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Land evaluation of University of Khartoum top farm using remote sensing and geographic information system

Ibrahim M.M.M[1], Dafalla M.S.[2], Elhag A.M.H[3], Ibrahim S.I.[4]

1Department of Soil and Environment Sciences, University of Khartoum, Sudan
2Department of Soil and Environment Sciences, University of Khartoum, Sudan
3Department of Basic Science, University of Bahri, Sudan.
4Department of Soil and Environment Sciences, University of Khartoum, Sudan

Abstract- This study focused on the classification and evaluation of land, determination of suitability for surface irrigation, suitability for agriculture under irrigation and crop suitability in Khartoum University top farm (Shambat area), Khartoum State, Sudan. Through monitoring and mapping the changes that occurred in the soil due to drought and climate change in relation to land degradation processes in the study area was the main goal of this research.

The research was based on the data and information deduced and relied on field work, laboratory analysis and geographic information systems.

The study revealed that the soil is moderately suitable for agriculture due to limitations for optimal use, such as low fertility, soil cracking and wetness, this indicated that the soil is non-saline, non-sodic and calcareous. However, there are some small pockets of saline and sodic soil.

The results showed that the bulk density is relatively high, ranging from 1.5 to 1.9 g / cm3, this affects the physical environment of the soil while the spatial variability analysis of electrical conductivity of saturation extract (ECe), sodium adsorption ratio (SAR) and pH showed that there are no significant variation in these properties among the soils of the farm since all the soil samples were non-saline, non-sodic, and moderately alkaline.

The study proved that the use of global position system (GPS) and geographical information system (GIS) techniques are effective in soil evaluation.

Index Terms- land evaluation, remote sensing, geographical information system, land suitability, soil characteristics.

I. Introduction

The Sudan falls within the zone where the risks of land degradation are great. Total area of 65 million hectares, lying between latitude and longitude (32° 52' 16.48"E, 14° 24' 05.65"N) and latitude and longitude (32° 8' 1.48"E, 15° 9' 33.48"N).extending across the Country from east to west has been decertified or degraded land [1].

Soils are natural bodies on the earth surface, modified or sometimes even made by man of earthy material contains living matter and supporting or capable of supporting plants out doors. Soil is a natural medium for the growth of plants. It covers the earth as a continuum, except on rocky slopes in region permanently covered with ice, in very salty playas, and elsewhere where the cover of soil disappears [4].

Soils tend to show a strong geographical correlation with climate, especially at the global scale. Energy and precipitation strongly influence the physical and chemical reactions on parent material. Climate also determines vegetation cover which in turn influences soil development. Precipitation also affects horizon development factors like the translocation of dissolved ions through the soil. As time passes, climate tends to be a prime influence on soil properties while the influence of parent material becomes less important [10].

The land suitability refers to the fitness of a given area of land for a defined kind of land use. Land suitability is usually assessed on the assumption that the defined land use will be sustained and the environmental quality must be preserved or even improved on the site and the surrounding area [11].

The term Land Information System (LIS), is often used for spatial systems handling landscape data, at larger mapping scales. It is technology management tools, in the storing, retrieving, analyzing, and updating of large quantities of map and land survey data. It has been motivated by budget constrains to face the need for quick decision- making and the rapid decrease in computer costs [8].

II. Study Area

The study area, University of Khartoum top farm, is located in Khartoum North, Khartoum State, Sudan. It is situated on the eastern bank of the River Nile. The area extends 3.5 km along a southeast-northwest direction and extends 1.5-2 km east west. It is bounded on the east by Shambat road. Fig.1 presents the coordinates of the traverse inclosing the area and location map respectively (300feddan). The study area is more or less a flat plain with a gentle south east to North West direction and east to west tilt towards the River Nile.

