

Monitoring, Predicting and Quantifying Soil Salinity, Sodicity and Alkalinity in Sudan, Using Soil Techniques, Remote Sensing and GIS Analysis, Case Study: University of Khartoum Top Farm

Ibrahim M.M.M^{*}, Dafalla M. S^{**}, Elhag A.M.H^{***}, Ibrahim S. Ibrahim^{****}

^{*} University of Khartoum, Faculty of Agriculture, Dept. Soil and Environment Sciences, Ministry of Higher Education and Scientific Research, Khartoum North, (Shambat), Sudan

^{**} University of Khartoum, Faculty of Agriculture, Dept. Soil and Environment Sciences, Ministry of Higher Education and Scientific Research, Khartoum North, (Shambat) Sudan

^{***} University of Bahri, Faculty of Natural Resources, Basic Science Department, Ministry of Higher Education and Scientific Research, Khartoum North (Al- Kadaro) Sudan

^{****} University of Khartoum, Faculty of Agriculture, Dept. Soil and Environment Sciences, Ministry of Higher Education and Scientific Research, Khartoum North, (Shambat) Sudan

Abstract- This study focused on the assessment of land degradation in University of Khartoum (Shambat Area), Khartoum State, Sudan. Through mapping and monitoring the changes that occurred in the soil properties, due to drought and mismanagement. The study attempted also to update some information in the study area such as chemical properties using different methods of data transformation and analysis such as: Soil analysis technique, GIS and remote sensing analysis.

The research was based on the data and information deduced and extracted from soil survey data, soil analysis, and remote sensed data, in addition to fieldwork verification and other sources. The study covered an area about 300 Acers.

Soil analysis indicated that soil degradation was taken place in the study area specially the top northern and southern parts of the area which were affected by some buckets of salinity, while the north-eastern and south- eastern parts were affected by sodicity buckets.

The study showed that there was a hardpan (Average bulk density of soil, 1.9 g/cm³) at subsurface layer (30-60 cm) and subsoil layer (60-90) that impedes the water infiltration and crop growth since tilling is done only in the surface soil to the depth of 25 cm (infiltration rate < 0.07cm/hr.). Evaluation of soil properties and degradation hazard, According to framework of the land suitability (FAO, 1976) revealed that the soil of the study area is moderately suitable (S2) for agriculture.

I. INTRODUCTION

The world's demand for food is increasing at such a rate that the ability to meet anticipated needs in the next several decades is becoming questionable. Irrigated agriculture presently accounts for about one-third of the world's production of food and fibre; it is anticipated that it will need to produce nearly 50 percent by the year 2040 (FAO, 1988). This will likely be difficult, because extensive areas of irrigated land have been and are increasingly becoming degraded by salinization and waterlogging resulting from over-irrigation and other forms of poor agricultural management (Ghassemi, et al., 1995).

Monitoring soil degradation is not only necessary to determine changes related to the real extent of erosion areas but also it enables the evaluation of programmes of soil conservation programme executed in that area.

According to Eswaran and Kapur (1998) before monitoring, we should determine what to monitor and what should be the time interval for that monitoring, because different processes of degradation require different time intervals to be recognized. They also stated that salinization monitoring should be probably, done every year, sheet erosion-monitoring could be done every five years while gully erosion monitoring may require more than five years.

Little is known about land degradation in the Khartoum area although some scattered studies were carried out on the fertility status of the soil in the state. In addition, some studies were conducted on land degradation using remote sensing techniques in the western of the Khartoum state. However these studies were mainly in the soil of Khartoum state, to the west of the study area. (Kapur, 1998).

