# Impact of Land Use Management Systems on Some Soil Properties. The Case of South Khartoum State


By:

**Hind Ahmed Mohamed Abd El Magid**

**B. Sc. crop science (Honors)**

**College of Agricultural Sciences**

**University of Gezira, 1999**

**Supervisor:**

**Dr. Eltegani Mohamed Salih**


***A dissertation submitted to University of Khartoum in partial fulfillment of the requirements for the degree of Master of Science in Desertification***


**Desertification and Desert Cultivation Studies Institute**

**University of Khartoum**



**December, 2007**

# List of Contents

# *DEDICATION*

*To my mother*

*To my father*

*To my family*

*To my friends*

*With love and respect.*

# ACKNOWLEDGEMENT

First, I am most graceful to Allah, the almighty for assistance, health and patience given me to complete this work.

I wish to express my special appreciation to my supervisor Dr. Eltegani Mohamed Salih for his help, suggestions and advices to carry out this study.

I am gratefully indebted to my colleagues, Mohamed Osman, Mohamed Suliman, Abu talib Balla and my sister Eiman for their help.

Also I would like to express my thanks to staff and technicians of the Department of Soil and Environment Science, Faculty of Agriculture, University Of Khartoum for their help.

Finally, special thanks are extended to the UNESCO Chair of Desertification studies for offering me the scholarship. Also to the staff of Desertification and Desert Cultivation Studies Institute, Khartoum University for their help.

# ABSTRACT

The impact of land use management systems is major process that plays a key role in reducing or aggravating desertification. Consequently, this study was implemented to fined out the impact of land use management systems on private farms located south of Khartoum State. Some land degradation indicators (physio-biological) were used in order to assess the current performance status of these farms, mindful that such assessment was not conducted since their establishment.

Soil samples were collected from four private farms using auger, beside samples from uncultivated area as control. Samples were collected from three depths (0-30, 30-45, 45-60cm). Also, samples of water were collected from the wells constructed in the farms for irrigation and drinking purposes.

Statistical analysis indicated that there was a significant difference ($P \leq 0.05$) in most soil characteristics in the area of the study. The study showed that the applied irrigation system has led to secondary salinization in soil. It has been found that the value of ECe (3. 04 $dSm^{-1}$) in the uncultivated area was similar to ECe value in the Korean Company Farm (3.38 $dSm^{-1}$), because they use central pivot irrigation. Moreover, it was found that the ECe value in other farms ranged between (5.48$dSm^{-1}$ to 8.47$dSm^{-1}$), which reflected the improper irrigation system that led to increase of salts in the soil.

Experiments showed that the increased quantity of Residual Sodium Carbonate (RSC) in the irrigation water led to accelerate the creation of sodic pockets in soil, namely in Alhaj Ahmad farm.

On the other hand, it was found that the appropriate land use pattern reduced the amount of sand, consequently reduced the land vulnerability to wind

erosion. On the other hand, land use pattern reduced the bulk density of the soil, the value of B.D was high in the uncultivated area and low in the farms.

Analysis showed that the water was suitable for irrigation except in Alhaj Ahmad farm, where the quantity of Residual Sodium Carbonate (RSC) increased, which reflect the un-suitability of water for irrigation.

Analysis has proved that the water in study areas is suitable for drinking and conforming with the standard specifications of the World Health Organization.

# ملخص الأطروحة

يعتبر نظام إدارة الأرض عاملاً رئيسياً إذ انه يلعب دوراً هاماً في تقليل اوتفاقم عملية التصحر، بناء علي ذلك نفذت هذه الدراسة لمعرفة اثر نظام إدارة الأرض علي مزارع خاصة تقع جنوب ولاية الخرطوم . بعض مؤشرات التصحر (الفيزوبيولوجية) استخدمت من اجل تقدير الحالة الراهنة لتلك المزارع الخاصة، علما بأنه لم تجرى دراسة تقدير أداء لهذه المزارع منذ نشأتها.

تم جمع عينات من التربة من أربع مزارع خاصة باستخدام البريمة بجانب عينات من تربة أرض غير مزروعة للتحكم , اخذت هذه العينات من ثلاثة أعماق (0-30، 30-45، 45-60 سم), وكذلك أخذت عينات للمياه من الآبار التي انشأت في هذه المزارع بغرض الري والشرب.

وضح التحليل الإحصائي أن هنالك فرقاً معنوياً في معظم خصائص التربة في مواقع الدراسة, كما أوضحت الدراسة أن الري المطبق أدي تملح ثانوي بالتربة. حيث نجد في الأرض الغير مزروعة كانت قيمة التوصيل الكهربي( 3.04) والوضع مشابه لقيمة التوصيل الكهربي في مزرعة الشركة الكورية (3.38) إذ أنها تستخدم الري المحوري، علاوة علي ذلك نجد إن قيمة التوصيل الكهربي في باقي المزارع تتراوح بين ( 5.48 - 8.47 ) وهذا يعكس نظام الري الغير ملائم الذي يؤدي إلي زيادة كمية الأملاح بالتربة.

أظهرت التجارب إن ازدياد كمية كربونات الصوديوم المتبقية في مياه الري أدت إلي الإسراع في خلق جيوب صودية في مزرعة الحاج احمد.

ومن ناحية أخري نجد إن نمط استخدام الأرض الملائم قلل من كمية الرمل وبذلك قلل من قابلية الأراضي للتعرية بالرياح وكذلك قلل من الكثافة الظاهرية للتربة حيث نجد إن قيمة الكثافة الظاهرية عالياً في الأرض الغير مزروعة ومنخفضاً في المزارع.

اظهر التحليل أن المياه كانت مناسبة لعملية الري إلا في مزرعة الحاج احمد, حيث كانت كمية كربونات الصوديوم المتبقية عالية مما عكس عدم ملائمة الماء للري .

برهن التحليل أن المياه في المنطقة صالحة للشرب ومطابقة للمواصفات القياسية لمنظمة الصحة العالمية.

# List of Tables

## List of Figures

**Figure** **Page**

## List of Maps

**Map** **Page**

# Chapter One

# Introduction

Land degradation in Sudan is mainly attributed to mismanagement of the land, in other words it is an adverse human induce process, but in some fragile areas, the recurring spells of drought aggravate the situation. Land degradation leads to drop in the land productive capacity and this, in turn causes the income failure of the rural poor people to meet the family essential needs, in turn more sufferings ends up in abandonment of the whole rural life (Osman, 2005).

Desertification is truly a global problem, the world has become aware of it and tried to solve it by adopting a Plan of Action 1977 to combat desertification and mitigate drought effects in the affected countries, especially in Africa (Fadul, 1998). Sudan is one of the first countries signed and ratified the UNCCD, (1995) and designated the National Drought and Desertification Control Coordinating and Monitoring Unit (NDDU) as a focal point of the UNCCD.

Dry lands in Sudan are confined between latitude 12° N and 22° N, under different climatic zones: hyper arid, arid, semi- arid and dry sub humid (Fadul and Gani, 2000).

According to Salah Aldin (2000), the attention to land degradation in Sudan has been first drawn during the thirties of last century when reference was made to vegetation degradation being spotted in different part of the Sudan. Concern about the phenomenon culminated in establishment of the soil conservation committee 1942. The report of the committee attributed land degradation to misuse of land resources. Presently, decertified areas in the country defined in thirteen states between latitudes 10° and 18° degrees north. The Sudan has collaborated with and contributed to the international efforts to combat desertification through the elaboration of the United Nations Convention to Combat Desertification (UNCCD) and the preparation of the National Action Program for Combating Desertification (NAP). Khartoum State was identified as one of thirteen states affected by desertification (Salih, 1996).

According to DECARP, (1976a) the total area affected by desertification consists approximately 650,000km².The area affected by drought and desertification impacts includes the semi-desert, arid and semi-arid ecological regions (486,000km²), which include most of the Northern State, Northern Kordufan and Darfur states and some parts of the Central and Eastern states.

Major causes of soil degradation are overgrazing (47%) improper agricultural practices and mechanized rainfed agriculture (22%), deforestation for firewood and urban demand for charcoal (19%) and over-exploitation of vegetation for domestic use 12%, (Ayoub, 1998).

Monitoring and evaluation of agricultural practices in the Southern area of Khartoum state are lacking, because most the areas are utilized by the private sector. Nonetheless, it is very important to carry out scientific studies and research in order to monitor land degradation and to assess the current performance status of these farms.

Specific objectives can be summarized below:

i. Assessment of agricultural practices in the farms, south of Khartoum state.

ii. Assessment of the impact of land use in the farms, south of Khartoum state.

iii. Suitability of the water for irrigation and drinking.

iv. Application of some indicators to assess desertification impacts in the area.

# Chapter Tow
# Literature Review

## 2.1 Introduction:

Stebbing (1953) counted the causes of land degradation to practices of shifting agriculture plus the largely increased number of grazing animals, annual firing of natural vegetation and misuse of natural resources by human which represents the cause of degradation of forests to turn into scrub type and can be traced to climatic change. Baumer and Tahara (1979) reported that the desert encroachment in Sudan is mainly man made phenomenon caused by the misuse of land. The cultivation in marginal areas was assumed to be one of the main causes of land degradation/desertification.

Dry land degradation may be triggered by global climatic change and/or human mismanagement, while the former may result in more frequent drought events, the latter is mainly caused by inappropriate land use. Both may include changes in surface soil properties, there by affecting the type and density of the vegetation cover. Olsson (1981) and Dregene (1986) stated that, desertification is not a new phenomenon, it began before the 1969–1973 sahelian drought phenomenon. Spooner (1989) and Grainger (1990) agreed with Olsson and Dregene point of view and added that, archaeological evidence suggested that desertification began several centuries ago and can be traced back to the Mediaeval and even Neolithic period.

The balance between the economic development and natural resources conservation has been one of the most vital contemporary issues, natural resources integrity is, often in conflict with human being attempts to tap the natural resources base to achieve social and economic benefits in order to satisfy their needs. Over exploitation of the genetic resources and biodiversity in the Arab region, inevitably introduced series of adverse effect that bring about partial or total degradation of this resource base, (AOAD, 2001).

Several factors and natural events, in addition to human activities have accentuated natural resources deterioration, triggered land degradation and caused declined productivity in major agricultural production system. The excessive use of resources, particularly the uncontrolled and irrational expansion of agriculture at the expense of plant resources in marginal areas exacerbated land degradation. The occurrence of recurrent droughts in the past few decades has augmented this undesirable trend and accelerated the rate of desertification that resulted in the negative impact of poverty, which led to over exploitation of natural resources, beside the lack of appropriate policies to ensure sustainable management of natural resources. These conditions have been worsened by the lack of suitable legislation to support the conservation and rational use of the resources. The limited enforcement of sectoral laws that exist, stressed the urgent need to review and streamline natural resources regulations to ensure their complementarily and to avoid contradictions (AOAD, 2002).

Desertification is a major environmental and socio-economic problem facing people in the dry lands of the world. According to internationally negotiated and adopted definition in United Nations Conference on Environment and Development (UNCED, 1992) held at Rio-de Janeiro, and adopted by United Nation Convention to combat Desertification (UNCCD) 1994, desertification defined as “land degradation in arid, semi arid and dry sub-humid lands resulting from various factors including climatic variations and human activities". Where land in this context include, soil, local water resources, land surface, and vegetation or crop, while the term degradation implies, reduction of resource potential of land (Lean, 1995).

### 2.1.1 Land degradation in the world

The United Nations Environment Program (UNEP, 1977) studies explained that lands cover 14.9 billion hectares of the earth's surfaces. 6 billion hectares are dry land of which 1 billion hectares are naturally hyper arid - moreover, considerable parts of the dry lands are either desert or being threatened by desertification, further more one quarter of the world population inhabit in the dry lands and depend on this area for their livelihood. Koohafkan (1996) stated that, desertification affects about two-thirds of the world countries, and one – third of the earth's surface, on which one billion people live i.e. one-fifth of the world population. Accumulation of excess salts in the root zone resulting in a partial or complete loss of soil productivity is a world wide phenomenon. The problems of soil salinity are most widespread in the arid and semi-arid regions, where evaporation potential is high and rainfall is not sufficient to leach the salts from the soils, but salt affected soil also occur extensively in sub-humid and humid climates (FAO, 1988). The most serious salinity problems are being faced in the irrigation arid and semi-arid regions of the world and it is in these regions that irrigation is essential to increase agricultural production to satisfy food requirements. Both salinization and sodication have been identified as processes of land degradation, affecting the physicochemical properties of the soil, which drastically reduce plant growth and eventually lead to desertification (FAO, UNEP, 1984). Nearly 10% of the world's total land is estimated to be significantly affected by salts; limiting its utilization for crop production in at least 75 countries. About 30% of the irrigated land in the world is seriously affected by salt, decreasing its productivity, and threatening the economy of many of the arid countries, such as Egypt, Iraq and Pakistan (Rhodes, 1990).

### 2.1.2 Land degradation in the Sudan:

The first serious sign of soil degradation in the Sudan was reported by Cooke (1944). He showed that, rapid deterioration of soil and vegetation were occurring in parts of the Red Sea Hills, which was considered as a warning that such problems might be developing else where, particularly around town peripheries and settlement areas in Kordofan and Darfur regions. The Ministry of Agriculture in its plan to combat desertification in Sudan reported that the affected areas in Sudan have been divided into five regions comprised, the following; rainfed and traditional agriculture in different areas of Sudan, rehabilitation of Gum Arabic belt between lat.$9^{\circ}$-$15^{\circ}$ N (Gedarif, Kordufan and Darfur), establishment of shelter belts around villages and irrigation schemes in Northern region, water harvesting in Red Sea, Kassala, Gedarif, Kordufan and Darfur areas. Reclamation of gurdud soils in Kordufan and Darfur region. The total areas to be treated in the five regions are estimated to be 525.000$km^2$ (DECARP, 1976a).

Baumer and Tahara (1979) stated that desertification is spreading like cancer in other areas including the adjacent low rainfall savanna and it is quite clear that desert encroachment in the Sudan is mainly a man made phenomenon caused by the misuse of land resources. Cultivation in marginal areas was assumed to be one of the main causes of desertification.

In the late 1970s to the early 1990s, several global or regional attempts of land degradation/desertification assessments have covered, among other countries, the Sudan (UNEP,1977; FAO/UNEP, 1984; UNEP/ISRIC

GLASOD, 1990; Dregne; 1991) stated that the land surface of Sudan excluding the hyper-arid zone, agricultural land, pasture, forest and woodland amount to170 million ha in total, nearly 75 million ha (45%) have been degraded severely to very severely by human activities in recent history. The highest estimate was that of Dregne (1991), while the estimates of UNEP (1977) and FAO/UNEP (1984) were similar. GLASOD (1990) soil degradation assessment show that severe and very severe degradations totaled 65 million ha. The difference between GLASOD and other assessments could be vegetation degradation without significant soil degradation (Ayoub, 1998).

The study carried out by the NDDU in 1995 reported that 1.259.743 $km^2$ (50.1%) of the total area of the Sudan (2.492.360 $km^2$), are subject to different degrees of degradation, the affected area includes 13 States as reported by Salih, (1996). The magnitude of desertification in Sudan was assessed by assimilating the existing information through the use of GIS. The study based on the available information using the Geographical Information System (GIS) and Remote Sensing (RS) techniques to classify the status of desertification in the affected areas. The indicators used were: land use, geomorphology, human settlements, soil and drainage pattern, and rainfall distribution. Accordingly, five classes of desertification were reached: very severe, severe, moderate, slight and very slight. These affected areas include the following 13 States: Red Sea, North Darfur, River Nile, Northern, Kassala, Khartoum, North Kordofan, Al Gedarif, West Darfur, Gezira, White Nile, West Kordofan, and Sennar. The decertified area in the country is confined to five ecological zones lying between latitude $10^{\circ}$- $18^{\circ}$ north ,and these are :the hyperarid ; arid ;semi-arid ;dry sub-humid; moist sub-humid. Sudan is one of the Sudano-Sahelian countries that have been seriously affected by drought and desertification since the late sixties of the past century to the present. This has its lasting imprints on natural habitats, means of livelihood and socio-economic fabric of the society (Salih, 1996).

According to Osman (2005), 64 million hectares of soil are degrading in arid, semi-arid and dry sub-humid zones of the country. Erosion by wind affects 27 million hectares, most of it was found in the arid and semi-arid zones in Kordofan and Darfur where vegetation is scarce and soil particles are loose. Moreover, about 18 million hectares of soils are affected by water erosion. Top soil loss through sheet erosion, is a common form of water erosion, and about 10 million hectares are vulnerable to erosion due to their sloppy terrain, denuded of their vegetation cover, and about 16 million hectares of the reddish yellow sandy soils in central, southern Kordofan and Darfur areas are experiencing high rates of nutrient depletion. These soils are inherently poor in nutrient. The situation will be aggravated if all biomass has been cleared, and agriculture is practiced without sufficient application of organic or mineral fertilizers. Meanwhile, about 30 million hectares of the Sudan's soil are stable under natural conditions. These are lands under forest, swamp, mostly in southern Sudan. Another 4 million hectares are stable under sustainable agriculture, these mostly include the large irrigated schemes such as the Gezira, New Helfa and Rahad...etc...

## 2.2 Soil degradation indicators:

According to AOAD (2002) the main indicators of land degradation are physical, chemical and biological that includes the followings:

- Climate; rainfall, temperature, relative humidity, wind speed, sun shine and evapotransperation.
- Suspended particulates sedimentation.
- Floods parasitic plants in the arable land.

- Decreasing of under ground water replenishment.
- Low quality and suitability of under ground water.
- Salinization, Alkalinization and Sodication.
- Decreasing of porosity and low surface drainage, and those directly imply physical, chemical and biological deterioration of the soil.

**2.3 Pattern of land uses that lead to land degradation in the Sudan:**

ElSammani (1986) stated that the patterns of land uses that lead to land degradation in the Sudan are the followings:-

1. Repeated cultivation of land without adequate fallow period to help the regeneration of soil fertility.
2. Monoculture cropping systems of sorghum or millet which exhaust the soil.
3. Irrational use of heavy machinery that has negative impact on soil physical properties.

**2.4 Causes of land degradation in the Sudan**:

ElSammani (1989) stated that the main causes of land degradation are related mainly to:

1. Mismanagement of lands.
2. Removal of vegetation cover.
3. Inefficient management and utilization of irrigation water.
4. Population growth.
5. Drought.
6. Erosion.
7. Salinization.
8. Soil pollution.
9. Depletion of soil fertility.

Over grazing is a widely spread cause of soil degradation in Sudan, which affects about 30 million hectares. Second cause is the clearance of forests and woodland cover for fire wood and charcoal, this affects about 22 million hectares. Cropping without appropriate nutrients, inputs have degraded about 12 million hectares (Ayoub, 1998).

