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Full Length Research Paper

Spatial variability mapping of some soil properties in El-Multagha agricultural project (Sudan) using geographic information systems (GIS) techniques

M. Y. Mohamed[1]* and B. M. Abdo[2]

[1]Faculty of Agriculture, Alzaiem Al-Azhari University, Khartoum North, Box 1432, Sudan.
[2]Ministry of Agriculture and Forestry, Sudan.

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Soil surveying and mapping is an important operation, since it plays a key role in the knowledge about soil properties and how it can be used for agriculture, irrigation, urbanization and other land uses. This study was carried out in order to map out some soil characteristics in the Northern State in resettlement projects associated with the newly established Merowe Dam. Some physical and chemical properties of the soil were determined to assess the current situation of the region, since no similar study had been conducted in the area to assess the soil status. The use of the geographic information systems (GIS) and sampling broad analysis through the use of GPS is found to be a very efficient tool. This study demonstrates the usefulness of these technologies in soil survey. The objective of this study is to conduct a soil survey in a new developing area using a nontraditional technique. GIS was used in this study to present the laboratory findings of the soil analysis; as such, this was achieved through a preparation of digital maps for soil properties. These digital maps can be used in precision farming studies with the application of variable rate technology. The obtained results showed the alkaline reaction of soil, where the range of pH was between 8.8 and 7.0. Moreover, the EC's range was found to be 2.34 to 3.30, where the value of 3.38 dS/m was found in depth of 30 to 60 cm. Nonetheless, the SAR values fall within the slight, moderate and strong degrees of salinity.

Key words: Geographic information systems (GIS), global positioning system (GPS), soil survey, soil properties mapping, spatial variability.

INTRODUCTION

Soils play a central role in the life and development of lands. They provide a vital substratum for people, animals, plants and micro-organisms. They are a key component of the ecosystems, in particular for water and nutrients cycling. In addition, they constitute a major genetically reservoir and are a place of major regulation and transformation processes. As a central element of the mountainous landscape, soils have always occupied a central position in the cultural and economic life of human communities. In particular, they constitute the basis for agriculture, including forestry and raising of livestock, and a major component for recreational and touristic activities. It is therefore essential to promote the conservation and sustainable use of the soil resource, taking into account the specific sensitivity of soils to degradation and alteration processes.

Soil survey can be of use to the agricultural producers, farm managers, and consultants; hence, it contains information that is the basis for conservation efforts aimed at erosion protection from wind and water (FAO, 1988). Soil survey evaluation is a tool to assess, manage and induce changes in the soil and to link existing resource concerns to environmentally sound land management practices and soil survey assessment, which is thus used to evaluate the effects of management on the soil. An

*Corresponding author. E-mail: Mustafayousif70@yahoo.com. Tel: 0024915677988.

intimate knowledge about the types of soils and their spatial distribution is a prerequisite in developing rational land use plan for agriculture, forestry, irrigation and drainage etc.

Soil survey provides an accurate and scientific inventory of different soils, their kind, nature and extent of distribution so that one can make prediction about their characters and potentialities. It also provides adequate information in terms of land form, terraces and vegetation (Brown et al., 1978).

Reliable and timely information on soil is a vital issue conducted throughout the nation in order to gather spatial information and associated statistics on crops, rangeland and other related types of soil uses. Such types of information are most important for the implementation of effective management and decisions making at district levels.

Advent of GIS technology and its great potential in the field of soil have opened newer possibilities of improving soil statistic system as it offers accelerated, repetitive, spatial and temporal synoptic view. GIS is a potential tool for handling voluminous data and has the capability to support spatial statistical analysis, thus there is a great scope to improve the accuracy of soil survey through the application of GIS. It may be difficult to implement such programs without regulations to deal with information that enables researchers and decision-makers to benefit from the vast quantity of data and maps that can be used effectively by using methods of collection, storage and traditional or customary analysis; therefore, it is now important to use some systems such as GIS so as to create geographic information rules that will help in the accounting and analysis of the achievements and maintenance programs. The development of plans and processes of data acquisition and analysis is very fast through the use of GIS as compared to conventional methods.