Salt-affected soils in the Sudan occur in the desert and semi-desert climatic zones, e.g. the high terrace of the River Nile and its tributaries, and in the arid regions. Most of the salt-affected soils in the Sudan have a relatively low nutrient status and contain 0.01 -0.02% organic nitrogen. The impact of salinity on agriculture is now being felt in irrigated areas in which soil- and waterborne salts are accumulating during repeated cycles of water use. Nonsaline soils could easily be damaged and degraded by secondary salinization through irrigation with water from the Blue Nile, White Nile and River Nile (Abdalla 1986; Mustafa 1986). These problems will become more serious as increasing population leads to more intensive use of land and water, and as presently unused or marginally used resources are pressed into service. The entire physical and biological systems involved in saline agriculture must be understood and carefully managed if increased production is to be achieved without exacerbating the existing problems.

Salinity and sodicity are separate and unique descriptions of the impact of soluble salts in soil and water. Sodicity

represents the relative predominance of exchangeable sodium compared to other exchangeable cations, chiefly calcium, magnesium, potassium, hydrogen and aluminium 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 is a characteristic of soils relating to their content of water-soluble salts and expressed mostly as E_{Ce} (electrical conductivity of paste extract) and is measured as dS m⁻¹ (Charm an and Murphy, 2000). The interrelation of all these soil parameters is important for the Interpretation of their measures (van de Graaff and Patterson, 2001).

II. STUDY AREA

Study area, University of Khartoum top farm was located in Khartoum North, Khartoum State, Sudan. It is situated on the eastern bank of the River Nile.

The study area extends about 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. It is situated between longitudes 44° 01" and 44° 02" East and latitudes 03° 59" and 03° 00" North and covers an area of about 300 Acres (Fig. 1).

Populations are mainly farmers live around the study area. The soil of the study area is black cotton soil (Vertisols) and recent deposition soils (Entisols), and some parts are saline and/or sodic while are alkaline.

In the west of the Khartoum state (Omdurman city), land degradation and sand encroachment is whipping out a life that is centuries old. "Sand movement has exhausted us". Like this farmer, thousands of villagers, along the Underman area who own narrow strips of arable land that borders the study area, watch the sand moving closer every day. They are watching the land that degraded or eroded. So most of the land was lost or degraded. Then most farmers left their homeland seeking for new opportunities of work (Elamein 2005).

III. METHODOLOGY

Four false colour composite (FCC) subsets images from Landsat TM and ETM dated (1973, 1986, 2000 and 2008) covering the study area (300 Acres) were used in this study. The field work was conducted during the period 15 to 25th may 2009 aided by GPS receivers (Garmin 60C). Radiometric and image to ground points geometric corrections were conducted. Soil samples were collected from different selected locations to cover the variability that observed from satellite image analysis. Global Positioning System (GPS) was used to locate the position of the check sites. Different soil samples strategies were applied depending on satellite image interpretation and morphological and differences physical properties (colour, texture, structure...etc.). Soil samples were collected from three different depths (0-30 and 30-60cm) with a total number of 126, 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 (E_{Ce}): The electrical conductivity of the saturation extract (E_{Ce}) 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).
- 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 past extract. Exchangeable sodium percentage (ESP) was from regression equation of ESP on SAR) (Klute, 1965).

IV. RESULTS AND DISCUSSION

The soil analysis indicated that most of the soils of the study area are non-saline and non-sodic, except some buckets at surface and subsurface and subsoil samples at the top north and southern parts of the study area which was saline soil. SAR values indicated that some parts at north east and south west part of the study were sodic soil, while most of the area was non-sodic. These findings agreed with UNDP (1970).

The spatial variability of E_{Ce} for the surface, sub-surface and subsoil are shown in Figures 3 (a, b and c). Figure (a) showed that Soils with values of E_{Ce} 0.1- 0.25dS/m was located in the northern, middle, and some southern parts of the study area while soils with E_{Ce} values 0.25-0.38 dS/m are found in the eastern and south western parts, on the other hand E_{Ce} values 0.38-0.58 and 0.58-1 dS/m was found in the middle western parts of the study area. Figure 3 (b and c) showed similar results mentioned above.