### 2.4.1: Mismanagement of lands:

It means here the mismanagement of resources according to the proper conservation measures and rationale exploitation to achieve the optimum benefits, but not ignoring the sustainability of the natural resources. The absence of wise management leads to negative impacts causing decrease of productivity. It is known that land is managed according to the nature of the land with its topography and production system. In general, management is nearly absent in the rainfed agriculture. In mechanized farms areas, methods were adopted in accordance with nature of lands and its potential that supporting sustainable use and protecting it from deterioration are not yet found. The system of cultivation is still following the single crop system leading to decline in the content of organic matter, porosity, fertility and productivity. In addition to these changes the usage of machines plays a prominent role in soil consolidation, as well as the absence of application of suitable rotation system or application of mineral fertilizers and plant residues to the soil. It is recognized that most of agricultural areas do not follow the system of land protection by establishing wind breaks and shelter belts (AOAD, 2002).

### 2.4.2 Removal of vegetation cover:

Irregular grazing and cutting, randomized removal of forest that destroys vast areas of pastures led to the decreasing of vegetation cover. Ayoub (1998) cited that the clearance of forests and woodlands cover for firewood and charcoal making and over exploitation of vegetation is affecting 22 m ha. Felling of trees for different reasons and the use of fuel wood energy are the causes of deforestation leading to desertification in forest areas. Removal of vegetation cover causes fragile conditions and that increases the severity of environmental factors negative impacts particularly drought.

Abu Suwar *et.al* ( 2002) cited that the over cutting of wood for fuel and building purposes has a catastrophic effect on environment leading to desertification and land degradation and the wood consumption for fuel wood that amounted to 21 million cubic meters in 1957, increased to 28 million cubic meters in 1964 and 67.6 million cubic meters in 1997.

### 2.4.3 Inefficient management and utilization of irrigation water:

Some of irrigated areas are characterized by decreasing in the efficient usage of irrigation water and carelessness of drainage system to release the water after washing. Most areas follow the system of inundation that uses a large quantity of water which helps in the concentration of salts after evaporation and in case of heavy muddy areas causes water logging (AOAD, 2002).

### 2.4.4 Population growth:

The high population growth ratios considered as major factor in lands deterioration, leading to the intensive usage of lands and changing utilization system to face the increasing demand for food and to increase family income. Population growth also contributes to the encroachment of cultivation in the marginalized lands to increase family income under worse climatic conditions when considering the fluctuations of rainfall and drought. In this context (Goda, 1977) indicated that with increasing population, and expansion in agricultural development and livestock rising, there will be more pressure on natural resources. Salih (1996) stated that the growth ratios ranged between 2.8 to 3.

### 2.4.5 Drought:

The drought that covered the whole country in 1984 has led to the death of many of trees and removal of some by wind in the semi – desert belt and low rainfall savanna where soil exposed to erosion. People have adapted to this situation by expanding their agricultural lands in areas used as pastures to increase the production to face families' needs for food and cereals. Some of them, especially the poor one cut trees to have fuel wood and charcoal as resource of income that influence the increasing ratio of vegetation removal and exposed more areas to erosion (AOAD, 2002).

Land degradation is also influenced by wind and water erosion and its symptoms reflected on adverse effects on natural resources, compiled with salinity and alkalinity. Physical manifestations of erosion as fine particles transportation, sedimentation of reservoirs, irrigation canals and hafirs, in addition to creation of gullies and mobile sand dunes are obvious symptoms in many parts of the Sudan.

### 2.4.6 Erosion:

In the absence of shelter belts and wind breaks soil becomes vulnerable to erosion due to the removal of the vegetation cover and ploughing at the steeper areas. In such conditions, soil erosion factors become active. All these require the essential proper management of soil and its components, hence the gained result will be a good environment for social and economical benefits (Ibrahim, 1988).

### 2.4.7 Salinization and water logging:

Land degradation is resulting from the bad management or bad irrigation methods beside the absence of good drainage system, which will lead to the concentration of salts. Also, the land of some areas was classified as saline soil according to its location and formation in arid environment (desert and semi desert areas) and containing a high percentage of salts because of the scarce rainfall to leach the salts (AOAD, 2002). Soil salinity is one of the major a biotic stresses of crops affecting their productivity world-wide (Borsani.*et.al*, 2003).

Conventional breeding methods were attempted to improve salinity tolerance of crops with appreciable success, but they need a lot of work and time. Tissue culture was suggested by many researchers for selection and production of new lines with valuable agricultural characters especially resistance to adverse ecological and climatic conditions such as salinity and drought (McCoy, 1987).

### 2.4.8 Soil pollution:

Chemical agricultural inputs include fertilizers, pesticides, insecticides and fungicides are used for ten years. Some of these compounds are hydrolyzed in soil and changed into non harmful elements and the others conformed into harmful and toxic to human and animals. When staying for along time, they might be absorbed by plants and crops and also leached down to the under ground water. In both cases, usage of these compounds in suitable time, way, and quantity besides taking in account the necessary precautionary action, will make their usage with out any harm or limit their negative impacts and the changes come from their misuse (FAO, 1994).

### 2.4.9 Depletion of soil fertility:

Maintaining of soil fertility and improving its qualities could be achieved by wise management, through integration of chemical and organic fertilizers, agricultural wastes, practicing of rotation and agroforestry. When the situation was revised in Sudan it was found that the irrigated agriculture system was having several practices such as following the agricultural rotational system, while subjected soil to several preparation that help rapid decomposition of soil organic matters, that causes soil consolidation. The traditional rainfed and mechanized agriculture do not use the chemical fertilizers and rarely adding of organic fertilizers and at some time the remains of crops is burned accompanied by cultivation of one crop and short fallow period, all these lead to decreasing of soil fertility (Farah, 2000).

## 2.5 Land use systems in Sudan:

### 2.5.1 Patterns of land use systems in Sudan:

Sudan is a large country, with a diverse range of ecological zones. These ecological zones extend from the desert in the north to the forest in the south. It is extends between latitudes 3° and 22° N and longitudes 21° and 38° E, climate is classified as "tropical continental" and varies dramatically from the desert in the north to the equatorial rainy climate of south, with arid and semi-arid conditions in the centre. The total area amounts to 250 million hectares; arable land covers about 84 million hectares, irrigated agriculture covers 2 million hectares, mechanized rain-fed agriculture covers 6 million hectares, traditional rain-fed agriculture covers 9 million hectares, rangeland covers 39 million hectares, woodland covers 64 million hectares and 63 million hectare for other uses. The population of Sudan is around 36 million inhabitants and about 75% of them sustain their livelihoods from farming and livestock raising (EL Hassan *et.al*. 2005).

Sudan is primarily an agricultural and pastoral country, will about 80% of economically active engaged in these sectors. Approximately, 75% of the total crops grown in the Sudan are produced in the rain belt. About 29 million feddans are currently cultivated under rainfed, 4.7 million feddans are under irrigation, and additional 95.2 million feddans are easily cultivable which are currently natural rangelands, forests, or swamps, (DECARP, 1976a).

There are four distinct types of land use systems, through out the country as follows:-

1. Irrigated agriculture;
2. Mechanized rainfed agriculture;
3. Traditional rainfed agriculture and
4. Livestock-raising.

**2.5.1.1 Irrigated agriculture: -**

This is practiced either by tenant farmers, in large scale schemes which are owned by the government e.g. Gezeira Scheme, or on small scale private schemes irrigated by pumps. The large- scale schemes grow mainly cotton, wheat, sorghum and groundnut, while the small-scale schemes concentrate on vegetables and fruit. The total area covered by this type of land use is about 2 million hectares. The irrigation water comes mainly from the Nile and its tributaries by way of gravity flow from the dams, pump up lifting from the river or flood irrigated in Tokar & Gash plains (Atta ELmoula, 1985).

**2.5.1.2 Mechanized Rainfed Agriculture**:

The mechanized rain-fed agriculture in the Sudan started during the colonial era in 1940 to provide food for Allied forces during the Second World War (Atta ELmoula, 1985). This type of land use includes large–scale farms (1000 feddans) covering of about 6 million hectares mainly in the central clay plains. The principle crops are sorghum, sesame, groundnut, sunflower, guar and cotton. It is characterized by fluctuation in yield per unit area. This is mainly attributed to the irregular distribution of rainfall during the season as well as to lack of proper soil conservation measures. Farmers use machinery in land preparation and harvesting their crops, some of them use herbicides to obtain high yield. Operation such as weeding, sesame harvesting, dura stalk cutting, cotton picking are manual. However, in the 1970, and with the beginning of drought and desertification impacts, that affected most parts of the Sudan, signs of land and yield deterioration appeared in rainfed mechanized schemes (Buraymah and Dawood 1984).

**2.5.1.3 Traditional Rainfed Agriculture:**

The area traditionally cultivated is estimated about 9 million ha mostly in Western and Southern Sudan and in certain areas of central Sudan. It is practiced by rural people at small-scale level (10-50feddans). According to the soil type it can be divided in to two types of land use. On clay soils, people concentrate mainly on sorghum and seasame cultivation and they use the traditional tools for ploughing and other land preparation operations. While on the sandy soil, the farmers grow millet, groundnut, kerkadi and watermelon. Because of the fragile nature of the sandy soils, people practice a kind of shifting cultivation (EL Hassan *et.al*. 2005).

**2.5.1.4 Livestock – Raising:**

Sudan enjoys an extensive area of communal rangeland and forests. Rangeland covers an area estimated about 117 million hectares which represents about 60% of the total area of the Sudan. Nearly 80% of the total range area is located in semi-desert and low rainfall savanna zones characterized by un predictable rainfall (RAP, 1993).

Most range land fall within fragile environment and facing frequent drought period, seasonal bush fire, change in species composition, increasing pressure on the range resources especially around water points, expanding cultivation destruction of the local situations and the gradual loss of traditional knowledge, increase in animal population and low off take, blockage of the livestock migration roots and lack of local community participation in the planning and execution of range program (Mustafa *et al*, 2000).

Another factor that annually causes a great loss of the range resources is fire, which may destroy up to 30% of the areas (RAP, 1990). Some of these fires are deliberately set by the nomads to induce fresh growth of perennial grasses. Environmental degradation severely affects range land, forest and livestock production. Range land degradation and desertification is defined as the general destruction of the biological ability of land, which ultimately leads to desert like condition. The total amount of forested land about 212,335,000 feddans, and represents around 36 percent of Sudan’s surface area (World Bank, 2001). Three millions are designated as protected forest reserve in states, which are government owned. Tree and land tenure is particular constraint for land use planning for forestry in rainfed areas, land in rainfed areas is unregistered and therefore, owned by government, in the terms of the unregistered land act, this lead to national conflicts (El Mahi, 2004). The misuses of natural resources such as over grazing, over cutting of wood biomass, frequent burning of vegetation and expansion of rainfed farming in marginal land are among the major factors of range land degradation and desertification (Abu Suwar and Darrag, 2004).

## 2.6 Soil properties in south Khartoum:

### 2.6.1. Physical characteristics of the soil:

Three qualities are considered under this heading particle size distribution (texture), structure and consistency.

#### 2.6.1.1. Particle size distribution:

Particle size distribution (texture) is one of the most distinct characteristics of the soil surface layer of the study area. Sand percentage ranges mainly between 10.0 and 74.0 percent and slit between 4.0 and 34.0 percent, clay ranged between extreme values of 4 and 70 percent for individual horizons but mainly fall between 30 and 50 percent (Younis, 1985).

**2.6.1.2. Structure:**

No quantative 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 (Younis, 1985).

**2.6.1.3. Consistency:**

This is usually a direct reflection of soil texture and moisture, though salinity also has some effect. The soils were almost invariable dry near 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 15-20 cm ,and becoming hard or firm below 50 cm . Below 50-90 cm, where the sub –soils are calcareous matrix the consistency becoming very hard, usually remained very hard or extremely hard up to 2 m (Younis, 1985).

**2.6.2 Chemical characteristics of the soils:**

**2.6.2.1 Salinity:**

Saline conditions in the active root zone of the soil can inhibit plant growth, by the total concentration of the soluble salt.

Salinity is increase with increasing aridity. Very high saline soils only occur in areas where the average rainfall is less than 200 mm. On the same kind of soils. For example, typic and ustic chromusterts there is a marked difference in salinity between the north Gezira with low rainfall (slightly above 200 m m) and the south and central Gezira with an average annual rainfall between 360 and 460 mm (Younis, 1985).

**2.6.2.2. Sodicity:**

Sodicity conditions in the soil inhibit plant growth:

1. By causing low permeability.
2. By preventing calcium up take by plants.

If the exchangeable sodium percent is more than 15 there may be difficulty in maintaining soils permeability.

**2.6.2.3. Composition of soluble salts**

It is the fact that the dominance of sodium ions in the soluble salt is rather severe (more than 80% of all cations percent). Na is the dominant cation in the top, as well as in subsoil. Whereas, sulphate are equally important and form about 70 % of the anions. It is noticeable that both sodium and sulphate occurs in almost equal proportions in the soil (Younis, 1985).

It may therefore, be suggested that the sodium sulfate in the major salts component in the soils of the study area, however, it has been concluded by Nachtnegaele (1976), that the sodium chloride is nearly absent in the Gezira area and becomes important constituent further north of it. The dominance of sodium sulfate in the saline layers of investigated area might be considered as less harmful to plant growth.

**2.6.2.4. Calcium carbonates**:

The calcium carbonate percentage is generally low throughout the soil profiles less than 8 % (Younis, 1985).

**2.6.2.5. Hydrogen-ion activity (pH):**

The pH is not an independent variable but rather is a function of several interrelated factors:

1. The composition and structures of the parent material.
2. The rate of leaching and temperature.

For example, when $CaCO_3$ is present in the parent material at levels as low as 1% of the soil, they can dominate the course of soil development because this amount is sufficient to buffer the pH values over neutrality and sustain a high level of biological activity (Brown. *et.al,* 1977)

The overall average of pH for all depths is 8.0 the average pH of the top soil is 8.7 and sub soil is 8.6. pH values on saturated paste are almost invariably low, reflecting the effect of exchangeable sodium.

**2.6.2.6. Organic carbon:**

The highest value recorded was 0.42 percent on a surface soil and the lowest 0.05 percent on the second horizon.

The average value of 0.2 is lower than desirable for agricultural use and demonstrates the poverty of these soils in organic matter (Younis, 1985).

**2.7. Water sources and suitability in south Khartoum:**

U.S. Salinity Laboratory Staff (1964) gives a general irrigation water classification in terms of total salinity expressed by electrical conductivity, and alkalinity or sodicity, expressed by sodium absorption ratio (SAR).

Most surface irrigation water of which source is snow–fed rivers, has a total salinity of less than about 0.5 to 0.6 dS/m. Ground water in the semi-arid 1dS/m to more than 12 to 15 dS/m. Sea water is highly saline with an average total soluble salts content of about 35g/l corresponding to an electrical conductivity of about 50dS/m (FAO, 1988).

The water of the White Nile has low salinity, low sodium hazard and water quality of the well is classified as medium saline and low sodium hazard.

**2.8. Degradation and land use in Khartoum State:**

The land of Khartoum State is generally flat with a gentle slope towards the west of the main River Nile and its tributaries, the Blue and White Niles. The surface elevation ranges between 380 to 400 meters above sea level. Elevated ridges and isolated hills are encountered. The main watercourses are the Blue Nile, the White Nile, the main River Nile and some seasonal water courses “ Khors” originated within the state or from south western States.

The soils of Khartoum State are formed of geological drifts that were subjected to alteration by climate and topography to various degrees, depending on their textures and composition, they are composed of three different groups, namely high level dark clay or sands located east of the main Nile and the White Nile, recent alluvial soils of the Nile system, and that of the Nubian Series including the red sand ironstone soils, pea-iron gravel soil and eroding Nubian sandstone soils (Worral,1957). The high level dark clays, the northern stretches of Gezira clay plain, are saline and sodic. The contents of moisture, soluble salts, and sodium increase with depth to a maximum of 60 to 90 cm deep. The salt accumulation layer is 30 to 60 cm deep, whilst the highest concentrations of moisture and sodium are located in deeper horizons. The high level sands are wind-formed drifts resting on high-level clays (saeed 1969).

According to the U.S.A irrigation water classification system the main water resources are the three rivers, in addition to them there are seasonal running wadis and deep and shallow ground water in all geological formation. The quality of water from the upper aquifer ranges from acceptable to poor for domestic uses whereas, that from the lower aquifer is comparatively good for both drinking and household purposes, although very saline and hazardous zones were encountered in places. The irrational use of the slight to moderate salinity level of groundwater on clay soils makes it potentially hazardous for irrigation purposes.

Since the late sixties, early seventies and eighties a few fragmented studies have shown that the deserts expanding from the north of Sudan at an alarming rate threatening the livelihoods, habitats and population, as well as the ability of the areas to feed itself is affected, by sand encroachment and desertification. Various rates of desert margin advancement have been given in reports, papers, maps and bulletins. The quoted desert margin is that of Harrison and Jackson (1958) and Lamprey (1975), which estimated the desert advancement of 100 km in the 17 years between 1958 and 1975, with a rate of 5 to 6 km, per year (Salih, 2005). Khartoum State is the most densely populated State in Sudan, with steadily increasing density. The 1993 census revealed that its population was 3.512.000 and the estimate for the year 2003 was 5.352.000. The rural population constituted 13.5%, with 52.9% males and the average annual growth rate was 4.04% for the period 1998-2002. Migration to Khartoum State has increased during the past two decades due to desertification and drought that afflicted many areas in Sudan.

The phenomenon of the aridity and desertification caused negative impacts on different areas in the State. Mass movement of people to the State has resulted in high pressure on all services, increase in mortality of animals, failure of some seasons and accordingly, yield of cereal crops has declined to less than 50 kg/fed. All these resulted in deterioration of soil, plant cover and eventually deterioration of the state rangelands, as stated by (Abdalla, *et.al*. 2004).

Over grazing in this region is the main cause for destruction of vegetation, the intensive cultivation is confined to the Nile banks while the area away from the Nile are left for nomads, especially, the danger to the destruction of vegetation comes from the cultivation of marginal areas and over grazing that run the soil and increase the extent of desert creep southwards (Abdalla, 1998).

# Chapter Three

# Materials and methods

## 3.1 General description of the study area:

### 3.1.1 Location:

South Khartoum area located between latitudes15° 14´ and 15° 30´ N and longitudes 32° 30´ to 32° 57´ E (ELtom, 1973 and AOAD, 1974).