2.1 Climate

According to Van der Kevie [7] the study area falls in the arid climatic zone of the Sudan just to the south of the fringes of the semi-desert - climatic zone. The arid climate is characterized by summer rains and warm winters. The climatologically normal of the Khartoum meteorological station (the nearest station of the study area) are presented in Table (3.2). The main annual temperature is 29.9oC. Average maximum temperature in the hottest months (April-June) is 41.2^{o}C while the average minimum temperature for the same period is 6. 3^{o}C. the average minimum temperature during the winter (Dec-Feb) is 16.5°C. The relative humidity fluctuates during the day (GMT) and during the year (season). The mean annual relative humidity ranges between 26-21 % (Jan to Feb), 15-26 % (March to June) and 41-48 % (July to September, the wettest three months). The average annual rainfall is about 121mm falling mainly in July and August with lower amounts in September. The rainfall is erratic in quantity, intensity and distribution. The high temperature coupled with strong solar radiation result in values of potential evapotranspiration exceeding by far the rain fall almost throughout the year, except in July, August and September. This is not unexpected under the semi-desert climate prevalent in the study area. Vegetation of the study area is more or less devoid of vegetation possibly due to the land clearance. However there are scattered bushes of tundub (*Capparisdeciduas*), Talh (*Acacia seyal*), Usher (*Clatropisprocera*), and whistling thorn (*Acacia var. seyal*), North of the area the vegetation is undisturbed.

The soils of the area are alluvial deposits consisting of abandoned (second and third) terraces of the River Nile. The alluvium belongs to the Quaternary period [9]. The solid geology to the east of the study area consists of the Nubian Sandstone formation, continental classic sediments including sandstone, siltstone, and mudstone and conglomerate, belonging to the cretaceous age. The Nubian Formation in study area is recharged from three main sources: percolation of rain water, seepage through the beds of the *khores* and *wadis,* and seepage from the bed of the River Nile.

III. METHODOLOGY

Global Positioning System (GPS Garmin 12 XL) was used to locate the position of the check sites. 47 soils check sites were located, (42 auger sites and 5 profiles), soil samples were collected from three depths 0-30, 30-60 and 60-90 cm. The soil samples were kept in labelled plastic bags. The American System of soil classification was used to classify and Rating the land Qualities of the study area. A total number of 133 samples, the distance between adjacent soil samples (in all directions) was 250 m, fig 2. The soil samples were analyzed using the facilities of the department of soil and environment science Faculty of Agriculture, U of K. The flowing properties were determined in soil samples:

- Soil Reaction: Soil pH was measured in soil paste using analogue pH-meter JENWAY.
- The Electrical Conductivity (ECe): The electrical conductivity of the saturation extract (ECe) was measured by conductivity meter WAPcm 35 (model cm 35).
- Soluble Calcium and magnesium: Calcium and magnesium were determined volumetrically with titration against ethylene diamine tetra acetate (E.D.T.A).
- Soil Nitrogen (% N).
- Carbon/Nitrogen Ratio (C/N).
- Macronutrients (NPK).
- Soluble cations (Ca^{++}, Mg^{++}, Na^{+} and K^{+}) and anions (CO_3, HCO_3, CL and SO_4).
- Sodium: Sodium was determined photometrically using Corning EEL flame photometer.
- Sodium Absorption Ratio:

Sodium absorption ratio was estimated from values of calcium, magnesium and sodium of saturated paste extract. Exchangeable sodium percentage (ESP) was from regression equation of ESP on SAR.

- Bulk density (BD).
- Infiltration rates (IR).

IV. RESULTS AND DISCUSSION

According to the American system of soil classification [3]. The soils of the study area belong to the order Aridisols. These soils lack available water most of the time when the soil temperature (isohyperthermic) suitable for plant growth. The soils of the study area fall into three different groups; first terraces, second terraces and third terraces, Table 1 and figure 3 showed that the soil of the study area was classified into to the order Vertisols, Aridisols and Entisols.

Table1: Classification of the soil of the study area

Unit No:	Profile No.	Classification	Area (Feddan)	%
1	UofK TOPFARMP01	Fine, mont, superactive, isohyperthermic, TypicHaplotorrert	46	18
2	UofK TOPFARMP02	Fine, mont, superactive, isohyperthermic, VerticTorrifluvents	20	20
3	UofK TOPFARMP03	Fine, smectitic, superactive, isohyperthermic, EnticHaplotorrert	50	20
4	UofK TOPFARMP04	Fine, mont, isohyperthermic (superactive), VerticTorriorthents	50	20
5	UofK TOPFARMP05	Fine, mont, superactive, Isohyperthermic (superactive), VerticHaploargids	53	22