The main objective of this study is to conduct a soil survey in a newly developing area using a nontraditional technique. GIS will be used in this study to represent and illustrate the geo-referenced the laboratory's analysis findings of the soil analysis, spatially to help in identification of areas suitable for the cultivation of crops in the study area and to develop a suitability map for the study area. This will be achieved through the preparation of a digital map for some soil properties. New tools allow both the scientists who implement soil survey and the decision makers who use them to better analyze and utilize the data. GIS has greatly improved the ability to analyze and spatially depict soil data. In addition, custom soil data queries can be made and the results can be presented spatially using real world locations.

MATERIALS AND METHODS

This work was conducted in a study area located in the Western bank of the River Nile, in the Northern State of Sudan, and the area was confined between longitudes 30º 00' 08" and 31º 15' 31"E and latitudes 17º 50' 11" and 18º 10' 11" N (Figure 1).

The total area of the project is about 147000 km^2. The project area is a true desert with extremely high temperatures and solar radiation in summer, low temperatures in winter, low rain fall and high wind speed. The diurnal range of temperature is wide all year round. The mean maximum and minimum temperatures are 37 and 19°C, respectively, whereas the climate is hyper-arid with low vapor pressure and relative humidity. The shine duration of the mean bright sun is 10.5 h; nevertheless, solar radiation is as high as 25.88 MJM in May. Rainfall is low with a mean annual amount of 21 mm, whereas the wind prevails from the North for most parts of the year. The winter season is characterized by the strong dry North direction winds which cause serious sand drift in the area. However, the average wind speed is 15.7 km/h (Ministry of Agriculture and Forestry (MAF), 1999).

The data required for this study were collected from different sources and were used in the database construction. The ground truth and field observations were obtained using a GPS navigator at a 500 m grid interval covering the study area. The field activities included an examination of the landscape set up and description of the soil mapping units and laboratory analysis of the collected soil samples from the field. The data were collected from the Ministry of Agriculture and Forestry for characterization of the standard chemical and physical properties and the general properties of the soil of the Northern State area.

RESULTS AND DISCUSSION

Soil surveying and mapping is an important operation, since it plays a key role in the knowledge about soil properties and how it can be used for agriculture, irrigation, urbanization and other land uses. This study was carried out to in order to map out some soil characteristics. As such, some physical and chemical properties of the soil were determined to assess the current situation of the region; thus the results from this study can be presented as follow.

Chemical properties of the soil

The values of soil analysis showed that pH has no significant difference ($P \leq 0.05$), in all depths. In the depth of 30 to 60 cm, alkaline soils have a pH of 7.5 to 8.2. The overall average of the pH for all depths is 8.0, while the average pH of the top and sub soils is 7.6 and 6.3, respectively. The pH values on saturated paste were almost invariably low reflecting the effect of exchange-able sodium, whereas the pH values for the soil samples in different depths were plotted and interpolated using kriging interpolation algorithm method to show the spatial distribution of the pH in 0 to 30 and 30 to 60 cm depths, respectively as shown in Figures 2 and 3.

From Figure 2, it can be observed that the alkaline soils are dominant in the study area and they occupy more than 80% of the area, while the acidic soils cover only about 8% of the area. The spatial distribution of the pH on the sub soil layer (30 to 60 cm) shows that the soils are alkaline.