### 3.1.2 Climate:

The area lies within the semi-desert region of the Sudan, the climate is characterized by a very hot dry summer (April –June), a moderately hot and humid summer (July to October) and cool dry winter (November-March). Rains are characterized by marked variation in amount and distribution over time and space. The State receives an average rainfall between 75 and 150 mm with peaks in August and September. The average air temperature in the State ranges between 21.6° C to 37. 87° C, the mean annual evaporation rate is close to 7.7 mm/day, and the daily average relative humidity ranges between 21% and 38 % (EL tom 1973, AOAD 1974 and Met.2007).

Saeed (1969) reported that “due to the intense solar heating in summer particularly during the period between April and the onset of rains, the weather is very unstable and dust storms “haboobs” become more frequent. These “haboobs” usually occur on the hottest part of the day and sometimes are associated with precipitation, which assists in the fixation of dust on the upper layer of the soil.

### 3.1.3 Physiography and Geology

Almost the whole area is a flat plain with a gentle slope to the west. The highest point in the area is in the southern part at 386.2m above sea level

(ASL), and the lowest one is in the north at 380.2 m above sea level (ASL). The underlying geological materials of this area are included in the Nubian series. This Mesozoic Nubian sand stones lie horizontally or with a gentle dip on a platform eroded from the folded rocks of the pre-cambrian basement complex (ELtom, 1973).

The area is underlain at depth by the predominantly crystalalline and fesphathic metamorphic rocks of the pre-cambrain basement complex whose surface forms a platform on which the Mesozoic Nubian sandstone lies. Tertarity deposits are not known to occur in the area. Quaternary sediments overly the Nubian series and are comparatively thin. They consist mainly of unconsolidated alluvial sands, rarely gravely, overlain by clay materials, these continue to the surface (Younis, 1985).

### 3.1.4 Soil Genesis:

The most up-to-date theory is that deposition was from a seasonal inundation of the Blue Nile and its tributaries whose higher situation and larger summer flood enabled its alluvium to cover all the Gezira plain, and extending to the white Nile north of Jubel-Aulia, in the last period of deposition only fine textured sediments were laid down uniformally all over the central plain.

It consists the material originated in the Ethiopian highland and derived from basaltic and other rocks high in Ferro-magnesium. The soil developed on these fine textured materials are vertisols,  areas located on river levees along the Blue Nile river and old meander channels contain recent alluvial deposits, this soil material is coarser textured than older alluvium (Nachtengaele, 1976). The soil between the Blue and White Nile Rivers are alluvial deposits accumulated by both rivers (Williams and Adamson, 1976)

The soils of this area were found to belong to three soil orders, Vertisols, Entisols, and Aridisols. The majority of the area belongs to the order Entisols (ELtom, 1973).

### 3.1.5 Natural vegetation:

According to ELtom (1973) and AOAD (1974) vegetation of the area is very scattered with extensive areas without trees and with only a scanty shrub, much of the present condition can be attributed to grazing and firewood cutting. The dominant shrubs and grasses in the area are as follows:-

Shrubs:

- *Capparis decidua* "Tondob"
- *Acacia Arabica* "Sunt"
- *Acacia seyal* "Talh"
- *Acacia orfota* "laot"
- *Solvadora persica* "arak"

Grasses:

- *Aristida mutablis* " Elgau"
- *Cyperus rotundus* " Elsaida"
- *Euphorbia spp* "Umm libanaa"
- *Tremulous terresfris* " Eldirassa"

### 3.1.6 Water:

The quality of water has its effect on the essential activities when intended to be taken. Thus quality can only be evaluated in the context of a specific need of conditions. For the purpose of irrigation, water quality must be considered together with climatic condition in the region, soil types and crops. (Younis, 1977).

The area is dominated geologically by the Nubian sand stone sedimentary rocks, which are water bearing rocks. Accordingly, under ground water is available in sufficient quantities to support irrigation purposes, or other wise act as supplementary source of irrigation (Younis, 1985).

### 3.1.7 Land tenure:

Lands in Sudan are managed by three main types of land ownership, inherited, governmental and private ownership besides illegal ownerships within the frame of this tenure. The system of land tenure in the study area is private ownership.

### 3.1.8 Land use:

The system of land use in the study area is mainly traditional agriculture. Fooder crops and vegetable are cultivated in most areas, and irrigated by under ground water; central pivot, and by canal. The major problem in the area with reference to land use has been the practice of traditional and mechanized farming at the expense of the vegetation covers. The large-scale vegetation clearance operation has resulted in a complete removal of trees.

The over cutting activities are widely practiced in this area for the supply of fuel wood and irregular animals grazing. The main types of livestock in the area include sheep, cattle and goats (Younis, 1985).

### 3.1.9 Tribal Groups:

The area is inhabited by different tribes, Gamoaya, Gaalien, Kawahla, Kamalab, Hassania, Butahein, Mahas and Rufaa, they are depending mainly on agriculture, commerce and marginal professions for their living.

## 3.2. Materials and Methods of data collection:

### 3.2.1 Collection of Soil and Water Samples:

Forty five Auger samples were collected from four farms, and uncultivated area (control) in the southern area of Khartoum state. Soil samples were taken from three depths (0-30cm), (30-45cm) and (45-60cm) respectively. Sample collected by auger from five locations in cultivated private farms, Korean Company Farm, Abed Al mutaIib farm, Ahamed Alhaj farm, Alhaj Ahamed farm and uncultivated area as control in the area south of Khartoum (Map 3.1). The distance between each auger hole was 50 meters along the area with three replicates. Also water samples were collected from four wells at the same private farms. The agriculture practices in all farm started since 1985.

#### 3.2.1.1 Korean Company Farm:

This is a private farm with an area amounting to eight feddans is located opposite Al Shigalab Girls Secondary School, to the east of Jebel Aulia Rood. The system of irrigation used is central pivot irrigation.

#### 3.2.1.2 Abed Al mutaIib farm:

The farm area is six feddans, and located opposite to Um Haraz Satellite Station to the east of Jebel Aulia Rood.

#### 3.2.1.3 Ahamed Alhaj farm:

The farm area is thirteen feddans, and located opposite Alzhara village.

#### 3.2.1.4 Alhaj Ahamed farm:

The farm area is ten feddans, and located south of Taybt Alhassnab village.

#### 3.2.1.5 Uncultivated area (control):

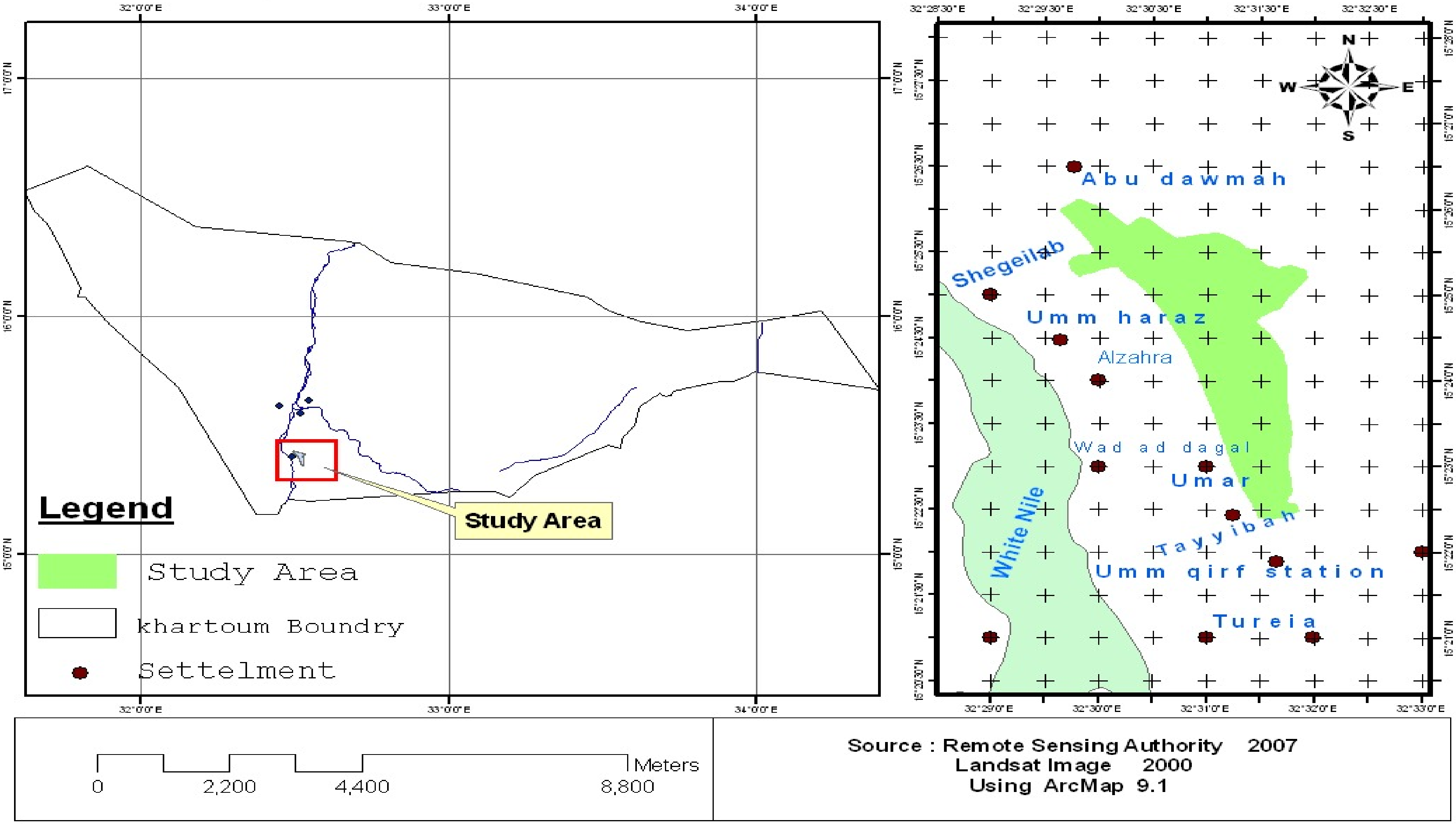
Soil sample collected from the adjacent area to the Korean Company farm, the uncultivated area covering with a scanty shrub.

Soil samples were carefully packed in bags to avoid distortion of aggregates and taken for further measurement and analysis. Enough weight of soil sample (1.5 kg) was taken from each auger hole. Water samples for analysis of salts content were taken in tight plastic cans.

### 3.2.2 Personal contact information:

The data concerning land use was collected through the personal contact. All farms adopted the cultivation of fodder Sorghum (Abu Sabein), in addition to that, they cultivate vegetable for self consumption in small areas since 1985.

# Map (3.1) .Location Of Study Area




Source : Remote Sensing Authority 2007
Landsat Image 2000
Using ArcMap 9.1

### 3.3. Data Analysis:-

#### 3.3.1 Laboratory Analysis:-

##### 3.3.1.1 Analysis of Soil Samples:-

All soil samples were ground to pass 2.00 mm sieve and mixed thoroughly. The sieved samples were used for determination of various mechanical and chemical compositions of the soils.

Soil pH paste was determined using pH-meter (U.S. Salinity Laboratory Staff. 1954) method. The electrical conductivity of each saturated soil was measured by using ECe-meter (ECe-bridge).

Cation Exchangeable Capacity of each saturated soil extract (CEC) was determined by the difference in the quantity of the calcium added and the amount found in the solution (Rible and Quick 1960).

Calcium (Ca) and Magnesium (Mg) were determined by titration against EDTA according to method described by Cheng and Bray (1951).

Cloride (CL) was determined by titration with Silver Niterate (Reitemer, 1943). Bicarbonate ($HCO_3$) was determined by titration with acid (Reitemeier, 1943). Sodium (Na) and Potassium (K) were determined by using flame photometer.

The Saturation Percentage (SP) was estimated by Wilcox methods (1951). The bulk density (B.D) was determined by measurement of volume and mass (Blake and Hartge, 1986).

Particle size distribution was determined by hydrometer method (Black *et.al*, 1965). The texture classes of the soil samples were determined according to United States Department of Agriculture (USDA) textural triangle.

The Exchangeable Sodium Percentage (ESP) and the Sodium Adsorption Ratio (SAR) are calculated after determining Ca, Mg and Na concentrations in saturation extract (U.S. Salinity Laboratory Staff, 1954). Soil Adsorption Ratio (SAR) was calculated according to the following equation:

$$SAR = \frac{Na^{+}}{\sqrt{\frac{Ca^{++} + Mg^{++}}{2}}}$$

The Exchangeable Sodium Percentage (ESP) was calculated according to the following equation:

$$ESP = \frac{Exh.Na}{CEC} X100$$

**3.3.1.2 Analysis of water Samples**:

Water samples collected from wells of the study area were used to determine pH, EC, RSC, SAR soluble Anions and Cations, using the same methods followed in the analysis of soil paste described above. The Residual Sodium Carbonate (RSC) calculated according to the following equation:

$$RSC = (CO_3^{--} + HCO_3^{-}) – (Ca^{++} + Mg^{++})$$

The cations concentrations are expressed in (meq/L).

### 3.3.2 Statistical Analysis

#### 3.3.2.1 Soil and Water Analysis:

Randomized Complete Block Design (RCBD) was used to estimate the effects of the measured parameters. Each soil sample was analyzed in three replications.

The Completely Randomized Design (CRD), were used for analyzing water sample. These samples were analyzed in triplicate also.

The data obtained from water and soil samples were analyzed according to SAS program version (3), (SAS, 1994).

For soil and water, the significance level accepted was $P \leq 0.05$ and means were separated according to Least Significant Difference (LSD) According to Gomez and Gomez (1984).

# Chapter Four

# Results

Table 4.1 through 4.5 illustrated the results of mechanical and chemical analysis of soil in the Korean Company Farm, Abed Al mutaIib farm, Ahamed Alhaj farm, Alhaj Ahamed farm and uncultivated area (control) respectively. Moreover, tables 4.6 to 4.9 illustrated the average of soil properties in the study sites.

The results reflect soil properties of the study sites. The obtained results show the alkaline reaction of soil, where pH ranges between 6.9 to 8.8, moreover ECe 1.0 to 17.5, where the value of 17.5 dS/m found in depth of (45-60) in Ahamed Alhaj Farm.

The SAR values fall within the slight, moderate and strong degrees of salinity. The exchange cations including K counted fair for the soil of South Khartoum also organic carbon and nitrogen content are low, according to the previous analysis of the soil conducted by the Soil Survey Administration (SSA, 1976) and (Younis, 1985).

The presence of HCO3 could influence the creation of some sodic pockets in the soil. The high clay content and the bulk density could affect the soil permeability. The results obtained show the high clay content which ranged between 22.8-62.6. This is coping with the classification of Worral, (1957).

The soil classified as Entisols Eltom (1973), nonetheless the soil have symptoms of vertisols that represented in dark brown colour and slight cracks, American Soil taxonomy, (1975).

**Table 4.1: Mechanical and Chemical Analysis of soil in Korean Company Farm:**

| Sample No | Depth (cm) | S.P | pH | Ece (dS/m) | ca+Mg (mmol+/l) | Na (mmol+/l) | Mg (mmol+/l) | K (mmol+/l) | SAR | $HCO_3$ (mmol+/l) | Cl (mmol+/l) | $SO_4$ (mmol+/l) | B.D (g/cm)3 | Exh.Na (mmol+/1) | CEC (nmol+/100g) | ESP | clay (%) | sit (%) | Sand (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A1 | 0-30 | 38.0 | 8.2 | 1.6 | 5.7 | 10.5 | 2.3 | 0.1 | 6.3 | 4.4 | 7.9 | 3.7 | 1.3 | 2.7 | 26.9 | 10.2 | 38.5 | 12.9 | 48.6 |
| | 30-45 | 44.4 | 7.9 | 3.7 | 14.3 | 22.7 | 4.7 | 0.1 | 7.2 | 6.5 | 12.2 | 18.4 | 1.3 | 2.4 | 31.4 | 7.6 | 40.9 | 11.6 | 47.5 |
| | 45-60 | 45.6 | 8.2 | 3.7 | 12.3 | 24.5 | 4.0 | 0.1 | 8.5 | 7.3 | 12.7 | 16.7 | 1.2 | 3.0 | 32.3 | 9.0 | 39.6 | 11.2 | 49.2 |
| A2 | 0-30 | 38.9 | 7.6 | 2.4 | 14.3 | 6.6 | 5.0 | 0.1 | 2.4 | 3.9 | 13.4 | 6.7 | 1.3 | 1.2 | 27.5 | 4.2 | 39.5 | 13.7 | 46.8 |
| | 30-45 | 38.9 | 7.5 | 3.7 | 18.0 | 15.3 | 6.3 | 0.1 | 5.3 | 4.5 | 15.8 | 16.4 | 1.3 | 1.9 | 27.5 | 6.6 | 37.2 | 12.6 | 50.2 |
| | 45-60 | 46.0 | 7.5 | 4.5 | 19.0 | 25.6 | 6.7 | 0.1 | 8.7 | 4.3 | 15.0 | 26.1 | 1.2 | 4.3 | 32.6 | 12.9 | 38.3 | 11.8 | 49.9 |
| A3 | 0-30 | 45.8 | 7.4 | 2.1 | 12.7 | 8.1 | 3.7 | 0.1 | 3.0 | 3.8 | 11.3 | 5.6 | 1.3 | 1.7 | 32.4 | 4.8 | 37.4 | 13.1 | 49.5 |
| | 30-45 | 36.2 | 7.6 | 3.4 | 17.3 | 17.0 | 5.0 | 0.1 | 5.3 | 3.8 | 16.9 | 13.7 | 1.3 | 1.5 | 25.6 | 5.5 | 41.0 | 12.5 | 46.5 |
| | 45-60 | 37.6 | 7.3 | 5.2 | 25.7 | 26.4 | 6.7 | 0.0 | 7.9 | 3.7 | 23.0 | 25.3 | 1.3 | 1.9 | 26.6 | 6.9 | 37.5 | 12.0 | 50.5 |