Field work and survey results revealed land degradation signs which might be due to bad management such as misuse of irrigation water (wrong scheduling). The survey data showed that there was surface salt accumulation at the top north eastern and eastern parts of the study area (Plate1).

Soil Reaction (pH): The analysis of the soil samples revealed that the soil reaction ranged from moderate to slightly alkaline, which is not unexpected for soils of arid and semiarid region. Spatial pH variability for the surface, subsurface and subsoil was shown in figure 5 (a, b and c). The spatial variability of pH, values was ranged between 6.5 to 8.5, and divided into four classes as shown Figure 5 (a, b and c).

Soils with pH values of 7 to 7.5 and 7.5 to 8 were found in the southern and western parts, while other soils with pH values 6.5 to 7 and 8.5, located within the eastern parts with scattered pockets in some parts of the study area.. Figure 5 (b and c) showed similar pattern to above mentioned one with increased of values ranged from 8 to 8.5 with the depth.

Figure (5) showed that about 18.73%, 33.89% and 38.96% of the surface, sub surface and subsoil respectively, fell within

values ranged between 6.5-7, while 28.43%, 30.96% and 28.57% of the surface, sub surface and subsoil, respectively, fell within values ranged between 7-7.5, 20.46%, 17.05% and 15.58% of the surface, sub surface and subsoil respectively, fell within values ranged between 7.5-8, 32.3%, 18.08% and 16.88% of the surface, sub surface and subsoil respectively, fell within values ranged from 8 to 8.5.

The spatial variability of SAR for the surface, sub surface and subsoil was shown in figures 4 (a b and c). Figure 4 (a) showed high SAR value (4.85 to 8) which concentrated in the north and middle east parts of the study area, while SAR values in most of the area ranged within the normal non-sodic range (less than 5). Figure 4 (a) showed that most of the area was non-sodic (less than 8). In addition weighted SAR values confirm the above mentioned and most of the SAR values fell within the normal range.

The SAR values ranged from 0.03 to 8.83. The lowest values of SAR were in the surface (0-30cm); 0.5% of the surface soil sample fell within the sodic class (SAR>13), while 99.5% fell within the non-sodic class (SAR<13). In the subsurface layer (30-60cm) SAR values ranged from 0.3 to 8.5 and approximately 0.9% of the sub-surface soil sample values fell within the sodic class and 99.1% fell within the non-sodic class. When In the subsurface layer (60-90cm) SAR values ranged from 0.4 to 10 and approximately 1.3 % of the sub-surface soil sample values fell within the sodic class and 98.7.1% fell within the non-sodic class.

Compared to some of the results of some previous studies showed that there was some changes in the soil properties such as: salinity and sodicity which indicates a deterioration of the soil, The results also indicated that about 72% of the soils of the study area were plowed to depths of 20cm despite the presence of a hardpan (Bulk density > 1.5 g/cm³) in some parts at the depth of 30 cm. In addition, cultivation of land more than three times per year with addition minimal of fertilizers.

V. CONCLUSION AND RECOMMENDATION

The study revealed different signs of land degradation in the study area as judged by change in soil chemical properties. These changes indicated decrease in cropped yield and productivity, decrease in vegetation cover, expansion saline and sodic soils around and inside the study area as increased of buckets of saline and sodic soils. These signs could be revised

with the use of agricultural indicators. Land degradation as reduction in biological productivity can be interpreted from crop yields.

Soil analysis showed that chemical properties of the soil had revealed different changes; some parts were affected by salinity and sodicity that had negative impact on the soil productivity. The observed land degradation (poor natural vegetation and poor soil fertility) was due to both climate changes and human activities.