On the other hand, the spatial analysis was used to

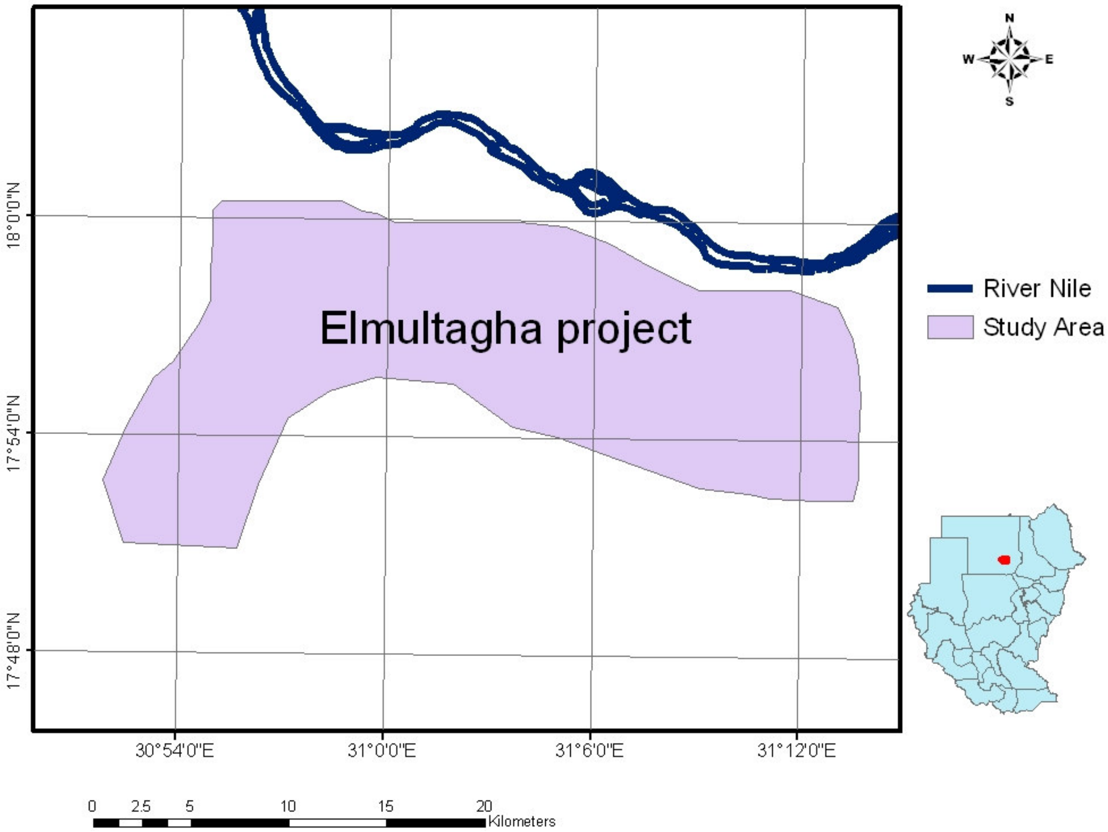

Figure 1. Location of El-Multagha project.

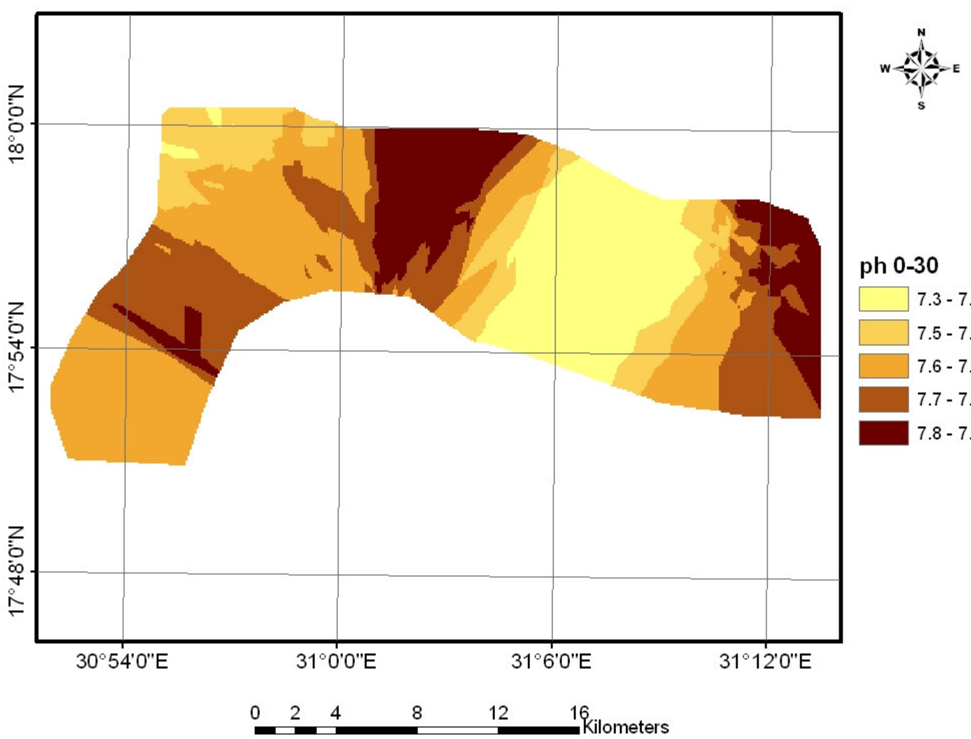

Figure 2. Spatial distribution of the pH in 0 to 30 cm depth.