**Table 4.2: Mechanical and Chemical Analysis of soil in Abed Almutalib Farm:**

| Sample No | Depth (cm) | S.P | pH | ECe (ds/m) | ca+Mg (mmol+/l) | Na (mmol+/l) | Mg (mmol+/l) | K (mmol+/l) | SAR | HCO3 (mmol+/l) | Cl (mmol+/l) | SO4 (mmol+/l) | B.D (g/cm)3 | Exh.Na( mmol+/1) | CEC (nmol+/100g) | ESP | clay (%) | sit (%) | Sand (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A1 | 0-30 | 51.2 | 7.9 | 2.2 | 10.5 | 11.2 | 2.7 | 0.2 | 5.5 | 3.9 | 14.2 | 3.6 | 1.3 | 2.3 | 36.3 | 7.5 | 40.4 | 13.0 | 46.6 |
| | 30-45 | 47.8 | 7.9 | 6.8 | 11.0 | 56.7 | 3.0 | 0.1 | 26.9 | 4.1 | 24.3 | 39.3 | 1.2 | 9.7 | 33.9 | 29.3 | 37.7 | 12.2 | 40.1 |
| | 45-60 | 45.1 | 7.7 | 8.3 | 14.7 | 68.7 | 4.0 | 0.2 | 28.0 | 4.3 | 41.1 | 38.0 | 1.2 | 8.4 | 31.9 | 26.0 | 35.6 | 12.2 | 52.2 |
| A2 | 0-30 | 53.7 | 7.9 | 9.1 | 14.7 | 76.3 | 4.0 | 0.1 | 28.1 | 4.6 | 38.0 | 18.3 | 1.2 | 9.7 | 38.0 | 26.3 | 42.3 | 12.9 | 44.8 |
| | 30-45 | 52.3 | 8.1 | 4.3 | 6.3 | 37.0 | 2.3 | 0.3 | 22.3 | 5.4 | 15.1 | 22.9 | 1.2 | 14.8 | 37.1 | 37.2 | 41.3 | 12.6 | 46.1 |
| | 45-60 | 52.7 | 7.9 | 6.7 | 13.0 | 53.6 | 3.3 | 0.1 | 21.4 | 4.8 | 29.2 | 32.6 | 1.3 | 8.0 | 37.3 | 20.6 | 41.6 | 8.8 | 49.6 |
| A3 | 0-30 | 38.4 | 8.1 | 2.6 | 10.0 | 16.0 | 3.0 | 0.1 | 6.7 | 5.2 | 13.9 | 6.9 | 1.3 | 2.3 | 27.2 | 8.6 | 30.3 | 13.3 | 56.4 |
| | 30-45 | 39.6 | 8.2 | 3.3 | 9.3 | 23.4 | 2.7 | 0.1 | 11.1 | 5.5 | 12.3 | 14.9 | 1.3 | 3.7 | 28.1 | 13.1 | 31.3 | 13.2 | 55.6 |
| | 45-60 | 43.7 | 8.1 | 6.1 | 18.0 | 43.5 | 7.7 | 0.1 | 17.3 | 5.4 | 24.6 | 31.3 | 1.3 | 5.7 | 31.0 | 17.3 | 34.5 | 9.0 | 56.5 |

**Table 4.3: Mechanical and Chemical Analysis of soil in Ahamed Alhaj Farm:**

| Sample No | Depth (cm) | S.P | pH | ECe (ds/m) | ca+Mg (mmol+/l) | Na (mmol+/l) | Mg (mmol+/l) | K (mmol+/l) | SAR | HCO3 (mmol+/l) | Cl (mmol+/l) | SO4 (mmol+/l) | B.D (g/cm)3 | Exh.Na (mmol+/1) | CEC (nmol+/ 100g) | ESP | clay (%) | sit (%) | Sand (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A1 | 0-30 | 52.7 | 8.0 | 4.5 | 9.0 | 36.1 | 3.0 | 0.05 | 17.02 | 4.90 | 24.10 | 16.00 | 1.21 | 6.88 | 37.32 | 18.4 | 41.6 | 12.9 | 45.5 |
| | 30-45 | 58.2 | 7.7 | 17.0 | 26.0 | 144.1 | 5.0 | 0.01 | 39.97 | 4.00 | 93.20 | 72.80 | 1.29 | 10.20 | 41.22 | 24.7 | 45.9 | 12.8 | 41.3 |
| | 45-60 | 63.4 | 7.5 | 15.0 | 24.0 | 126.1 | 6.0 | 0.01 | 36.40 | 4.00 | 88.50 | 57.50 | 1.27 | 10.80 | 44.90 | 24.1 | 50.0 | 12.8 | 37.2 |
| A2 | 0-30 | 48.60 | 7.85 | 2.80 | 6.00 | 22.10 | 2.0 | 0.11 | 12.76 | 4.40 | 14.20 | 9.40 | 1.23 | 5.79 | 34.42 | 16.82 | 38.30 | 12.40 | 49.30 |
| | 30-45 | 52.70 | 8.66 | 1.20 | 3.00 | 9.10 | 1.0 | 0.08 | 7.43 | 6.00 | 4.60 | 1.40 | 1.21 | 5.37 | 37.32 | 14.39 | 41.60 | 12.80 | 45.60 |
| | 45-60 | 64.30 | 7.66 | 3.70 | 9.00 | 27.90 | 3.0 | 0.05 | 13.15 | 4.00 | 7.00 | 26.00 | 1.26 | 6.61 | 45.54 | 14.51 | 50.70 | 12.80 | 36.50 |
| A3 | 0-30 | 64.30 | 8.50 | 2.60 | 5.00 | 21.10 | 2.0 | 0.12 | 13.34 | 6.6 | 7.40 | 12.00 | 1.26 | 8.61 | 45.54 | 18.91 | 50.70 | 13.10 | 36.20 |
| | 30-45 | 67.10 | 8.39 | 2.40 | 4.00 | 20.10 | 2.0 | 0.13 | 14.21 | 5.10 | 6.20 | 12.70 | 1.25 | 10.99 | 47.52 | 23.13 | 52.90 | 13.50 | 33.60 |
| | 45-60 | 84.80 | 7.99 | 6.40 | 8.00 | 62.10 | 2.0 | 0.06 | 31.05 | 4.10 | 26.40 | 33.50 | 1.23 | 20.14 | 60.06 | 33.53 | 56.90 | 13.10 | 30.00 |

**Table 4.4: Mechanical and Chemical Analysis of soil in Alhaj Ahmed Farm:**

| Sample No | Depth (cm) | S.P | pH | ECe (ds/m) | ca+Mg (mmol+/l) | Na (mmol+/l) | Mg (mmol+/l) | K (mmol+/l) | SAR | HCO3 (mmol+/l) | Cl (mmol+/l) | SO4 (mmol+/l) | B.D (g/cm)3 | Exh.Na (mmol+/1) | CEC (nmol+/100g) | ESP | clay (%) | sit (%) | Sand (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A1 | 0-30 | 47.00 | 8.61 | 1.50 | 3.00 | 12.20 | 1.00 | 0.09 | 9.96 | 4.00 | 5.60 | 5.40 | 1.23 | 6.20 | 33.29 | 18.62 | 37.10 | 13.80 | 49.10 |
| | 30-45 | 43.70 | 8.22 | 2.20 | 4.00 | 18.10 | 1.00 | 0.15 | 12.80 | 4.30 | 4.40 | 13.30 | 1.25 | 6.32 | 30.95 | 20.42 | 34.50 | 13.40 | 52.10 |
| | 45-60 | 86.90 | 8.23 | 3.20 | 4.00 | 28.00 | 1.00 | 0.07 | 19.80 | 4.40 | 4.30 | 23.30 | 1.23 | 18.72 | 61.54 | 30.42 | 58.60 | 13.40 | 28.00 |
| A2 | 0-30 | 48.30 | 8.06 | 1.60 | 2.00 | 14.10 | 1.00 | 0.12 | 14.10 | 4.40 | 4.80 | 6.80 | 1.33 | 10.35 | 34.21 | 30.25 | 38.10 | 13.10 | 48.80 |
| | 30-45 | 72.50 | 8.06 | 2.30 | 4.00 | 19.00 | 1.00 | 0.06 | 13.44 | 4.80 | 4.80 | 13.40 | 1.23 | 10.89 | 51.34 | 21.21 | 57.20 | 13.10 | 29.70 |
| | 45-60 | 97.10 | 8.69 | 15.13 | 67.97 | 23.50 | 16.00 | 0.09 | 4.03 | 6.60 | 105.10 | 179.60 | 1.23 | 10.61 | 68.77 | 15.43 | 62.60 | 13.00 | 24.40 |
| A3 | 0-30 | 40.80 | 8.70 | 8.16 | 12.24 | 69.50 | 4.00 | 0.07 | 28.09 | 4.90 | 65.10 | 11.60 | 1.27 | 7.10 | 28.89 | 24.58 | 32.20 | 12.90 | 54.90 |
| | 30-45 | 62.20 | 7.94 | 12.44 | 12.44 | 88.90 | 5.00 | 0.09 | 35.65 | 4.00 | 94.70 | 25.70 | 1.27 | 16.40 | 44.05 | 37.23 | 49.10 | 12.80 | 38.10 |
| | 45-60 | 76.60 | 8.31 | 15.32 | 15.32 | 98.95 | 5.00 | 0.07 | 35.75 | 4.50 | 83.30 | 65.40 | 1.22 | 20.75 | 54.25 | 38.25 | 60.40 | 12.80 | 26.80 |

## Table 4.5: Mechanical and Chemical Analysis of soil in Uncultivated area (control):

| Sample No | Depth (cm) | S.P | pH | ECe (ds/m) | ca+Mg (mmol+/l) | Na (mmol+/l) | Mg (mmol+/l) | K (mmol+/l) | SAR | HCO3 (mmol+/l) | Cl (mmol+/l) | SO4 (mmol+/l) | B.D (g/cm)3 | Exh.Na (mmol+/1) | CEC (nmol+/100g) | ESP | clay (%) | sit (%) | Sand (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A1 | 0-30 | 37.6 | 8.7 | 1.1 | 3.0 | 7.9 | 2.0 | 0.23 | 6.45 | 4.50 | 5.30 | 1.20 | 1.38 | 3.31 | 26.63 | 12.4 | 29.7 | 12.5 | 57.8 |
| | 30-45 | 35.5 | 8.8 | 1.6 | 3.0 | 13.0 | 1.0 | 0.41 | 10.61 | 4.30 | 4.50 | 7.20 | 1.40 | 4.89 | 25.14 | 19.5 | 28.0 | 12.4 | 59.6 |
| | 45-60 | 35.5 | 8.6 | 1.4 | 5.0 | 8.9 | 2.0 | 0.16 | 5.63 | 4.50 | 4.10 | 5.40 | 1.40 | 2.38 | 25.14 | 9.5 | 28.0 | 12.3 | 59.7 |
| A2 | 0-30 | 36.7 | 6.9 | 6.7 | 15.0 | 52.2 | 5.0 | 0.02 | 19.06 | 2.30 | 56.10 | 8.60 | 1.39 | 4.10 | 25.99 | 15.8 | 29.0 | 12.8 | 58.2 |
| | 30-45 | 38.4 | 8.0 | 6.5 | 20.0 | 44.9 | 5.0 | 0.01 | 14.20 | 4.50 | 46.10 | 14.40 | 1.39 | 2.97 | 27.20 | 10.9 | 30.3 | 12.8 | 56.9 |
| | 45-60 | 28.9 | 7.8 | 1.7 | 9.0 | 8.1 | 3.0 | 0.08 | 3.82 | 4.10 | 2.20 | 10.70 | 1.43 | 1.19 | 20.47 | 5.8 | 22.8 | 12.6 | 64.6 |
| A3 | 0-30 | 34.7 | 7.8 | 1.0 | 4.0 | 6.1 | 1.0 | 0.41 | 4.31 | 4.00 | 4.20 | 1.80 | 1.40 | 2.10 | 24.57 | 8.5 | 27.4 | 12.8 | 59.8 |
| | 30-45 | 37.6 | 7.7 | 3.0 | 18.0 | 12.2 | 4.0 | 0.03 | 4.07 | 4.10 | 9.90 | 16.00 | 1.38 | 1.26 | 26.63 | 4.7 | 29.7 | 12.7 | 57.6 |
| | 45-60 | 41.7 | 7.7 | 4.1 | 21.0 | 20.0 | 5.0 | 0.02 | 6.17 | 4.40 | 15.30 | 21.30 | 1.36 | 1.72 | 29.53 | 5.8 | 32.9 | 12.0 | 55.1 |

## Table 4.6: Average of soil SP, pH, ECe, Na in location of the study area

| Soil properties / Location | SP | | | pH | | | ECe(dS/m) | | | Na (mmol+/l) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **0-30** | **30-45** | **45-60** | **0-30** | **30-45** | **45-60** | **0-30** | **30-45** | **45-60** | **0-30** | **30-45** | **45-60** |
| Korean Company Farm | 40.86a | 38.91a | 43.03a | 7.73a | 7.61a | 7.64a | 2.04b | 3.67a | 4.44a | 8.57b | 18.68a | 23.58a |
| Abed Al mutaIib farm | 47.94a | 46.03a | 47.50a | 7.99a | 8.03a | 7.89a | 4.82b | 5.01ab | 6.64a | 35.34b | 40. 1ab | 51.37a |
| Ahamed Alhaj farm | 55.62a | 59.62a | 71.01a | 8.11a | 8.14a | 7.74b | 3.30b | 6.89a | 8.40a | 26.47a | 58.03a | 72.35a |
| Alhaj Ahamed farm | 48.52a | 59.32a | 84.31a | 8.46a | 8.09b | 8.41a | 3.79b | 5.72a | 15.91a | 31.99b | 39.58b | 65.99a |
| Uncultivated area (control) | 36.79c | 37.54c | 35.86d | 7.81a | 8.17a | 8.06a | 2.94b | 3.76b | 2.43b | 22.11a | 23.41a | 12.40a |

Values in the same column followed by similar letters are not significant differences at $P \leq 0.05$ in Least Significant Difference (LSD).

## Table 4.7: Average of soil Mg, K, SAR, $HCO_3$ in location of the study area

| Soil properties / Location | Mg (mmol+/l) | | | K (mmol+/l) | | | SAR | | | $HCO_3$ (mmol+/l) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0-30 | 30-45 | 45-60 | 0-30 | 30-45 | 45-60 | 0-30 | 30-45 | 45-60 | 0-30 | 30-45 | 45-60 |
| Korean Company Farm | 3.80b | 5.40a | 5.90a | 0.09a | 0.07a | 0.06b | 3.96b | 5.94ab | 7.52a | 4.12a | 4.96a | 5.09a |
| Abed Al mutaIib farm | 3.25b | 2.70b | 5.00a | 0.095a | 0.078ab | 0.059b | 13.28b | 19.84b | 21.16a | 4.63a | 5.04a | 4.91a |
| Ahamed Alhaj farm | 2.34b | 2.68a | 3.68a | 0.097a | 0.072ab | 0.046b | 14.26b | 20.59ab | 26.75a | 5.32a | 5.06a | 4.06b |
| Alhaj Ahamed farm | 2.00b | 2.33b | 7.33a | 0.24a | 0.09ab | 0.08b | 17.37b | 23.59ab | 35.98a | 4.43a | 4.37a | 5.17a |
| Uncultivated area (control) | 2.70a | 3.37a | 3.37a | 0.02a | 0.08a | 0.06a | 9.96a | 9.62b | 5.22a | 3.67b | 4.36a | 4.40a |

Values in the same column followed by similar letters are not significant differences at $P \leq 0.05$ in Least Significant Difference (LSD).

## Table 4.8: Average of soil CL, $SO_4$, B.D, CEC in location of the study area

| Soil properties / Location | CL (mmol+/l) | | | $SO_4$ (mmol+/l) | | | B.D $(g/cm)^3$ | | | CEC (mmol+/l) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0-30 | 30-45 | 45-60 | 0-30 | 30-45 | 45-60 | 0-30 | 30-45 | 45-60 | 0-30 | 30-45 | 45-60 |
| Korean Company Farm | 10.86b | 14.96ab | 16.91a | 5.31b | 16.2b | 22.7a | 1.21b | 1.23b | 1.21b | 29.07a | 28.21a | 30.58a |
| Abed Al mutaIib farm | 22.07ab | 17.26b | 31.66a | 9.60b | 25.66b | 32.72a | 1.22b | 1.24b | 1.26b | 33.90a | 33.20a | 33.45a |
| Ahamed Alhaj farm | 15.24b | 34.68a | 40.64a | 12.47b | 30.17ab | 39.0a | 1.25b | 1.23b | 1.22b | 39.02b | 42.02ab | 50.07a |
| Alhaj Ahamed farm | 25.17a | 34.63a | 64.23a | 7.93b | 17.47b | 89.43a | 1.26b | 1.23b | 1.22b | 32.17c | 42.15ab | 61.60a |
| Uncultivated area (control) | 21.90a | 20.20a | 7.23b | 3.87b | 12.55b | 12.47a | 1.39a | 1.39a | 1.40a | 25.69a | 26.38a | 25.17a |

Values in the same column followed by similar letters are not significant differences at $P \leq 0.05$ in Least Significant Difference (LSD).

**Table 4.9: Average of soil ESP, Clay, Silt, Sand in location of the study area**

| Soil properties / Location | **ESP** | | | **Clay** (%) | | | **Silt** (%) | | | **Sand** (%) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0-30 | 30-45 | 45-60 | 0-30 | 30-45 | 45-60 | 0-30 | 30-45 | 45-60 | 0-30 | 30-45 | 45-60 |
| Korean Company Farm | 6.52b | 6.70b | 9.59a | 38.61a | 39.75a | 38.29b | 13.07a | 12.20b | 11.79c | 48.32b | 48.05b | 49.92a |
| Abed Al mutaIib farm | 14.10a | 24.36a | 21.35a | 37.69a | 40.11a | 37.43b | 12.92a | 12.82a | 10.30b | 49.39a | 47.07b | 52.27a |
| Ahamed Alhaj farm | 18.31a | 20.73a | 24.05a | 43.68c | 46.55b | 52.51a | 12.91a | 13.18a | 13.08a | 43.41a | 40.26a | 34.41b |
| Alhaj Ahamed farm | 24.56a | 26.29a | 28.03a | 35.91c | 47.20b | 60.84a | 13.32a | 13.02a | 12.94b | 50.77a | 39.78b | 26.22c |
| Uncultivated area (control) | 12.47a | 11.77a | 7.07b | 29.27a | 29.49a | 28.11a | 12.45a | 12.48a | 12.32a | 58.28a | 57.98a | 59.58a |

Values in the same column followed by similar letters are not significant differences at $P \leq 0.05$ in Least Significant Difference (LSD).