The soil of the study area classified with respect to their suitability after rating the different qualities [12]. The suitability classes of all mapping units recognized are moderatelely suitable (S2) (land which is expected to be moderately productive for the defined use, yielding moderate benefits, with limitations which are moderately to reduce crop yields and/or increase recurrent inputs and the limitation includes fertility (f), wetness (w), salinity (s) and sodicity (s). The soil fertility of the area (five mapping units) was calculated using pH, OC%, N%, P, CEC, base saturation and micronutrients. The Table reflected low fertility (Rating 3) because the study area situated in arid region. The soils of the area are non-saline (Ece less than 4 dS/m). The soils are non-sodic (SAR 0-30 cm <8) and (SAR 30- 120 cm <18 Rating1). Erosion hazard of the study area are negligible because there were no evidences of sheet erosion (Rating 1). The soils are calcareous. The topography for gravity irrigation of the study area is smooth to promote uniform distribution of water and provide surface drainage to the all parts of the study area (Rating1). The workability of the study area is hard because it has clay texture, subangulgar blocky structure, and coarse gravels (<3% of the surface coverage) (Rating1) [5]. Table 2 and fig. 4 fore details.

The method of land suitability for irrigation is defined according to the value of the capability (or suitability) index (Ci), which was calculated by a weighted average for the upper 100 cm of the soil profile for slope class, texture, soil depth, calcium carbonate status, salinity, sodicity, and drainage.

The suitability classes for irrigation were identified in the study area Table 3 and Fig. 5. It is evident that the mapping units 1 and 3 are slightly suitable while other mapping units 2, 4 and 5 are almost unsuitable. This could be due to limitation of texture (clay) and drainage (low infiltration rate) [5].

In applying systems of crops suitability to the soils of the study area, the ranking of the suitability of the different mapping units of the study area was found as indicated below bearing in mind that these ratings were based on the weighted average. The suitability of the land to different crops was determined for field and horticultural crops (vegetables and fruits).

The land suitability for crops was calculated by matching site conditions, available in the land resources inventory, with the crop requirement with respect to the following characteristics: topography, drainage, physical soil (texture, structure), calcium carbonate and gypsum, soil fertility (apparent CEC, base saturation and organic carbon), salinity and alkalinity, climatic conditions. The methods used were based on qualitative evaluation [6]. The suitability of the field crops, vegetables and fruit trees are divided into excellent, good and moderate; For example the suitability for crop Alfa alfa (*medicagosativa*) of the soil mapping unit 1 was excellent for that crop; slope 0-2, moderate drainage, silty clay loam texture, with pH 7.4-8, ECe between 0-3 dS/m and SAR 0-8 and other requirements [2].

V. CONCLUSION AND RECOMMENDATION

The study revealed that the soil of the study area watched difference change under arid condition, inherently of low fertility (both macro and micronutrients) and some the soils of the study area are compacted and in some places hard pans were encountered. This will interfere with seed emergence and water infiltration down the profile and hence the establishment of good crop stand.

Based on these finding the following recommendation can be stated:

1. Subsoiling or ripping to a depth of 30 to 45 cm or more should be the practice to break the compaction and the hard pans and to improve the infiltration rates of the soil of the study area.
2. The reclamation of the slightly saline pockets of the soils which found in some parts of the study area should be attempted through the application of organic manure (farmyard and chicken manures) for the improvement of physical, chemical and biological properties.
3. Proper programs should be adopted for clearance of irrigation canals from weed and deposited siltation.
4. Salinity and sodicity pockets could be reclaimed through deep ploughing with leaching and addition of gypsum and/ or organic manures.