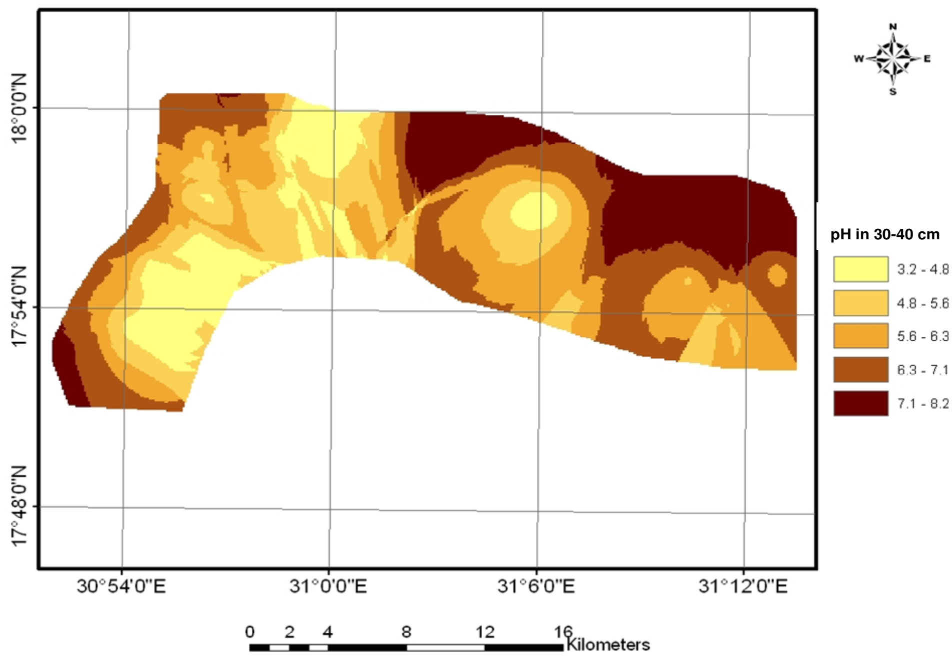

Figure 3. Spatial distribution of the pH in 30 to 60 cm depth.

show the distribution of the EC in the study area as shown in Figures 4 and 5 for the depths of 0 to 30 cm and 30 to 60 cm, respectively. From Figure 4, it can be observed that the non saline soils covered the majority of the soil, and this means the top layer of the soil (0 to 30 cm) in the study area is fertile and suitable for agriculture. From the same figure, the salty soil represent less than 5% of the soil and medium salinity covering 2%, while the high salt soils cover only 0.35% of the area.

In the depth of 30 to 60 cm, the non saline soil covers 90**%** of the area, while the saline soil represents 7% as shown in Figure 5. However, medium salinity soil represents 1.5% of the area and very saline soils covers only 0.50**%** of the area.

The results from soil samples analysis for sodium adsorption ratio (SAR) were plotted and spatially analyzed to show the distribution of SAR in the study area. Hence, Figures 6 and 7 show the spatial distribution of SAR.

From these figures, it can be observed that the majority of soils have less than 4 and less than 8 of the SAR in the depths of 0 to 30 cm and 30 to 60 cm, respectively. From Figure 6, the non sodic soils cover about 77% of the soils, while it covers 80% of the lower depth (Figure 7). Results showed that there were no statistical significant differences in SAR in the different depths.

Soil physical properties

Soil texture is one of the most important characteristic which influences the physical properties of the soil and has great significance in land use and management. The results show no significant difference in soil texture in different layers. Table 1 shows the soil texture in the different layers, while Figure 8 represents the spatial distribution of the soil texture in the study area.

No quantities measurements were made for soil structures and so reliance must be placed on qualitative field assessment. Generally, there are marked structure differences between the top and second horizon, which is usually a direct reflection of soil texture and moisture, though salinity also has some effect. The soils were almost invariably dry in close proximity to the surface and almost dry or only slightly moist at depth. The soils tended to become harder or firmer down the profile, being soft to slightly hard in the top 15 to 20 cm, and becoming hard or firm below 50 cm. Below 50 to 90 cm, where the sub soils are calcareous matrix, the consistency becomes very hard and usually remains very hard or extremely hard (Younis, 1985).