### 4.1 Soil Characteristics:

### 4.1.1 Chemical Characteristics:

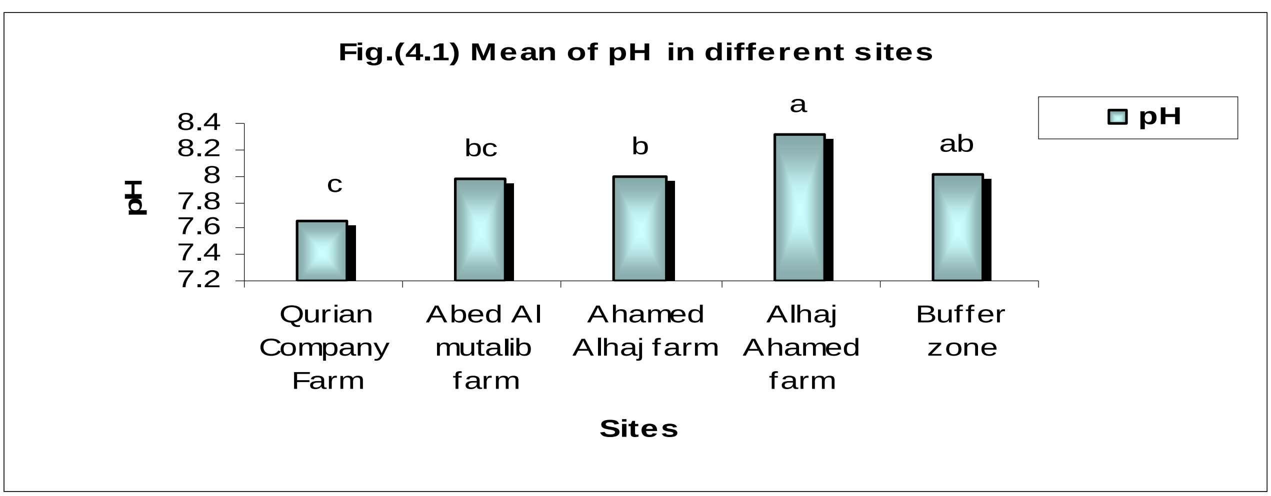
### 4.1.1.1 pH in different sites and depths:

The values of soil analysis showed that pH not significant difference ($P \leq 0.05$), in all depths exception in depths (30-45) in Alhaj Ahamed farm, (45-60) in Ahamed Alhaj farm, where it showed significant difference. The Korean Company farm recorded the lowest value (7.66) and Alhaj Ahamed farm highest value ( 8.32), (Table 4.10, and Fig 4.1).

Table 4.10: pH in different sites and depths:

| Sites / Depths(cm) | Korean Company farm | Abed Al mutaIib farm | Ahamed Alhaj farm | Alhaj Ahamed farm | Uncultivated area (control) |
|---|---|---|---|---|---|
| 0-30 | $7.73^{a}$ | $7.99^{a}$ | $8.11^{a}$ | $8.46^{a}$ | $7.81^{a}$ |
| 30-45 | $7.61^{a}$ | $8.03^{a}$ | $8.14^{a}$ | $8.09^{b}$ | $8.17^{a}$ |
| 45-60 | $7.64^{a}$ | $7.89^{a}$ | $7.74^{b}$ | $8.41^{a}$ | $8.06^{a}$ |
| Mean | $7.66b_{c}$ | $7.97_{bc}$ | $8.00_{b}$ | $8.32_{a}$ | $8.01_{ab}$ |

Values in the same raw followed by similar letters are not significant differences at ($P \leq 0.05$) in Least Significant Difference (LSD).



#### 4.1.1.2 Electrical Conductivity (ECe dS/m) in different sites and depths:

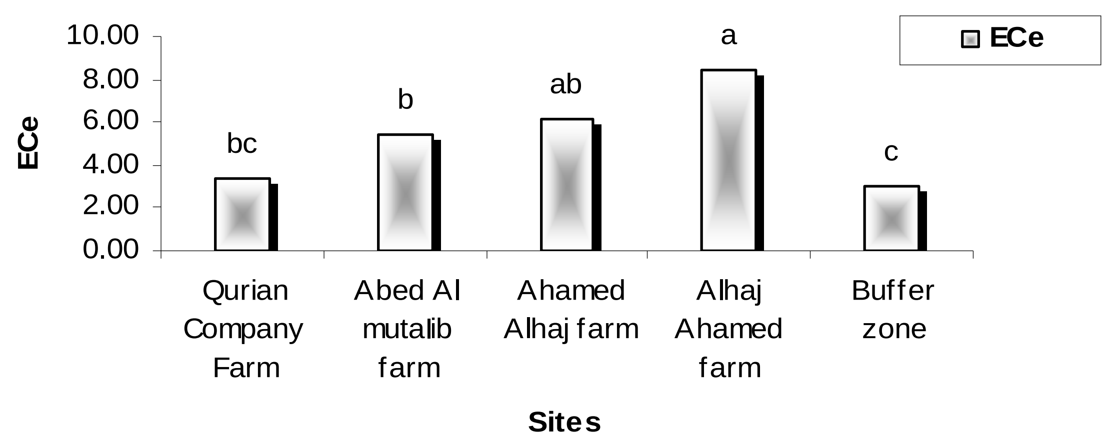
Statistical no significant difference(P≤0.05), was found with regard to ECe in all soil depths, exception is uncultivated area (control), where it shows significant difference in depth (30-45), (45-60). Furthermore, Alhaj Ahamed farm recorded the highest value (8.47), while the uncultivated area (control) recorded the lowest value (3.04), (Table 4.11, and Fig.4.2).

Table 4.11: Electrical Conductivity (ECe dS/m) in different sites and depths:

| Sites / Depths(cm) | Korean Company farm | Abed Al mutaIib farm | Ahamed Alhaj farm | Alhaj Ahamed farm | Uncultivated area (control) |
|---|---|---|---|---|---|
| 0-30 | $2.04^{b}$ | $4.82^{b}$ | $3.30^{b}$ | $3.79^{b}$ | $2.94^{b}$ |
| 30-45 | $3.67^{a}$ | $5.01^{ab}$ | $6.89^{a}$ | $5.72^{a}$ | $3.76^{b}$ |
| 45-60 | $4.44^{a}$ | $6.64^{a}$ | $8.40^{a}$ | $15.91^{a}$ | $2.43^{b}$ |
| Mean | $3.38_{bc}$ | $5.48_{b}$ | $6.20_{ab}$ | $8.47_{a}$ | $3.04_{c}$ |

Values in the same raw followed by similar letters are not significant differences at (P≤0.05) in Least Significant Difference (LSD).

Fig.(4.2) Mean of ECe dS/m in different sites



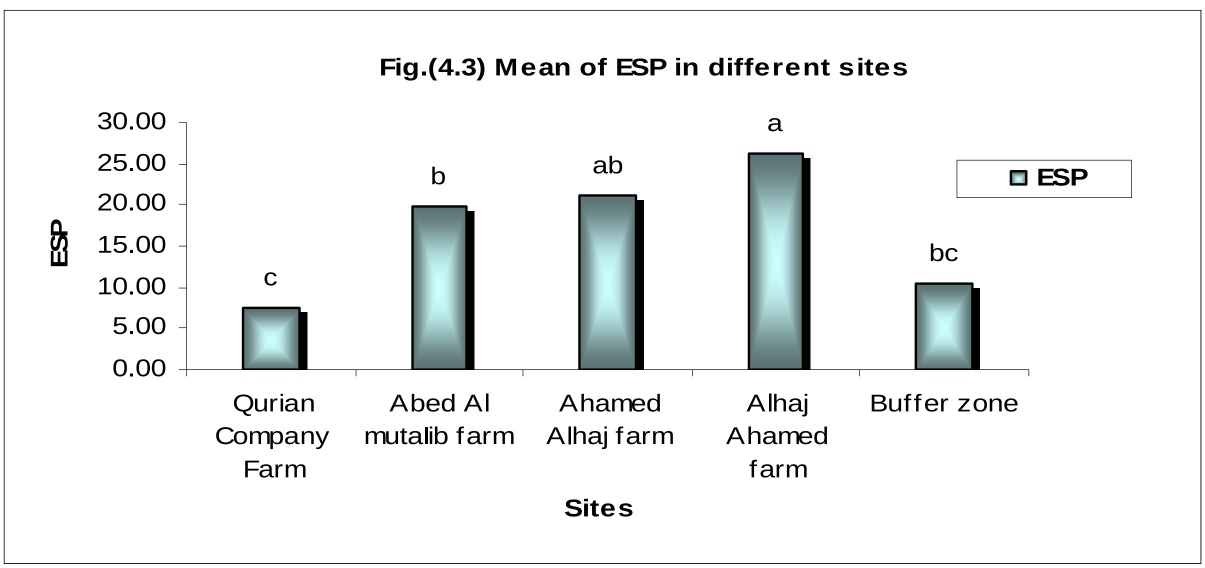
#### 4.1.1.3 Exchangeable sodium percentage ESP in different sites and depths:

Result showed that, ESP varied significantly (P≤0.05), among sites, where it shows no significant difference in all depths exception is Korean Company farm in depths (30-45), (30-45) and in depths (45-60) in Uncultivated area (control), (Table 4.12, and Fig 4.3).

Table 4.12: Exchangeable sodium percentage ESP in different sites and depths:

| Sites / Depths(cm) | Korean Company farm | Abed Al mutaIib farm | Ahamed Alhaj farm | Alhaj Ahamed farm | Uncultivated area (control) |
|---|---|---|---|---|---|
| 0-30 | $6.52^{b}$ | $14.10^{a}$ | $18.31^{a}$ | $24.56^{a}$ | $12.47^{a}$ |
| 30-45 | $6.70^{b}$ | $24.36^{a}$ | $20.73^{a}$ | $26.29^{a}$ | $11.77^{a}$ |
| 45-60 | $9.59^{a}$ | $21.35^{a}$ | $24.05^{a}$ | $28.03^{a}$ | $7.07^{b}$ |
| Mean | $7.60_{c}$ | $19.94_{b}$ | $21.03_{ab}$ | $26.29_{a}$ | $10.44_{bc}$ |

Values in the same raw followed by similar letters are not significant differences at (P≤0.05) in Least Significant Difference (LSD).



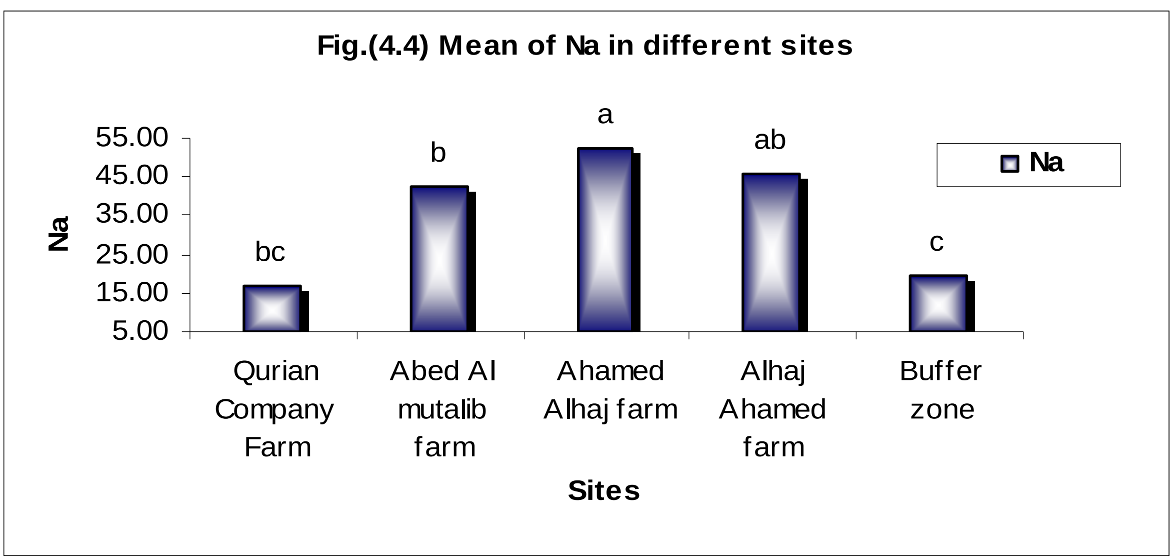
### 4.1.1.4 Sodium (Na) in different sites and depths:

Content of Na showed significant ($P \leq 0.05$), among sites, where it shows no significant difference in depths (45-60), but shows significant difference in Alhaj Ahamed farm in depths (30-45) and uncultivated area (control) in (0-30) it was observed increase of sodium content in depths (45 - 60 cm) and (30-45 cm), than depths (0 -30 cm) in all farms, (Table 4.13, and Fig 4. 4).

Table 4.13: Sodium (Na) in different sites and depths:

| Sites / Depths(cm) | Korean Company farm | Abed Al mutaIib farm | Ahamed Alhaj farm | Alhaj Ahamed farm | Uncultivated area (control) |
|---|---|---|---|---|---|
| 0-30 | $8.57^{b}$ | $35.34^{b}$ | $26.47^{b}$ | $31.99^{b}$ | $22.11^{a}$ |
| 30-45 | $18.68^{a}$ | $40.01^{ab}$ | $58.03^{a}$ | $39.58^{b}$ | $23.41^{a}$ |
| 45-60 | $23.58^{a}$ | $51.37^{a}$ | $72.35^{a}$ | $65.99^{a}$ | $12.40^{a}$ |
| Mean | $13.61_{bc}$ | $42.24_{b}$ | $52.28_{a}$ | $45.85_{ab}$ | $19.31_{c}$ |

Values in the same raw followed by similar letters are not significant differences at ($P \leq 0.05$) in Least Significant Difference (LSD).



### 4.1.1.5 Magnesium (Mg) in different sites and depths:

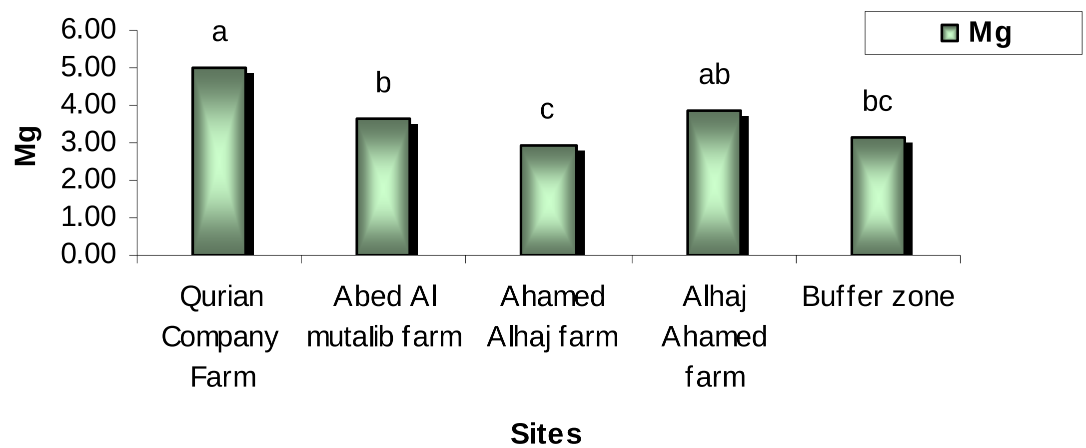
Content of Mg showed significant difference ($P \leq 0.05$), in depths and among sites, the exception is in depths (45-60), where it shows no significant difference. But Korean Company farm recorded the highest value (5.03) and Ahamed Alhaj farm lowest value (2.90), (Table 4.14 and Fig 4.5)

Table 4.14: Magnesium (Mg) in different sites and depths**:**

| Sites / Depths(cm) | Korean Company farm | Abed Al mutaIib farm | Ahamed Alhaj farm | Alhaj Ahamed farm | Uncultivated area (control) |
|---|---|---|---|---|---|
| 0-30 | $3.80^{b}$ | $3.25^{b}$ | $2.34^{a}$ | $2.00^{b}$ | $2.70^{a}$ |
| 30-45 | $5.40^{a}$ | $2.70^{b}$ | $2.68^{a}$ | $2.33^{b}$ | $3.37^{a}$ |
| 45-60 | $5.90^{a}$ | $5.00^{a}$ | $3.68^{a}$ | $7.33^{a}$ | $3.37^{a}$ |
| Mean | $5.03_{a}$ | $3.65_{b}$ | $2.90_{c}$ | $3.89_{ab}$ | $3.15_{bc}$ |

Values in the same raw followed by similar letters are not significant differences at ($P \leq 0.05$) in Least Significant Difference (LSD).

Fig.(4.5) Mean of Mg in different sites



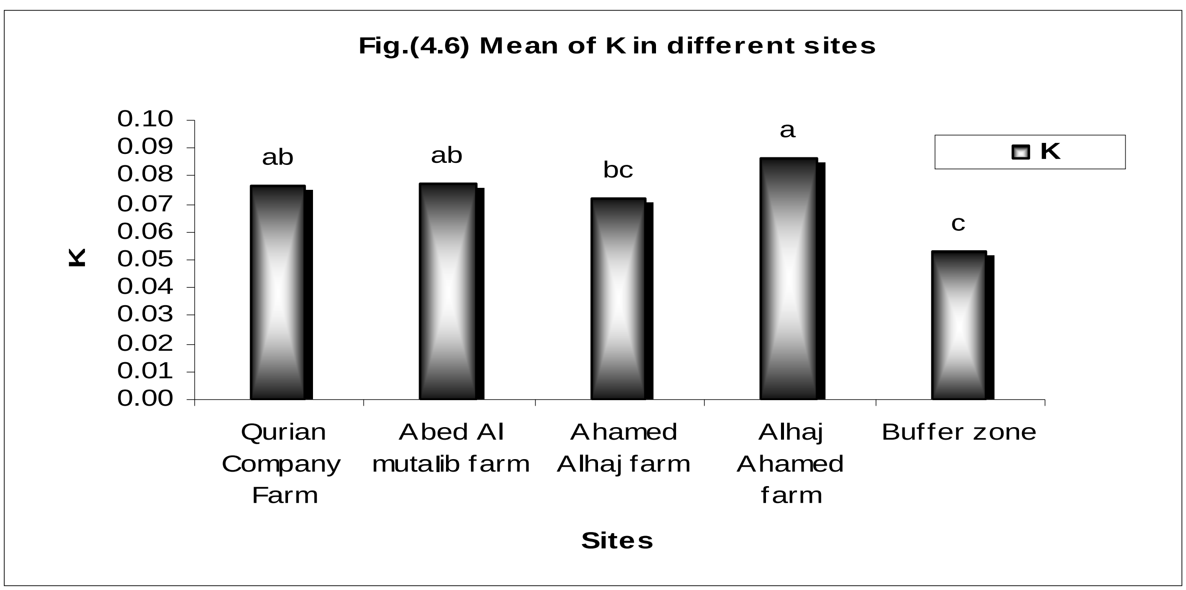
### 4.1.1.6 Potassium (K) in different sites and depths:

Potassium (K) in the soil showed significant differences (P≤0.05), among sites, where they show no significant difference along depths exception in uncultivated area (control) in depth (45-60). In Korean Company and Abed Al mutaIib farms show no significant change among them (Table 4.15, and Fig 4.6).