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 and/or sodic 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. Application of macro and micronutrients is essential at the following rates:
 - Phosphorous is recommended to be applied at the rate of 50 kg / feddan of triple superphosphate (%P = 46% P₂O₅) applied before sowing. Other sources e.g. diammonium phosphate (DAP= 21% nitrogen) may be used.
 - Potassium is recommended to be applied at the rate of 50 kg /feddan before sowing. The recommended source is potassium sulfate to make use of the contained sulfate in lowering pH of these alkaline soils which affect the availability of macro and micronutrients.
4. Proper programs should be adopted for clearance of irrigation canals from weed and deposited siltation.

APPENDIXES

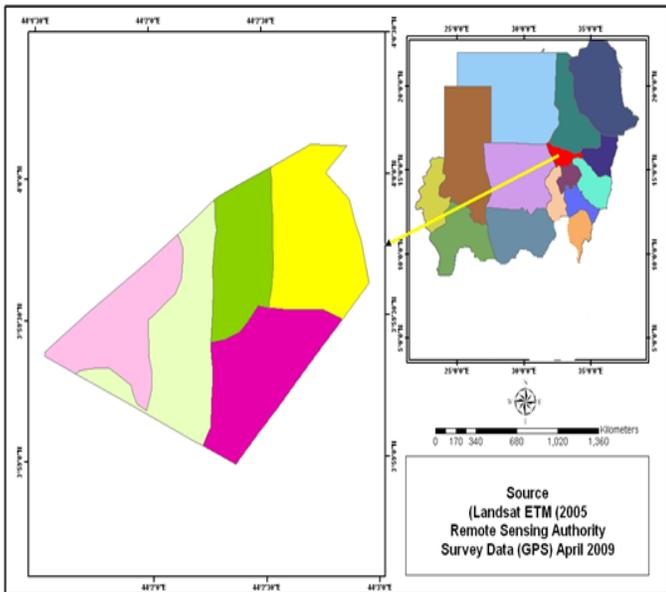


Figure 1: Location map of the study area

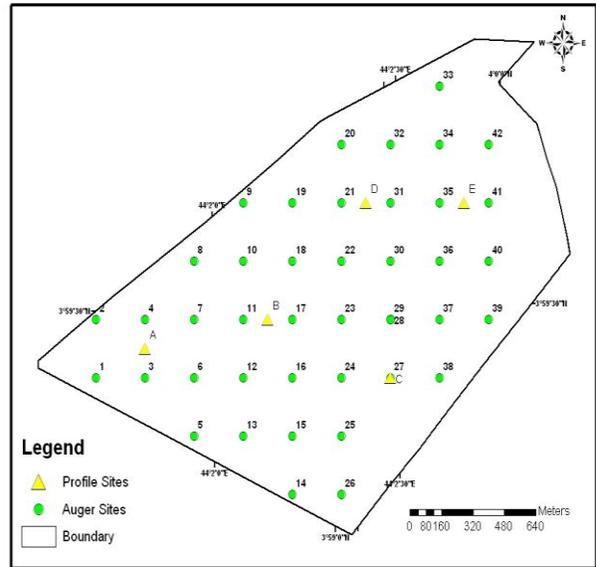


Figure 2: Location of auger and representative profiles sites



Plate No (1): Surface accumulation of salt and compacted soil, north of the study area
Source: Survey data 2009.