Land capability classification

Three classes were recognized in the capability order as S1, S2 and S3 and two classes in the unsuitable order as N1 and N2. Figure 9 shows the spatial distribution of the land suitability classes.

Conclusion

The outcomes from this study refer to the effective role

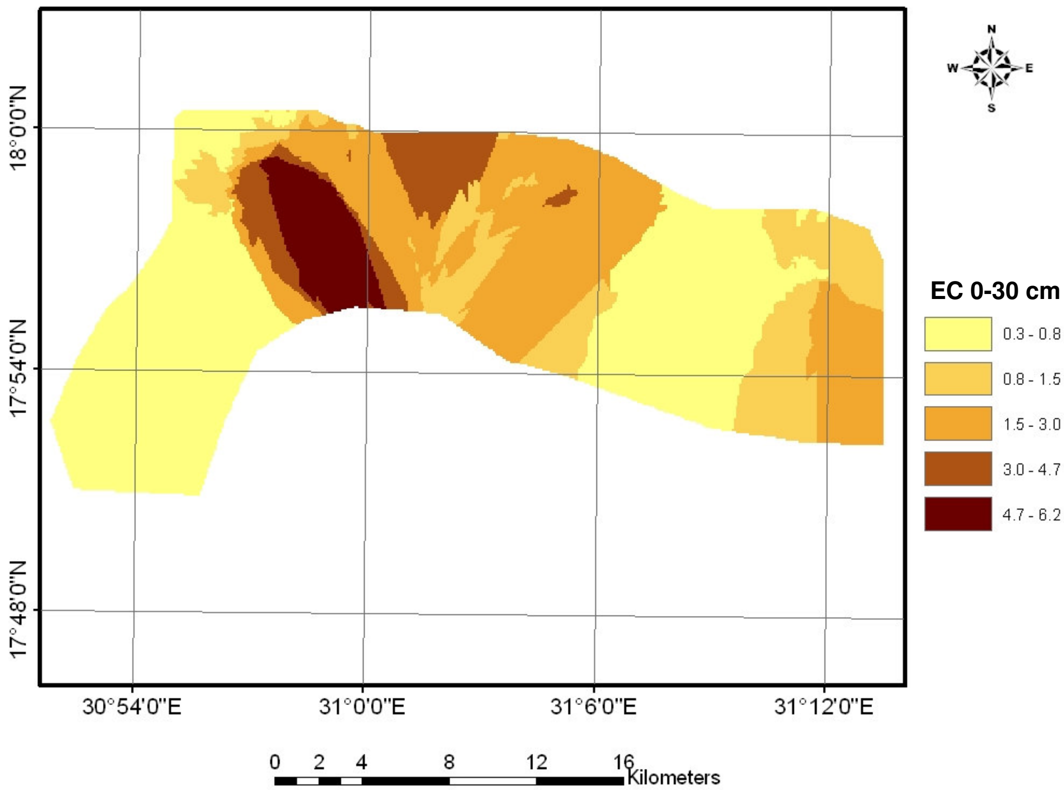

Figure 4. Spatial distribution of EC in 0 to 30 cm depth.