Table 4.15: Potassium (K) in different sites and depths:

| Sites / Depths(cm) | Korean Company farm | Abed Al mutaIib farm | Ahamed Alhaj farm | Alhaj Ahamed farm | Uncultivated area (control) |
|---|---|---|---|---|---|
| 0-30 | $0.090^{a}$ | $0.095^{a}$ | $0.097^{a}$ | $0.24^{a}$ | $0.02^{a}$ |
| 30-45 | $0.074^{a}$ | $0.078^{ab}$ | $0.072^{ab}$ | $0.09^{ab}$ | $0.08^{a}$ |
| 45-60 | $0.066^{b}$ | $0.059^{b}$ | $0.046^{b}$ | $0.08^{b}$ | $0.06^{a}$ |
| Mean | $0.08_{ab}$ | $0.08_{ab}$ | $0.07_{bc}$ | $0.09_{a}$ | $0.05_{c}$ |

Values in the same raw followed by similar letters are not significant differences at (P≤0.05) in Least Significant Difference (LSD).



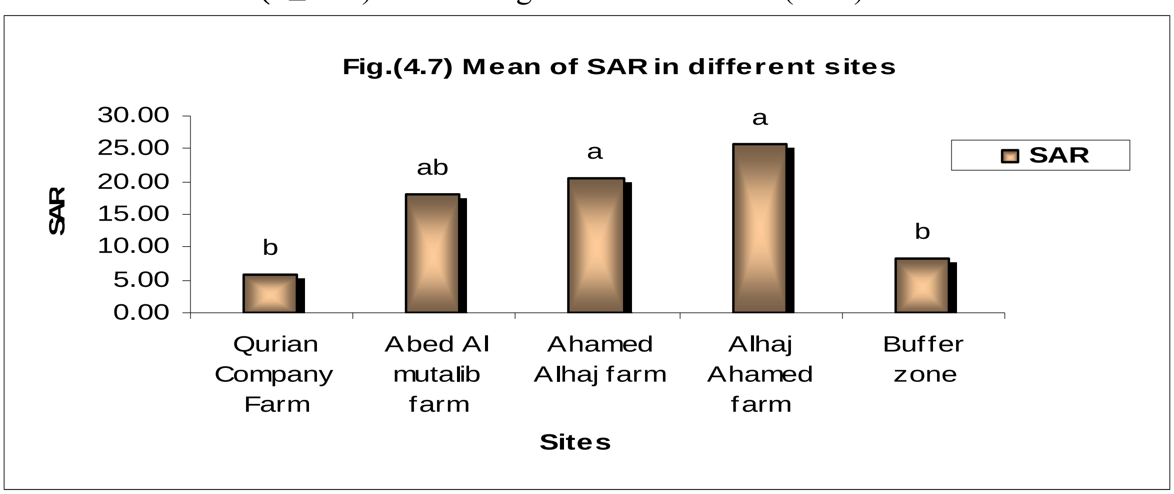
#### 4.1.1.7 Adsorption Ratio (SAR) in different sites and depths:

Result showed that there were no statistical significant differences (P≤0.05), in Sodium Adsorption Ratio (SAR) along depths. The exception is the uncultivated area (control) in depths (0-30), (30-45) where it shows significant difference, the results show no significant difference in (SAR) between Korean Company farm and uncultivated area (control), while the same was observed in Ahamed Alhaj and Alhaj Ahamed farms, where the results show significant difference between them and Abed Al mutaIib farm, (Table 4.16, and Fig.4.7).

Table 4.16: Adsorption Ratio (SAR) in different sites and depths:

| Sites / Depths(cm) | Korean Company farm | Abed Al mutaIib farm | Ahamed Alhaj farm | Alhaj Ahamed farm | Uncultivated area (control) |
|---|---|---|---|---|---|
| 0-30 | $3.96^{b}$ | $13.28^{b}$ | $14.26^{b}$ | $17.37^{b}$ | $9.96^{a}$ |
| 30-45 | $5.94^{ab}$ | $19.84^{ab}$ | $20.59^{ab}$ | $23.59^{ab}$ | $9.62^{b}$ |
| 45-60 | $7.52^{a}$ | $21.16^{a}$ | $26.75^{a}$ | $35.98^{a}$ | $5.22^{a}$ |
| Mean | $5.81_{b}$ | $18.09_{ab}$ | $20.53_{a}$ | $25.65_{a}$ | $8.27_{b}$ |

Values in the same raw followed by similar letters are not significant differences at (P≤0.05) in Least Significant Difference (LSD).



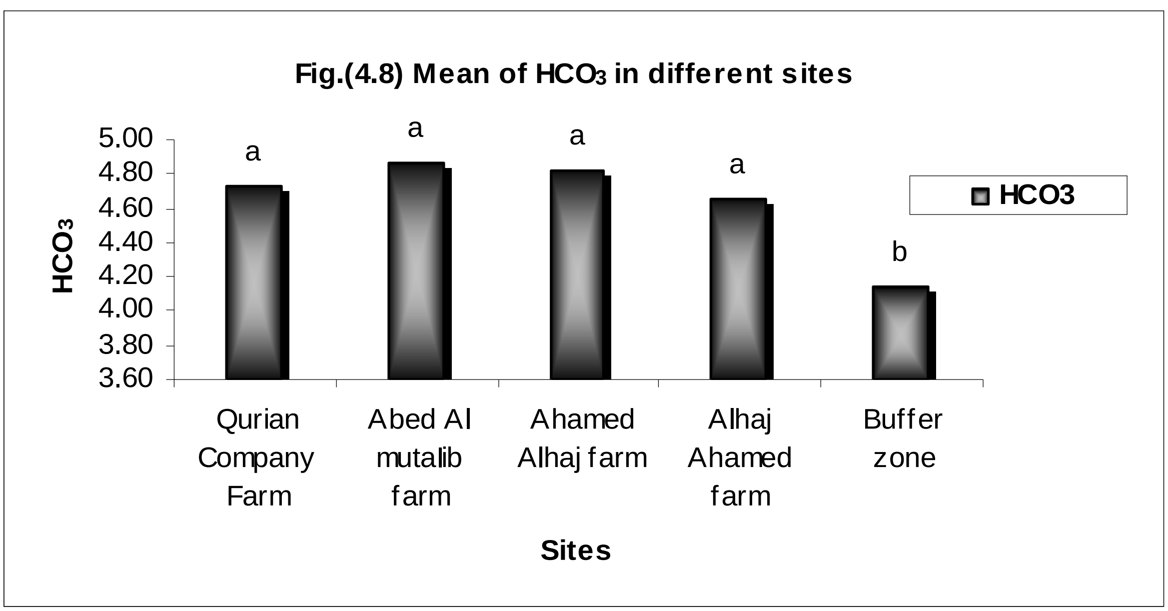
#### 4.1.1.8 Bicarbonate ($HCO_3$) in different sites and depths:

Table 4.17 and Fig. 4.8, showed significant difference of Soil Bicarbonate ($HCO_3$) along depths ($P \leq 0.05$), exception is uncultivated area (control) in depths (0-30), where it shows no significant difference. The results show no significant difference in ($HCO_3$) with in the farms.

Table 4.17: Bicarbonate ($HCO_3$) in different sites and depths**:**

| Sites / Depths(cm) | Korean Company farm | Abed Al mutaIib farm | Ahamed Alhaj farm | Alhaj Ahamed farm | Uncultivated area (control) |
|---|---|---|---|---|---|
| 0-30 | $4.12^{a}$ | $4.63^{a}$ | $5.32^{a}$ | $4.43^{a}$ | $3.67^{b}$ |
| 30-45 | $4.96^{a}$ | $5.04^{a}$ | $5.06^{a}$ | $4.37^{a}$ | $4.36^{a}$ |
| 45-60 | $5.09^{a}$ | $4.91^{a}$ | $4.06^{b}$ | $5.17^{a}$ | $4.40^{a}$ |
| Mean | $4.72_{a}$ | $4.86_{a}$ | $4.81_{a}$ | $4.66_{a}$ | $4.14_{b}$ |

Values in the same raw followed by similar letters are not significant differences at ($P \leq 0.05$) in Least Significant Difference (LSD).



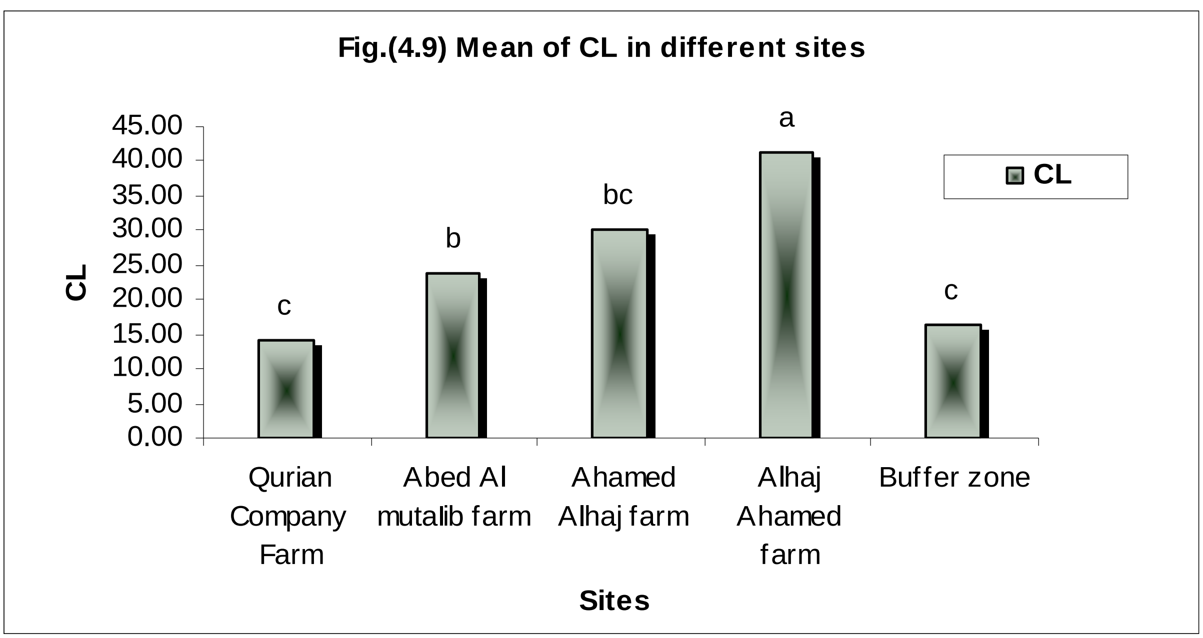
### 4.1.1.9 Cloride (CL) in different sites and depths:

Table 4.18 and Fig. 4.9, showed that CL contents no significant difference along depths (P≤0.05). Also there was no significant difference in CL between Korean Company farm and uncultivated area (control), where the results show significant difference between them and other farms.

Table 4.18: Cloride (CL) in different sites and depths:

| Sites / Depths(cm) | Korean Company farm | Abed Al mutaIib farm | Ahamed Alhaj farm | Alhaj Ahamed farm | Uncultivated area (control) |
|---|---|---|---|---|---|
| 0-30 | $10.86^{b}$ | $22.07^{ab}$ | $15.24^{b}$ | $25.17^{a}$ | $21.90^{a}$ |
| 30-45 | $14.96^{ab}$ | $17.26^{b}$ | $34.68^{a}$ | $34.63^{a}$ | $20.20^{a}$ |
| 45-60 | $16.91^{a}$ | $31.66^{a}$ | $40.64^{a}$ | $64.23^{a}$ | $7.23^{b}$ |
| Mean | $14.24_{c}$ | $23.66_{b}$ | $30.19_{bc}$ | $41.34_{a}$ | $16.44_{c}$ |

Values in the same raw followed by similar letters are not significant differences at (P≤0.05) in Least Significant Difference (LSD).



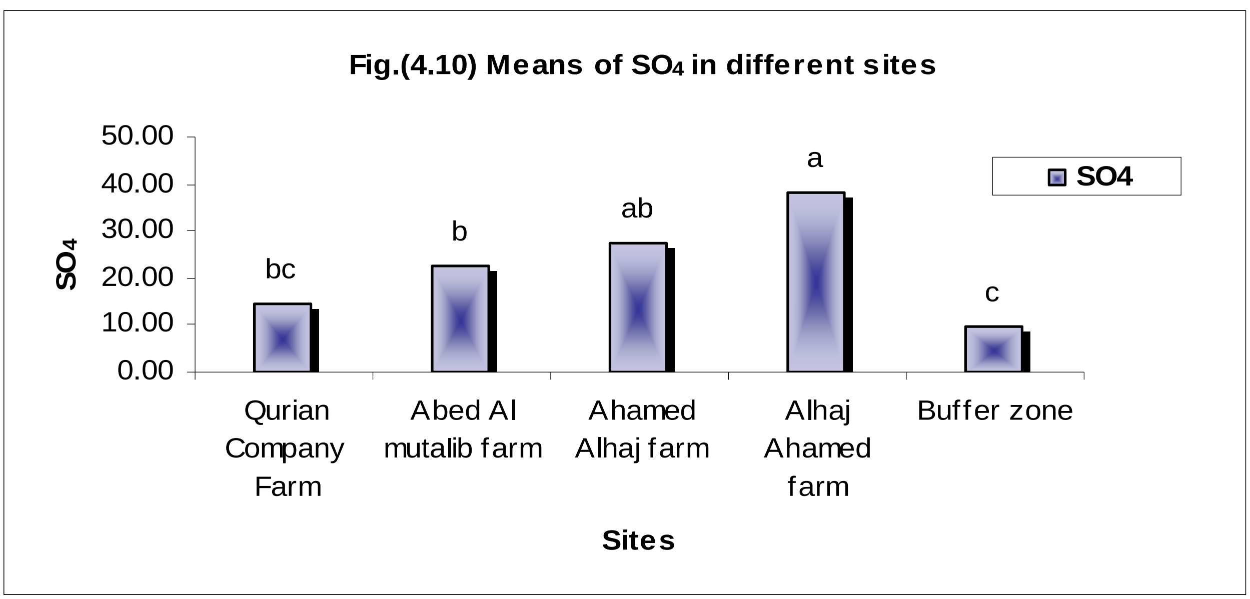
### 4.1.1.10 $SO_4$ in different sites and depths:

$SO_4$ in the soil shows no significant ($P \leq 0.05$), differences along depths, but it shows significant differences among sites (Table 4.19, and Fig 4.10), where Alhaj Ahamed farm recorded the highest value (38.28) and uncultivated area (control) lowest value (9.63).

Table 4.19: $SO_4$ in different sites and depths:

| Sites / Depths(cm) | Korean Company farm | Abed Al mutaIib farm | Ahamed Alhaj farm | Alhaj Ahamed farm | Uncultivated area (control) |
|---|---|---|---|---|---|
| 0-30 | $5.31^{b}$ | $9.60^{b}$ | $12.47^{b}$ | $7.93^{b}$ | $3.87^{b}$ |
| 30-45 | $16.19^{b}$ | $25.66^{b}$ | $30.17^{ab}$ | $17.47^{b}$ | $12.55^{ab}$ |
| 45-60 | $22.70^{a}$ | $32.72^{a}$ | $39.0^{a}$ | $89.43^{a}$ | $12.47^{a}$ |
| Mean | $14.73_{bc}$ | $22.66_{b}$ | $27.21_{ab}$ | $38.28_{a}$ | $9.63_{c}$ |

Values in the same raw followed by similar letters are not significant differences at ($P \leq 0.05$) in Least Significant Difference (LSD).



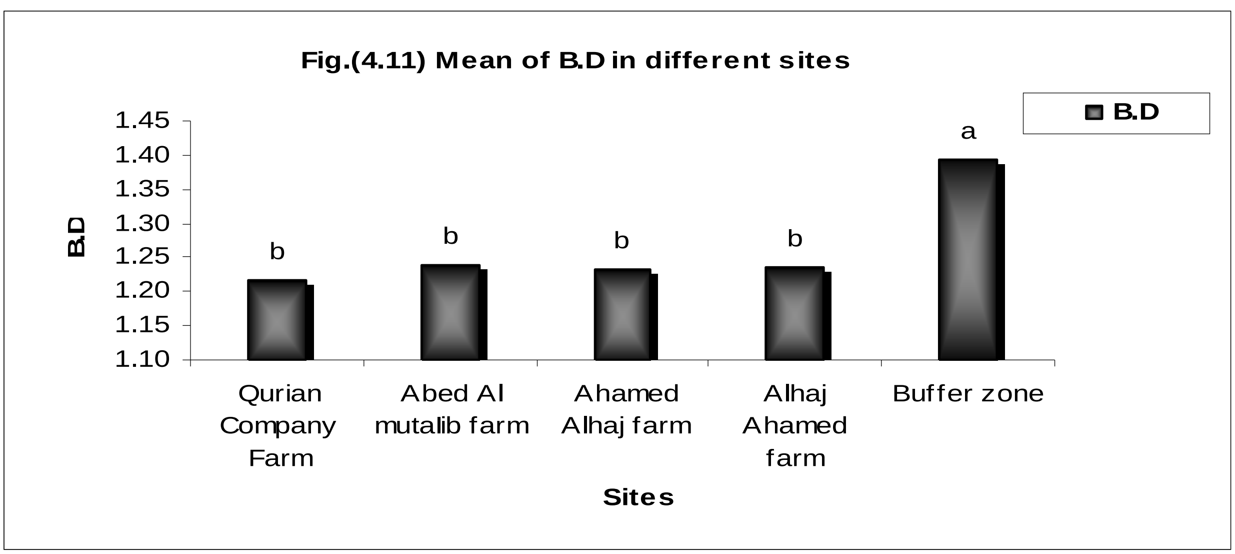
#### 4.1.1.11 Bulk density (B.D) in different sites and depths:

Table 4.20 and Fig. 4.11, showed no significant difference in Soil bulk density (B.D) along depths (P≤0.05), with the exception of uncultivated area (control) where it shows significant difference in all depths. The result shows no significant difference in B.D between farms, but they were significantly difference between them and uncultivated area (control).

Table 4.20: bulk density (B.D) in different sites and depths:

| sites / Depths(cm) | Korean Company farm | Abed Al mutaIib farm | Ahamed Alhaj farm | Alhaj Ahamed farm | Uncultivated area (control) |
|---|---|---|---|---|---|
| 0-30 | $1.21^{b}$ | $1.22^{b}$ | $1.25^{b}$ | $1.26^{b}$ | $1.39^{a}$ |
| 30-45 | $1.23^{b}$ | $1.24^{b}$ | $1.23^{b}$ | $1.23^{b}$ | $1.39^{a}$ |
| 45-60 | $1.21^{b}$ | $1.26^{b}$ | $1.22^{b}$ | $1.22^{b}$ | $1.40^{a}$ |
| Mean | $1.22_{b}$ | $1.24_{b}$ | $1.23_{b}$ | $1.24_{b}$ | $1.39_{a}$ |

Values in the same raw followed by similar letters are not significant differences at (P≤0.05) in Least Significant Difference (LSD).