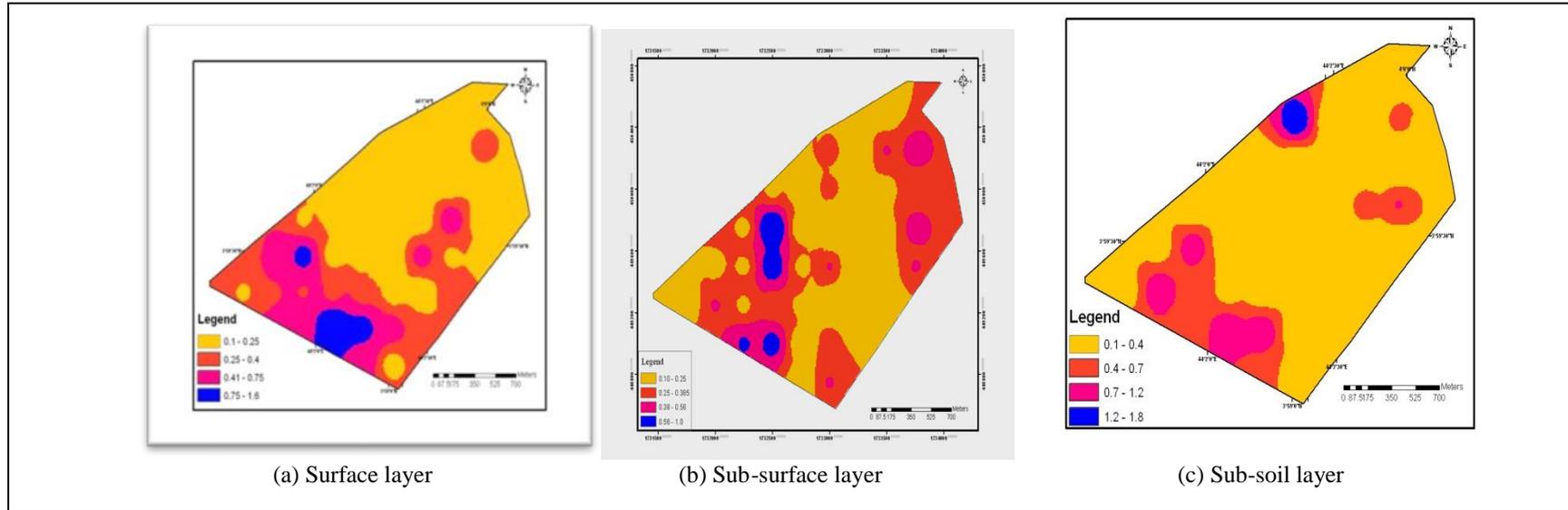


Fig 3: ECe Values for the surface (a), sub-surface (b) and (c) sub-soil layers

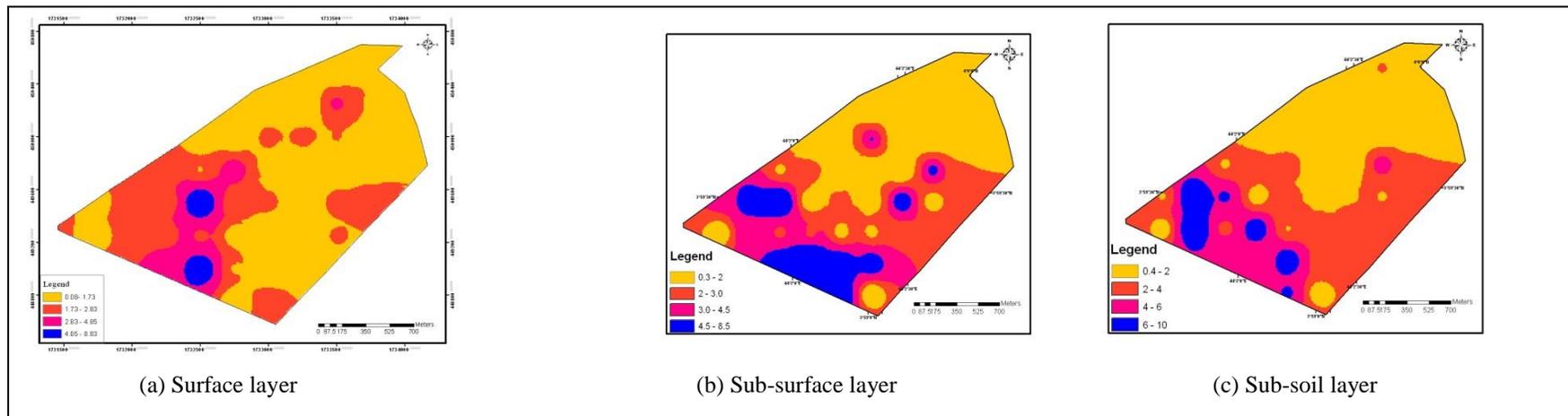


Fig 4: SAR Values for the surface (a), sub-surface (b) and (c) sub-soil layers

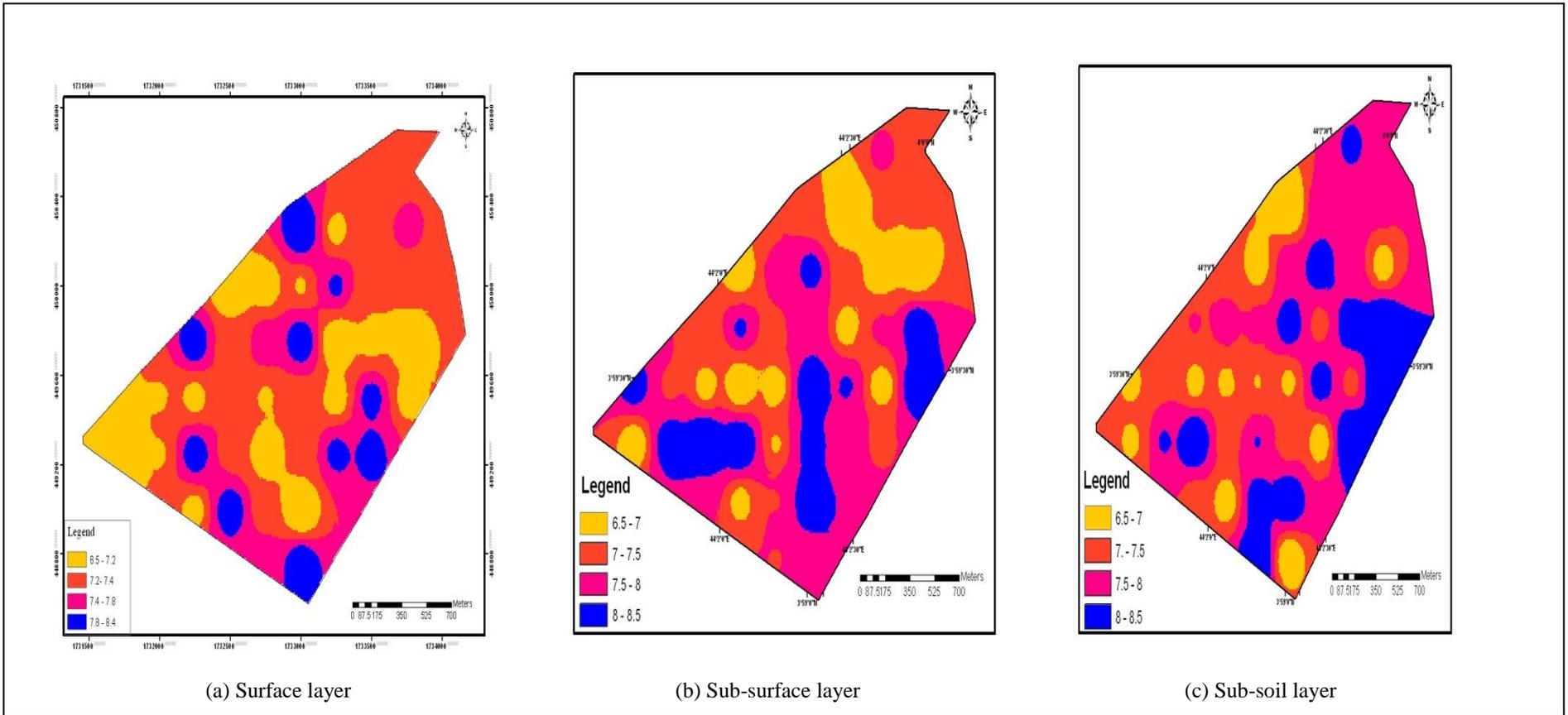


Fig 5: pH Values for the surface (a), sub-surface (b) and (c) sub-soil layers

REFERENCES

- [1] Eswaran, H. 1998. Impact of land degradation in the Mediterranean region. *Bulgarian J. of Agrc.Sci.*
- [2] Eswaran, H. and Kapur, S. (1998) Land degradation newsletter of the international task force on land degradation, Vol. 2001.
- [3] Abdalla, H.H. (1986). Extent and management of problem soils in Sudan saline sodic soil, *World Soil Resources Research* 58, 90-109.
- [4] Mustafa, M.A. (1986). Salt affected soils in the Sudan: their distribution, properties and management. *Reclamation and Revegetation Research* 5, 115-12.
- [5] UNDP (1970), Strengthening of the soil survey division of the ministry of agriculture, the Sudan, semi detailed soil survey of part of the central clay plain, technical report 3.