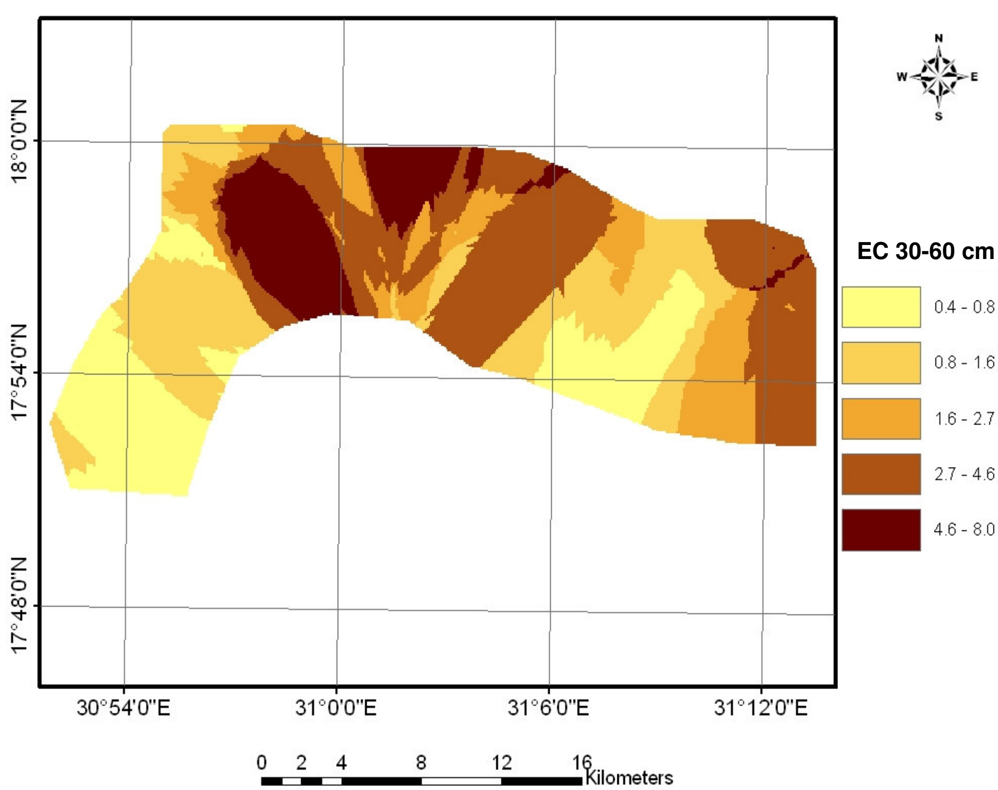

Figure 5. Spatial distribution of EC in 30 to 60 cm depth.

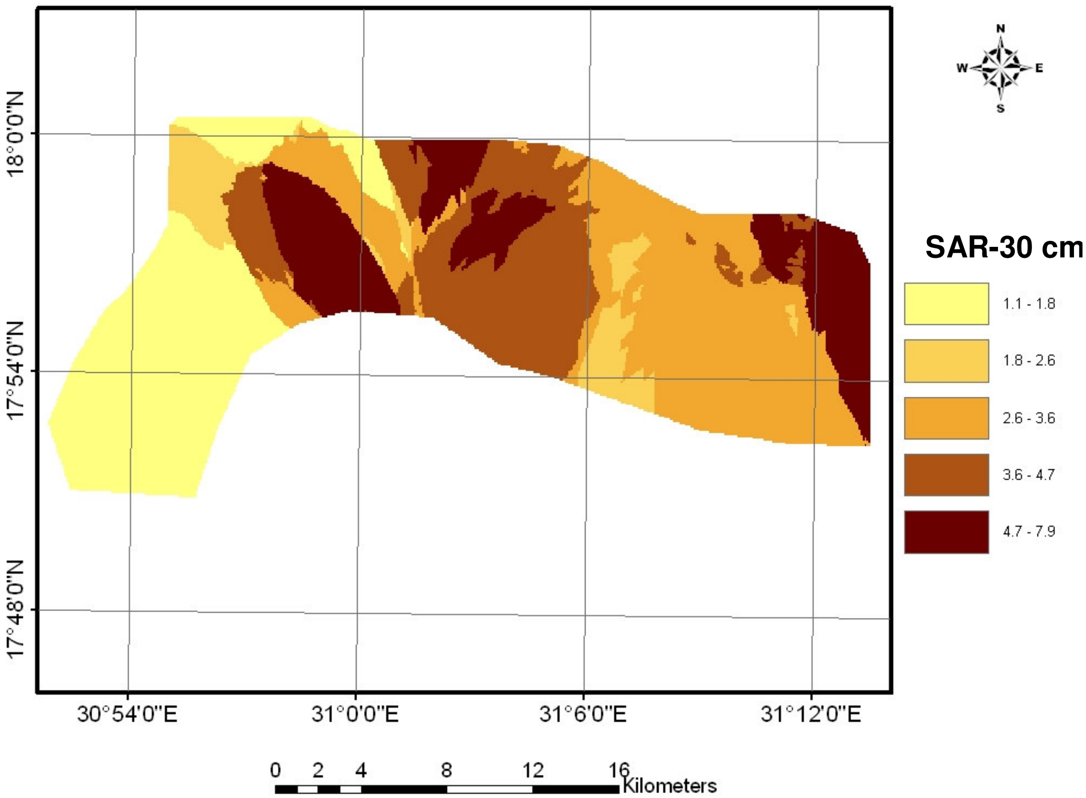

Figure 6. Spatial distribution of SAR in 0 to 30 cm depth.