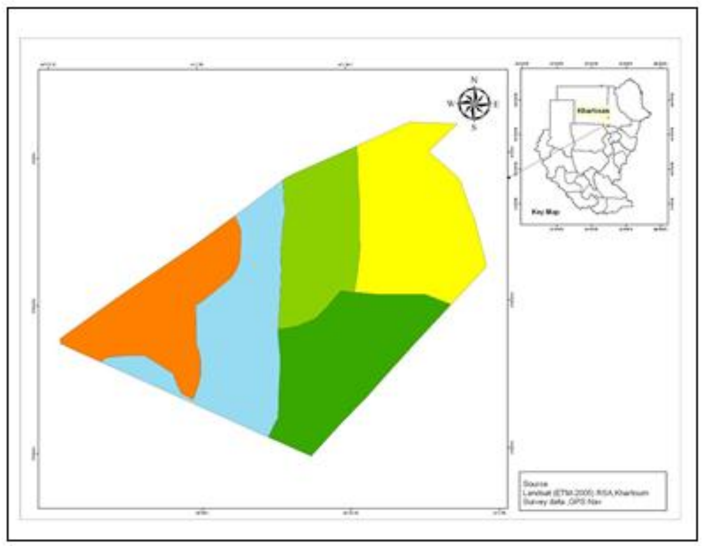

Figure 1: Location map of the study area.

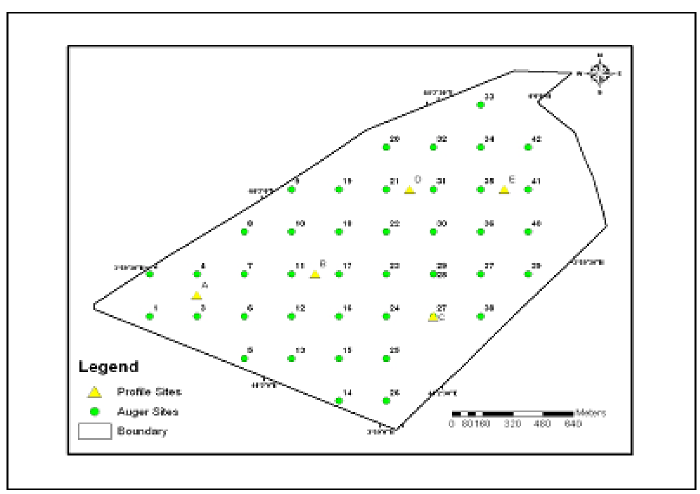

Figure 2: Location of auger and representative profiles sites.

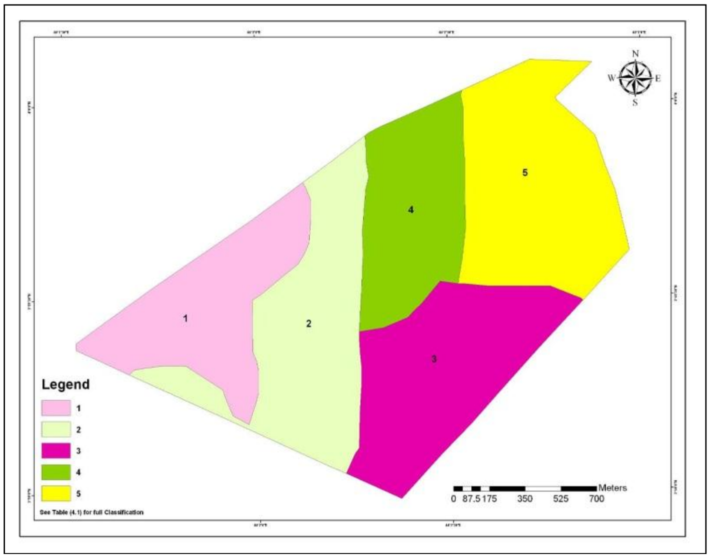

Figure 3: Taxonomic map units.

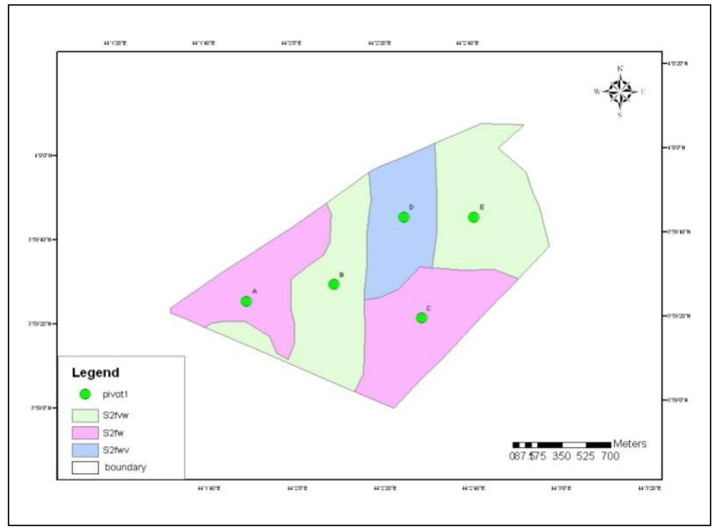

Figure 4: Land suitability of the soils of the study area.