- [6] KAPUR (S.), ESWARAN (H.), AKÇA (E.) and DINGIL (M.), 1998, Developing a sustainable land management research strategy for the GAP Project in Turkey. In: Abstracts of Presentations and Workshop Conclusions (ED. M.J. Jones) "The Challenge of Production System Sustainability, Long Term Studies in Agronomic Research in Dry Areas. Aleppo, Syria 8-11 December 1997. pp 24-25.
- [7] Van de Graaff, R. and Patterson, R. A.; 2001. Explaining the Mysteries of Salinity, Sodicity SAR, and ESP in On-site Practice; in: Proceedings of On-site '01 Conference: Advancing On-site Wastewater Systems, edited by Patterson, R. A. and Jones, M. J.; Lanfax Laboratories, Armidale, Australia.
- [8] FAO 1976. A framework for land evaluation. *Soils Bulletin* 32. Food and Agriculture Organization of the United Nations, Rome, Italy.
- [9] KLUTE (A.), 1965, Laboratory Measurement. *Methods of Soil Analyses* (ed. C.A. Black). Madison
- [10] FAO. 1988. *World Agriculture Toward 2000: An FAO Study*. N. Alexandratos (ed.). Bellhaven Press, London. 338 pp. Wisconsin, USA. 210-221.
- [11] Ghassemi, F., A. J. Jakeman and H. A. Nix. 1995. *Salinization of Land and Water Resources: Human Causes, Extent, Management and Case Studies*, CAB International, 526 pp.