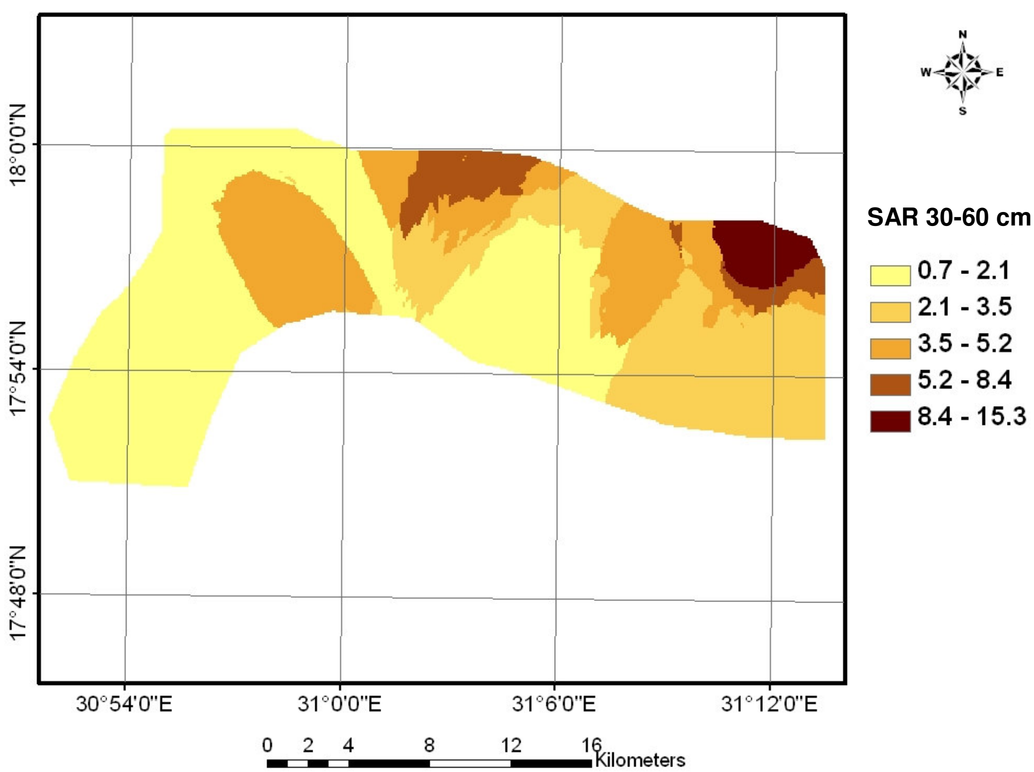

Figure 7. Spatial distribution of SAR in 30 to 60 cm depth.

Table 1. Soil particle size distribution in different depths.

Depth (cm)	Sand %	Silt %	Clay %	Soil texture
0 to 30	48.32	13.07	38.61	Loamy sand
30 to 60	45.05	15.20	39.75	Clay loam