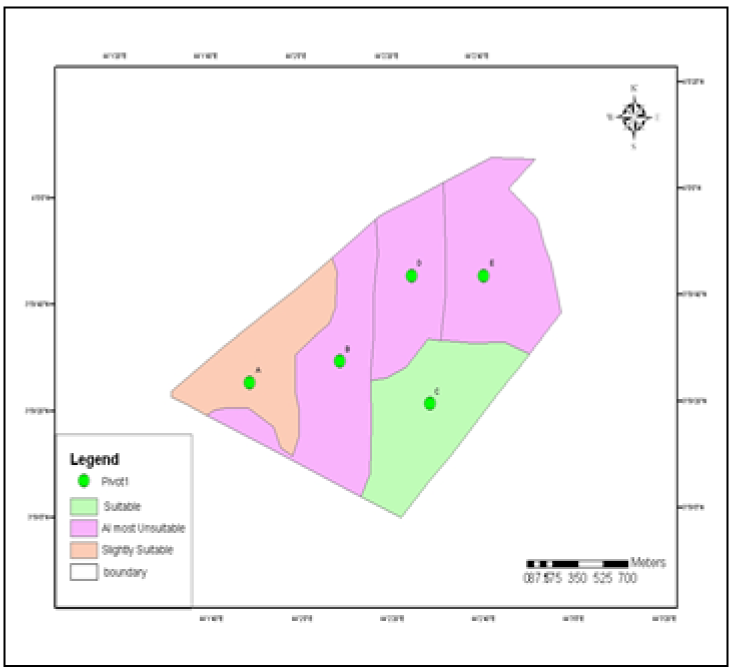

Figure 5: Land suitability for Surface irrigation.

Table 2: Land Suitability of the study area.

Soil Mapping Unit / **Land quality**	**1**	**2**	**3**	**4**	**5**
Soil moisture availability	1	1	1	1	1
Chemical soil fertility	3	3	3	3	3
Cond. For seed establishment	1	1	1	1	1
Drainage condition. In grow season	1	1	1	1	1

Workability	1	1	1	1	1
Possibility of mechanization	1	1	1	1	1
Salinity	1	1	1	1	1
Sodicity	1	1	1	1	1
Erosion hazards	1	1	1	1	1
Capabil. For maint. Surface water	1	1	1	1	1
Topography for gravity irrigation	1	1	1	1	1
Soil drainability	4	4	4	4	4
Land cover	1	1	1	1	1
Suitability classes	S2	S2	S2	S2	S2
Suitability sub classes	S2fw	S2fvw	S2fw	S2fwv	S2fvw
Kind of limitation	fw	fvw	fw	fwv	fvw

Note: f = fertility; w = wetnes; v= vertisolic limitation

Table 3: Land Suitability for Irrigation.

Unit	Profile	Slope	Texture	Soil depth	CaCO3	Salinity and alkalinity	Drainage				Definition
1	P1	95	85	100	100	100	65	0.52	III	Moderately drained	slightly suitable
2	P2	95	65	100	100	100	65	0.40	IV	Poorly drained	Almost unsuitable
3	P3	95	100	100	100	95	65	0.62	II	Moderately drained	suitable
4	P4	95	65	100	100	60	65	0.40	IV	Poorly drained	Almost unsuitable
5	P5	95	65	100	100	100	65	0.40	IV	Poorly drained	Almost unsuitable

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AUTHORS

First Author – Muzmmel Mustafa, Department of Soil and Environment Sciences, University of Khartoum, Sudan.
.

Second Author – Mohamed Salih Dafalla, Department of Soil and Environment Sciences, University of Khartoum, Sudan.
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Third Author – Abass Mohamed El Hag Hamed, Department of Basic Sciences, University of Bahri, Sudan.

Fourth Author – Ibrahim Saeed Ibrahim, Department of Soil and Environment Sciences, University of Khartoum, Sudan.