil texture) as well as the soil topography.

- The land suitability classification revealed that, land class S2 (moderately suitable lands), include the following sub-classes S2m covered an area about (565feddans), S2ma covered an area about (4299 feddans) and S3ma (marginal suitable lands), covered an area about (5068 feddans).
- The physiochemical of soil indicators namely: pH, Ece and SAR, their levels increases from surface soil to sub-soil accounted about, 8.3 - 9.3, 0.41 - 1.13 and 1.35 - 2.07, respectively. These findings may be attributed to the soil texture class. Clay content increases with depth leading to capture and raise the values of physiochemical of soil indicators.
- The dominant feature of the project area is the accumulation of sands covering the surface in different volume resulting in a very light textured soil.
- Regarding to the result of soil moisture content increased with depth and this finding coinciding with soil texture where clay content increases and texture classes from surface soil to sub-soil ranged between sandy loam-sandy and sandy clay – loam, respectively
- The highly undulating topography of variable rock out crops covering even the relatively flat areas.

4.2 Recommendation:

Regarding to the geo-morphological and soil limitations numbers of recommendations has been raised to conduct in order achieving irrigated agriculture in the study area, these recommendations are:

[1] It is necessary to re- levelling the sand dunes at the surface ensuring good seed bed structure, which allows placement of seeds at even depths and spacing, provided that nearly levelling fields are important for irrigation and fine retention of water (ie-the soil should be compact enough to allow good contact with the seed and good moisture retention for germination).
[2] Scraping of gravels or pieces of small rocks and assembling of rock out crops to facilitate working and land preparations, where big rocks can be used in the pivot wheel track.
[3] It is necessary to add composted manures & Agric sulfur at rate of (1-2) tons and 25 Kg respectively ,which release acids to minimize the high pH values as well as it improve both the water and nutrients holding capacities.
[4] Addition of chemical fertilizers as sources of NPK and other micro-nutrients include Fe, Cu, Zn and Mn.
[5] Introducing shelter belts to control erosion hazards.

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