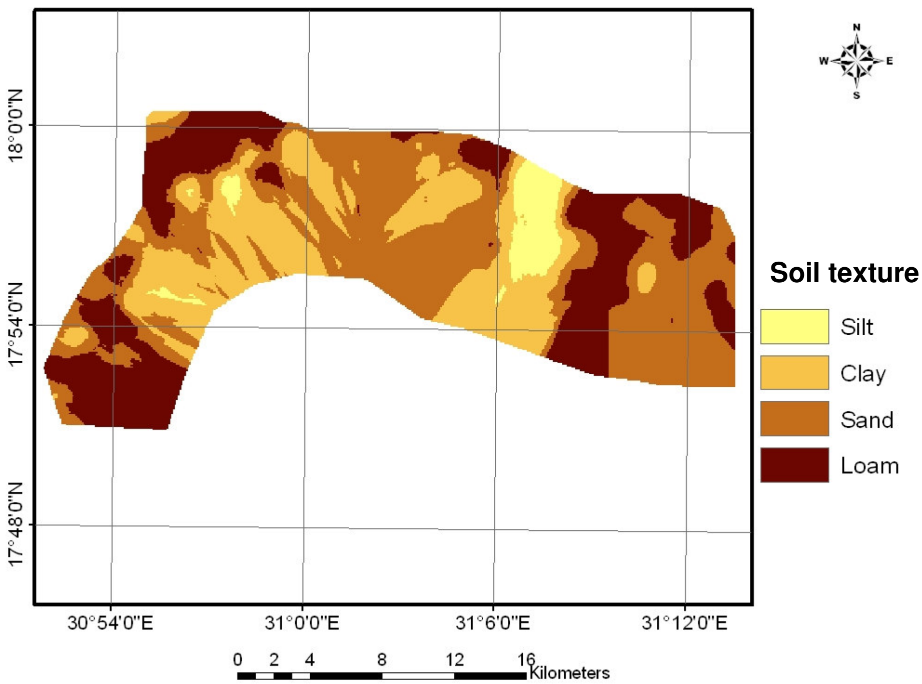

Figure 8. Spatial distribution of soil texture in the study area.

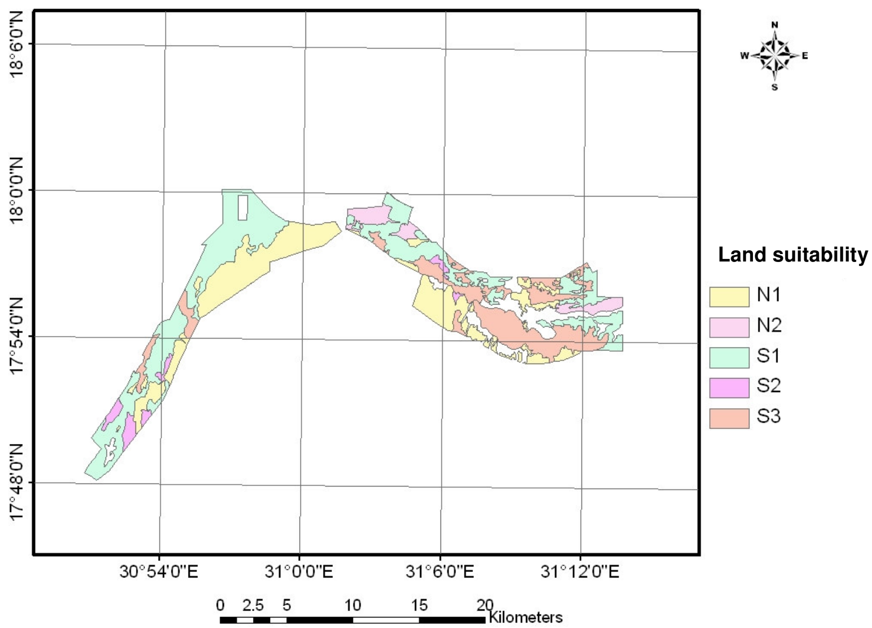

Figure 9. Spatial distribution of the land capability classes.

that can be played by GIS, especially in the stage of interpolation and analysis of soil classification of the soil suitability, in producing thematic maps such as soil physical and chemical properties maps. The use of spatial analysis in particular, shows that there is a difference in most of the moral characteristics of the soil in the study area; as such, the results reflect the soil properties of the study sites. The obtained results showed the alkaline reaction of soil, where the range of pH was between 7.5 and 8.2. The range of EC was found to be 2.34 to 3.30 where the value of 3.38 dS/m was found in the depth of 30 to 60 cm. However, the SAR values fall within the slight, moderate and strong degrees of salinity. According to the results of this study on soil types and impact of land use, it can be concluded that the soil is saline, and its texture varied from clay to clay loam content in the study area. The result showed a decrease of sand fractions in the cultivated area. It can be recommended here that the utilization of remote sensing and geographic information systems in the process of early warring desertification erosion due to wind and water help to supplement the survey and study the soil properties as well. Using the technology of GIS and digital mapping system to implement the variable rate technology is the logic direction to increase the agricultural operations efficiency.

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