### 4.1.1.12 Cation Exchange Capacity (CEC) in different sites and depths:

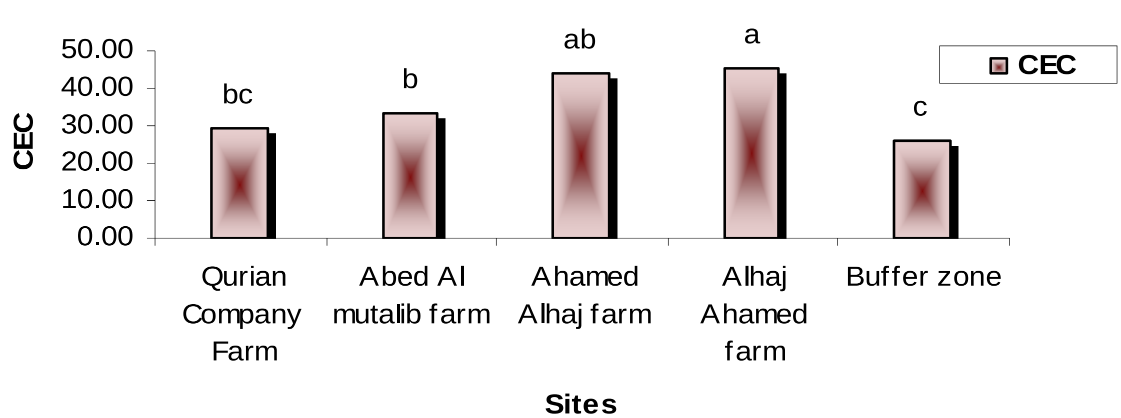
Result showed that CEC varied significant difference (P≤0.05), between sites, where it shows no significant difference in depths (30-45), (45-60). But shows significant difference in Ahamed Alhaj and Alhaj Ahamed farm in depths (0-30). When Alhaj Ahamed farm recorded the highest value (45.31) and the uncultivated area (control) lowest value (25.75), (Table 4.21, and Fig 4.12).

Table 4.21: Cation Exchange Capacity CEC in different sites and depths:

| Sites / Depths(cm) | Korean Company farm | Abed Al mutaIib farm | Ahamed Alhaj farm | Alhaj Ahamed farm | Uncultivated area (control) |
|---|---|---|---|---|---|
| 0-30 | $29.07^{a}$ | $33.90^{a}$ | $39.02^{b}$ | $32.17^{c}$ | $25.69^{a}$ |
| 30-45 | $28.21^{a}$ | $33.20^{a}$ | $42.02^{ab}$ | $42.15^{ab}$ | $26.38^{a}$ |
| 45-60 | $30.58^{a}$ | $33.45^{a}$ | $50.07^{a}$ | $61.60^{a}$ | $25.17^{a}$ |
| Mean | $29.29_{bc}$ | $33.52_{b}$ | $43.70_{ab}$ | $45.31_{a}$ | $25.75_{c}$ |

Values in the same raw followed by similar letters are not significant differences at (P≤0.05) in Least Significant Difference (LSD)

Fig.(4.12) Mean of CEC in different sites



### 4.1.2 Physical Characteristics:

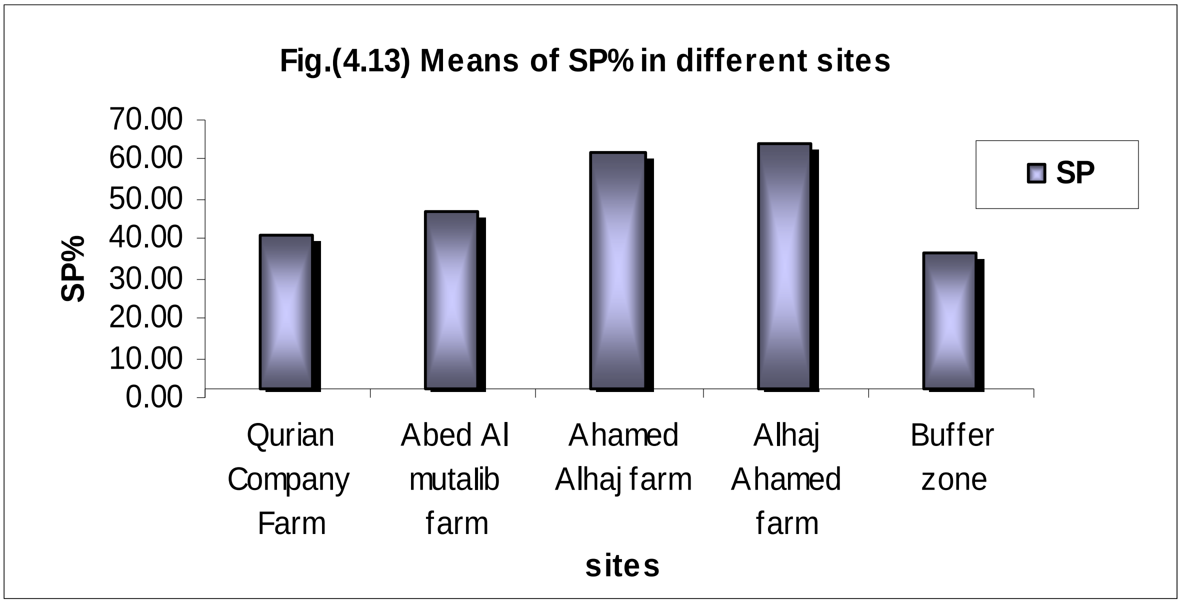
#### 4.1.2.1 Saturation Percentage (SP) in different sites and depths:

Statistically there was no significant difference found in Saturation Percentage (SP) in the soil along depths, but exception is uncultivated area (control), where it shows significant difference ($P \leq 0.05$) in all depths, however the results show no significant difference in SP between Korean Company and Abed Al mutaIib farms, the same was observed in Ahamed Alhaj and Alhaj Ahamed farms, where the results show significant difference between them and uncultivated area (control), (Table 4.22, and Fig.4.13).

Table 4.22: Saturation Percentage (SP) in different sites and depths:

| Sites / Depths(cm) | Korean Company farm | Abed Al mutaIib farm | Ahamed Alhaj farm | Alhaj Ahamed farm | Uncultivated area (control) |
|---|---|---|---|---|---|
| 0-30 | $40.86^{a}$ | $47.94^{a}$ | $55.62^{a}$ | $48.52^{a}$ | $36.79^{c}$ |
| 30-45 | $38.91^{a}$ | $46.03^{a}$ | $59.62^{a}$ | $59.32^{a}$ | $37.54^{b}$ |
| 45-60 | $43.03^{a}$ | $47.50^{a}$ | $71.01^{a}$ | $84.31^{a}$ | $35.86^{a}$ |
| Mean | $40.93_{b}$ | $47.16_{b}$ | $62.08_{a}$ | $64.05_{a}$ | $36.73_{d}$ |

Values in the same raw followed by similar letters are not significant differences at ($P \leq 0.05$) in Least Significant Difference (LSD).




### 4.1.2.2 Soil particle size distribution in different sites and depths:

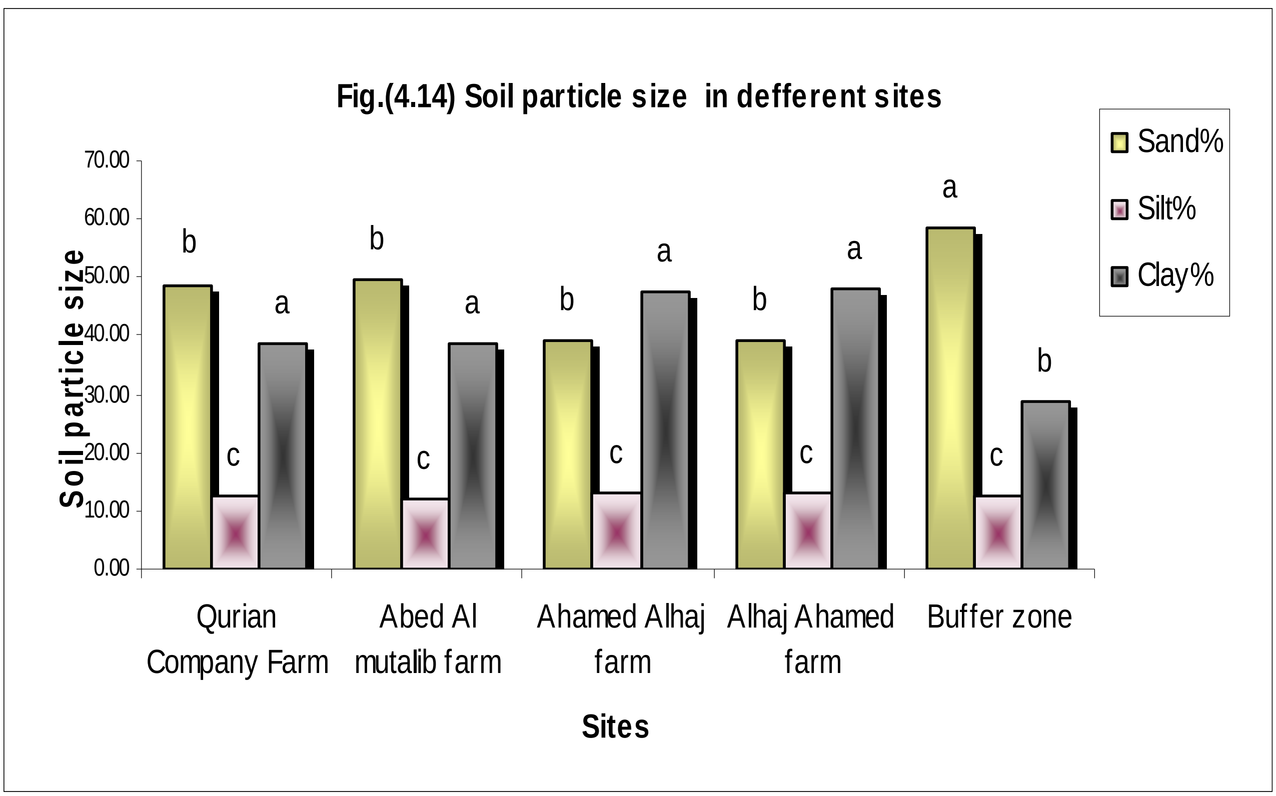
Soil texture in the study area ranged between Clay loam and Clay content, with significant difference along depths, but exception is the uncultivated area (control), which shows no significant difference along depths, nonetheless the result shows no significant difference in soil texture between farms (Table 4.23, and Fig. 4.14).

Table 4.23: Soil particle size distribution in different sites and depths:

| Sites | Soil depth(cm) | Sand% | Silt% | Clay% | Soil Texture |
|---|---|---|---|---|---|
| Korean Company farm | 0-30 | 48.32b | 13.07a | 38.61a | Clay loam |
| | 30-45 | 48.05b | 12.20b | 39.75a | Clay loam |
| | 45-60 | 49.92a | 11.79c | 38.29b | Clay loam |
| | **Mean** | 48.76b | 12.35c | 38.88a | |
| Abed Al mutaIib farm | 0-30 | 49.39a | 12.92a | 37.69a | Clay loam |
| | 30-45 | 47.07b | 12.82a | 40.11a | Clay loam |
| | 45-60 | 52.27a | 10.30b | 37.43b | Clay loam |
| | **Mean** | 49.58b | 12.01c | 38.41a | |

| | | | | | |
|---|---|---|---|---|---|
| Ahamed Alhaj farm | 0-30 | 43.41a | 12.91a | 43.68c | Clay |
| | 30-45 | 40.26a | 13.18a | 46.55b | Clay |
| | 45-60 | 34.41b | 13.08a | 52.51a | Clay |
| | **Mean** | 39.36b | 13.06c | 47.58a | |
| Alhaj Ahamed farm | 0-30 | 50.77a | 13.32a | 35.91c | Clay loam |
| | 30-45 | 39.78b | 13.02a | 47.20b | Clay |
| | 45-60 | 26.22c | 12.94b | 60.84a | Clay |
| | **Mean** | 38.92b | 13.09c | 47.98a | |
| Uncultivated area (control) | 0-30 | 58.28a | 12.45a | 29.27a | Clay loam |
| | 30-45 | 57.98a | 12.48a | 29.49a | Clay loam |
| | 45-60 | 59.58a | 12.32a | 28.11a | Clay loam |
| | **Mean** | 58.61a | 12.42c | 28.96b | |

Values in the same raw followed by similar letters are not significant differences at (P≤0.05) in Least Significant Difference (LSD)



## 4.2 Water Characteristics:

Table (4.24) shows the water quality in different farms of the study area. The EC value shows no significant difference between Ahamed Alhaj and Alhaj Ahamed farms but shows they were statistically significant difference between them, particularly in Alhaj Ahamed farm, which recorded the maximum value 0.530 while Abed Al mutaIib farm reflected the minimum value of EC 0.266 Fig (4.15).

Table (4.24): Water EC, pH, SAR, RSC in farm of the study area:

| Farm | EC dS/m | pH | SAR | RSC |
|---|---|---|---|---|
| Korean Company farm | $0.456_{b}$ | $6.823_{b}$ | $4.170_{b}$ | $1.533_{c}$ |
| Abed Al mutaIib farm | $0.266_{c}$ | $7.083_{a}$ | $4.616_{a}$ | $2.000_{b}$ |
| Ahamed Alhaj farm | $0.523_{a}$ | $7.066_{a}$ | $4.510_{a}$ | $2.233_{b}$ |
| Alhaj Ahamed farm | $0.530_{a}$ | $7.103_{a}$ | $3.770_{c}$ | $2.600_{a}$ |

Values in the same column followed by similar letters are not significant differences at ($P \leq 0.05$) in Least Significant Difference (LSD).

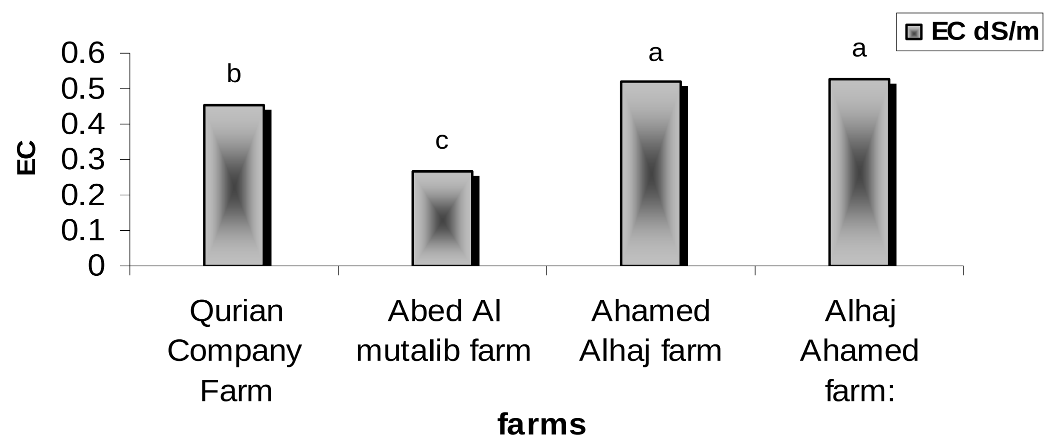



**Fig.(4.15 ) The water ECdS/m in the farms of the study area**

The results of this study revealed that the pH value showed no significant difference among the studied sites, however Korean Company farm shows significant difference, where the highest value (7.103) was recorded in Alhaj Ahamed farm and the lowest value (6.823) in Korean Company farm (Table 4.25, and Fig. 4.16).

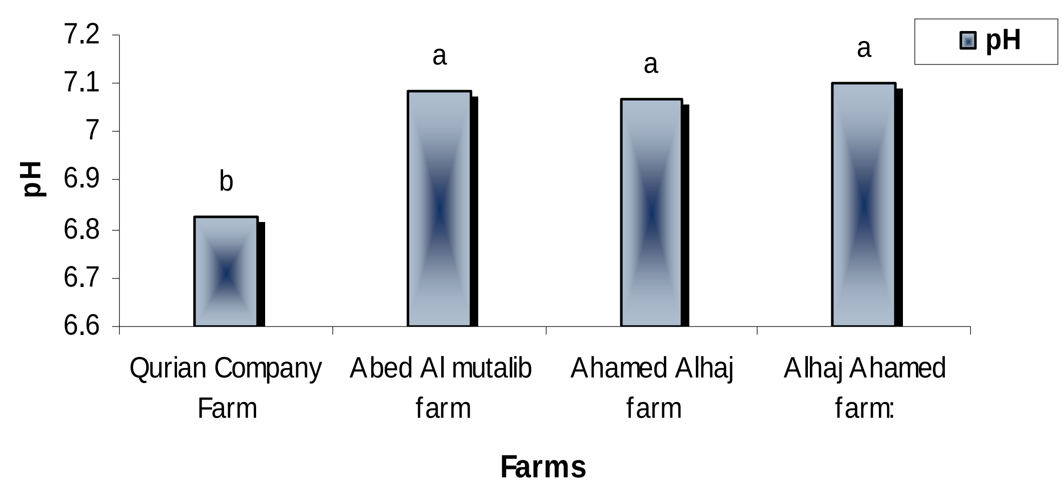
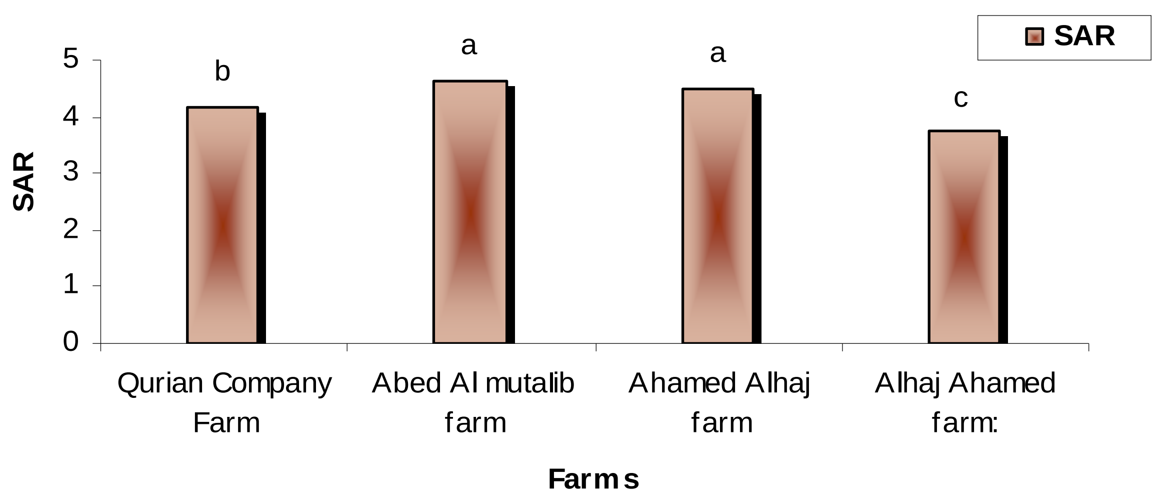



**Fig.(4.16 ) The water pH in the farms of the study area**

Statically they show no significant difference between Ahamed Alhaj and Abed Al mutaIib farms but shows significant difference between them and other sites of the study area, where the highest value (4.616) was recorded in Abed Al mutaIib farm and the lowest value (3.770) in Alhaj Ahamed farm (Table 4.25, and Fig. 4.17).