- [12] Elamin A. Elamin 2005 biodegradation of soil of University of Khartoum top farm, Shambat, Sudan.

AUTHORS

First Author – Muzamil Mustafa Mohammed Ibrahim, University of Khartoum, Faculty of Agriculture, Dept. Soil and Environment Sciences, Ministry of Higher Education and Scientific Research, Khartoum North, (Shambat), Sudan, Tel:/00249913009938 (Email: muzamil-2050@hotmail.com or muzamil2050@yahoo.com).

Second Author – Mohamed Salih Dafalla, University of Khartoum, Faculty of Agriculture, Dept. Soil and Environment Sciences, Ministry of Higher Education and Scientific Research, Khartoum North, (Shambat) Sudan, Tel:/00249121267929.(Email: mohmedsalihdafalla@yahoo.com).

Third Author – Abass Mohamed El Hag Hamed, University of Bahri, Faculty of Natural Resources, Basic Science Department, Ministry of Higher Education and Scientific Research, Khartoum North (Al-Kadaro) Sudan, Tel:/00249912815884. (Email: remotesensing_9@yahoo.com or remotesensing9@gmail.com).

Fourth Author – Ibrahim Saeed Ibrahim, University of Khartoum, Faculty of Agriculture, Dept. Soil and Environment Sciences, Ministry of Higher Education and Scientific Research, Khartoum North, (Shambat) Sudan. Tel:/00249912624298. (Email: ibraseed@hotmail.com).