Fig.(4.17 ) The water SAR in the farms of the study area




The results of this study revealed that the RSC value shows no significant difference between Abed Al mutaIib and Ahamed Alhaj farms but they were significantly different between farms in study area, the highest value (2.600) was recorded in Alhaj Ahamed farm and the lowest value (1.233) in Korean Company farm (Table 4.25, and Fig. 4.18).

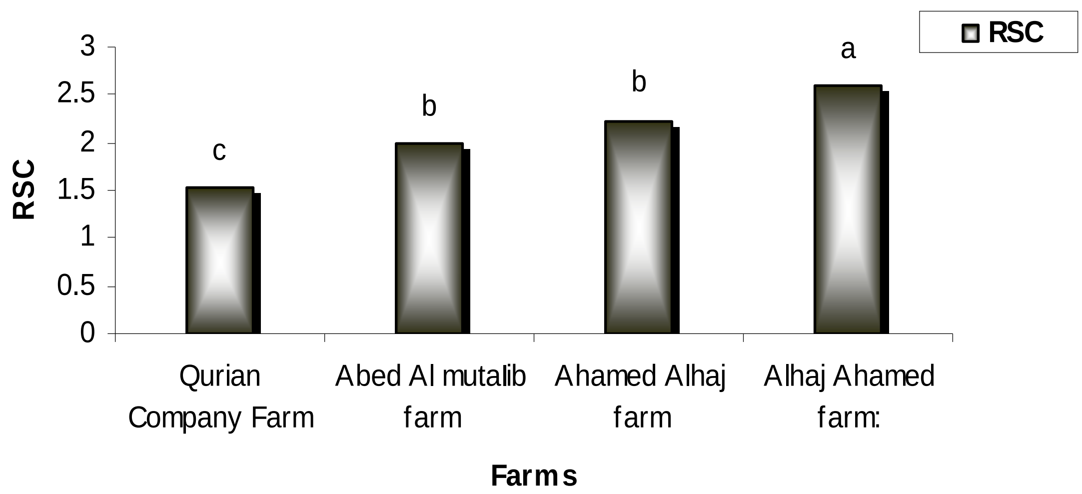



Fig.(4.18 ) The water RSC in the farms of the study area

# CHAPTER FIVE

# Discussion

## 5.1 Effects of land use on soil characteristics:

Soil quality depends on a large number of chemical, physical, biological and biochemical prosperities and its characterization requires selection of the propensities most sensitive to changes in management and land use pattern practices. The capacity of a soil to function within ecosystem boundaries is to sustain biological productivity, maintain environmental quality including promotion of plant and animal conditions. However, water deficit is the main factor behind declining productivity, unsustainable farming and development in the areas depending on ground water. It was obvious from the results obtained that a significant change has been observed among the sites with regard to the soil saturation percentage (SP), where the lowest values of SP were recorded in uncultivated area (control). These changes are reflecting the effect of land use practices in the study area.

Analysis of the collected soil samples from the study area showed that salinity ECe ranged between 2.04 in Korean Company farm and 4.82 in Abd Almutalib farm (0-30cm) depth, 3.67 in Korean Company farm to 6.89 in Ahmed Alhaj farm (30-45cm) depth, to 15.91 in Alhaj Ahmed farm (45-60cm) depth, which indicated high salinity in Alhaj Ahmed farm (table 4.6). FAO (2006) reported that ECe <0.75 none saline, ECe 0.72-2 slightly saline, ECe 2-4 moderately saline, ECe 4-8 strongly saline, ECe 8-15 very strongly saline and ECe >15 extremely saline. The adverse human activities cause increase of salinity in the soil, and this may be attributed to irrigation method used.

The results showed that the decrease in salt content in Korean Company farm and could be attributed to the system of irrigation used (central pivot). The findings reflected a very strongly saline (8.47) in Alhaj Ahmed farm and moderately saline (3.04) in uncultivated area (control).

The high values of pH, SAR, ESP indicate the increase in sodicity according to Richards, (1954). The maximum and minimum values ranged between (7.66- 8.01), (5.81-25.65) and (26.29- 7.60) respectively. The results showed the increased ESP in Alhaj Ahamed farm, could be due to the increase amount of Residual Sodium Carbonate (RSC) in irrigation water. Eaton (1949) reported that the increased amount of RSC, in irrigation water would accelerate the development of sodic soils.

The results of analysis showed that the bulk density value (B.D) ranged between 1.39 in uncultivated area (control) to 1.22 in Korean Company farm. FAO, (2006) reported that low bulk density generally indicates fair soil quality and ecosystem function, and high bulk density values indicates a poorer environment for root growth, in this context the proper land use could improve the soil bulk density.

Soil texture is one of the most important characteristic which influences the physical properties of the soil and has great significance to land use and management. The results obtained in this study indicated that the texture of study areas ranges between Clay loam to clay. Nonetheless, it was observed that the uncultivated area (control) showed increase of sand and decrease of silt and clay, which indicated that the area of the uncultivated area (control) affected by sand encroachment. The land use impact protected the quantity of clay content in the cultivated area, while the clay content decreased in the uncultivated area (control). This was indicated in table (4.9)

## 5.2 Water characteristic:

### 5.2.1. Indicators of water quality for irrigation:

The indicators used for appraising the quality of irrigation water are:

-The Electrical Conductivity (EC), which is indicative of the salinity hazard,

-Sodium Adsorption Ratio (SAR), which is indicative of the sodicity hazard

-the Residual Sodium Carbonate (RSC), which is indicative of the carbonate hazard and concentration of phototoxic element, e.g. boron Richards, (1954).

The low level of EC recorded from water sample collected from the study area indicated that the water is highly suitable for irrigation in all farms, where the values of EC ranged between (0.2 dS/m - 0.5 dS/m). Ayers and Westcot, (1985) reported that the degree of restriction on use of water for irrigation, is where the water EC is more than 3.0 dS/m defined as a severe degree for irrigation, and between 0.7-3 dS/m is a normal range for irrigation.

The water reaction (pH) of the study area ranged from 7.1 to 6.8, which indicates that the water quality is suitable for irrigation.

Water Sodium Adsorption Ratio (SAR), is suitable for irrigation in all farms, where the values of SAR ranged between (4.1 - 3.7) indicated that the water quality is suitable for irrigation.

The high level of water Residual Sodium Carbonate (RSC) obtained from water sample of the study area indicated that the water is not suitable for irrigation in Alhaj Ahamed farm (2.600) and marginal in others farms. Eaton (1949) reported that if $RSC > 2.5$ the water is not suitable for irrigation, if $1.25 < RSC > 2.5$ it is considered as marginal and if $RSC < 1.25$ it is probably safe for irrigation.

Al though relatively high RSC tends to develop high alkalinity, but sodium is not toxic to most crops except at very high concentration. The sodium damage usually manifests itself in the destruction of soil structure, with the consequent lowering of permeability.

**5.2.2. Indicators of water quality for drinking:**

Drinking water, vital to life as if may be, is subject to chemical and microbial contamination. Thus it could be a real health hazard.

Water is said to be potable when its general physical characteristics are acceptable by the average consumer. Hassan, (1986).

Table (5.1) shows the levels of, magnesium, calcium, sulphate, chloride, zinc and Total dissolved salt in all farms. It was observed that the result within the permissible range recommended by WHO (1984). Moreover, WHO reported that the water supply to be used for human or animal drinking should fall in the following limits:

| | |
|---|---|
| Total dissolved salt | 1500 p.p.m |
| Sulphates | 750 p.p.m |
| Chlorides | 600 p.p.m |
| Nitrates as $No_3$ | 221 p.p.m |
| Fluorides | 2 p.p.m |
| Magnesium | 180 p.p.m |
| Calcium | 200 p.p.m |
| Zinc | 20 p.p.m |

**Table (5.1): Water, T.D.S, $SO_4$, CL, NO3, F, Mg, Ca, and Zn in parts per million (ppm) in farms of the study area**:

| **Farm** | T.D.S | Sulphate | Chloride | Nitrate | Fluoride | Magnesium | Calcium | Zinc |
|---|---|---|---|---|---|---|---|---|
| Korean Company farm | 350 | 520 | 490 | 150 | 1.1 | 150 | 180 | 13 |
| Abed Al mutaIib farm | 203 | 460 | 380 | 110 | 0.9 | 110 | 160 | 17 |
| Ahamed Alhaj farm | 500 | 610 | 510 | 99 | 1.8 | 130 | 114 | 9 |
| Alhaj Ahamed farm | 500 | 600 | 320 | 180 | 1.5 | 98 | 109 | 12 |

# Conclusion and Recommendations

## Conclusion:

- The land use practices in the study area consisted of fodder Sorghum (Abu Sabein) production, in addition to that they cultivate vegetables for self consumption in small areas, and consequently fodder Sorghum impoverishes soil nutrients.
- The nitrogen in these soils is low and in turn affects the organic matter content, which changes the moisture regimes. Generally the organic carbon in these soils is low ranging between 0.42 to 0.05 percent as has been mentioned in previous few studies. In the same time the land users are not adding any mineral fertilizers or manure to soil, in order to improve the nutrients status. In this context the diversity of crops in rotation lead to diverse soil flora and fauna, as the roots excrete different organic substances that attract different types of bacteria and fungi, which in turn play an important role in transformation of these substances into plant available nutrients. Hence irrigation water is mainly under ground water, which differs from the surface water.
- The results showed that most desertification indicators of land degradation are prevailing in the study area. According to the results of this study on soil types and impact of land use, it concluded that the soil is saline soil, and its texture varying from clay to clay loam content in the study area.
- The result showed decrease of sand in cultivated area. Therefore, the adopted land use practices led to the protection of the area from sand encroachment, and improved the soil bulk density. But the improper land use pattern causes increase of salinity and sodicity,

which emphasized mismanagement of land and resulted in land degradation.

- The increased amount of Residual Sodium Carbonate (RSC), in irrigation water in Alhaj Ahamed farm would accelerate the development of sodic pockets in the soils.
- Land use pattern in private farms is similar to the traditional agriculture, by adopting single crop cultivation. The farms holders are targeting the benefit from fodder crops rather than to risk for other crops.

**Recommendations:**

1- It is recommended to reduce the salinity through the following:

- Construction of effective irrigation system that will guarantee the protection from water logging and salinization.
- Decrease upward movement of soluble salts by adopt suitable irrigation techniques to ensure none development of secondary salinization.
- Introduce deep plough to improve the soil drainage.

2- Reduction of sodicity through the following:

- Reduction of exchangeable sodium, by leaching and addition of manure or compost besides deep ploughing.
- The use of mineral fertilizers such as gypsum, calcium chloride and biological compounds.

3- Introduction animal in the farms to, benefit from their manure for improvement soil properties.

4- A proper rotation should be followed, if the irrigation water is available.

5- Application of appropriate techniques such as water conservation and water harvesting techniques, during a good rainy season.

6- Planting of wind breaks and shelter belts.

# References


Abdalla, A.A. (1998). Agroforestry for Combating Desertification. M.Sc. Thesis University of Gezira, Sudan.

Abdalla, M.A; Salih, E, M. and Hussein, A.O. (2004). A proposed Plan of Action for Scientific Research on Desertification: Khartoum State. Proceedings of the National Forum of Scientific Research on Desertification in the Sudan. ALsharga Hall, University of Khartoum, Khartoum, Sudan 16-18 March 2004.

American Soil Taxonomy, (1975). Soil classification.

Abu Suwar, A.; Baashar, M. and ELShinnawi, M. (2002), Pan- Arab integration in forage production and processing. AOAD, Khartoum.

Abu Suwar, A. O. and Darrag, A. (2004). Strategy and Methodology of Research on Desertification in the Sudan: Range Sector. Proceedings of the National Forum of Scientific Research on Desertification in the Sudan. ALSharga Hall, University of Khartoum, Khartoum, Sudan 16-18 March 2004.

AOAD, (2001).Arab Organization for Agriculture Development .In conservation Of Natural Parks and protected Areas in Arab region Lamaddalina, Sardinia, Italy.

Atta. ELMoula, M.E. (1985). On the problem of Resources Management in the Sudan. Environmental Monograph series, No. 4. General Editor: Dr. Mahadi Amin ELtom. Institute of Environmental Studies, University of Khartoum.

Ayoub, A.T. (1998),"Extent, severely and causative factors of land Degradation in the Sudan”, Journal of Arid Environment, No.38, pp.397.409.

Ayers, R.S. and Westcot, D.W. (1985). Water quality for agriculture irrigation and drainage paper 29. Rev.1. FAO;Rome. 174 p

Baumer, M.C. and Tahara, T., (1979). Ecological Management of Arid and Semi arid Range lands. Report of amission to the Sudan 14 May -22 June 1979. FAO, FAO/UNEP EMASAR/ Phase 11Project.

Black, C.A.; Evans, D.D., Ensminger, T.L and Clark, F.E. (1965). Methods of Soil Analysis are (part1). Agronomy Monograph. No. 9. American Society of agronomy, Inc., Madison, Wiscon. USA.

Blake, G. R. and Hartge, K. H., (1986).Bulk density. p. *363-375*. In: A.Klute et al.(ed.) Methods of soil analysis: Part 1: Physical and Mineralogical Methods. Monograph Number9 (Second Edition).ASA,Madison.WI.

Borsani, O.;Valpuesta,V.and Botella,M.A.(2003).Developing salt tolerant Plant in areas century .A molecular biology approach .Plant Cell. Tissue and Organ Culture 40 (2) 101-115.

Brown, G. A.C.; Newman, J. H.; Rayner and Weir, A. H. (1977).In 'The Chemistry of Soil Constitutions" D.J. Greenland & M.H.B. Hayes (eds.), chapter 2, 29-163.

Buraymah, I .M. and Dawood, H. A (1984). Workshop on Development on Natural Resources in Gedaref Area. Gedaref.

Cheng, K. L., and Bray, R.H. (1951). Determination of Calcium and Magnesium in Soil and Plant Material. *Soil. Sci*.72:449-458.

Cooke, K., (1944). The Red Sea Hills. In: Sudan Government Soil Conservation Committees Report. Khartoum: Mc Corquodale and Co. (Sudan) 174pp.

DECARP, (1976a). Sudan's Desert Encroachment Control and Rehabilitation Programmer. The General Adm. for Natural Resources and the Agr. Res Council, National Council for Res. In Coll. With UNEP, UNDP and FAO, 229pp.

Dregene, H.E., (1986).Desertification of Arid Lands. In : Physics Of Desertification .EL- Baz,F. and Hassan M.H .A .(eds).the Nether lads :Martinus, Nijoff.P 435-473.

Dregene,H.E.,(1991).DesertificationCost:Land damage and rehabilitation. Lubbock .International Centre For Arid and Semiarid Land Studies, Texas Tech.University31.

Eaton, F.M. (1949). Significance of Carbonates in Irrigation Water. *Soil SCi*.60:123-133.

El Hassan, A.A., Mohamed Osman .H.M.H and Mohammed, S.I. (2005) Rain-fed Agriculture and Climate and Weather Information with Special Reference to Rainfall and Yield .Khartoum may/2005.

El Mahi, A. G, (2004). Forest Policy Statement Principles. Values and Issues Underlining the Forest Policy. Issue Paper. TCPSUD 2903 Revision of Forest Policy, Legelisation and Institutional Reorganization.

El Sammani, M.O.,(1986) Environmental and Developmental Issues in Project Design in Combating Desertification , (Unpublished paper).

El Sammani, M.O., (1989) Rehabilitation Alternatives for pastoral Population in the Sudan.

El Tom, O.A. (1973). Semi – detailed Soil Survey of South Khartoum area. Soil Survey Dept., Ministry of Agric., Sudan.

Fadul, H. M. (1998).Review on drought and desertification in Sudan.

Fadul,.H.M. and Gani.M.E.(2000).Soil degradation and fertility restoration in the dry land. Symposium on Development challenges in Dry land, program and abstracts, under auspices of H.E:EB .Taha Minister Of Higher Education and Scientific Research .Al Shahid El Zubir Center .June 2000. Khartoum.19-20.

FAO/UNEP,(1984).Map of Desertification Hazards: explanatory note. Nairobi, Kenya: United Nations Environment Programmer.

FAO. (1988). Salt-affected soil and their management. Soils Bulletin No. 39.Rome.

FAO (1994).Farming System Development and Soil Conservation.

FAO.(2006) .Guidelines for soil description (fourth edition) .

Farah, S. M. (2000). The role of cultural practices on the control of desertification and land degradation under rainfed agriculture in Sudan. Proceedings of the workshop on the role of ARC on combating Desertification and land Degradation in Sudan , 18th Sept, Khartoum Sudan.

Goda, S., (1977). Plantation forestry in the Sudan. Sudan Silva 22:58-68.

Gomez, A.and Gomez, A.A.(1984).Statistical Procedures for Agricultural Research (2nd ed.) John Willy and Sons.pp 97-107.

Grainger, A., (1990). The threading desert. Earthscan, London.

Harrison, M.N.and. Jackson, J. K., (1958). Ecological classification of the vegetation of Sudan. Forest Bulletin No. 2, Khartoum and the Vegetation Map of Sudan printed by Sudan Survey Dept., Khartoum, Topo No. *5*. *625- 640*.

Hassan,K.Y.,(1986).Chemical composition of drinking water in U.A.E.M.Sc. Thesis, Faculty of Agriculture, University of Khartoum.

Ibrahim, F., (1988). Desertification processes at the frontier of the Rainfed Area of the Sudan and Tunisia. In Resource Conservation and Desertification Control in the Near East. Report of the International Training.

Koohafkan, P.A.,(may.1996). Desertification drought and their consequences. F.A.O Home Pages, http://WWWFAO:SDD mansions: Environmental.Convention.and.Agreements.ht

Lamprey, H.F. (1975). Report on the desert en croachment reconnaissance in northern Sudan, 21st October to10 November 1975, UNESCO/ UNEp, mimoeo, *16pp*.

Lean, G. (1995). Down to Earth. Published by the centre for our Common Future in collaboration with Interim Secretariat for the Convention to Combat Desertification, 32PP.

Lebon, J. H.,( 1965) land use in the Sudan, Geographical publication limited, Bude, Cornwall,.

McCoy, C.P. (1987). Characterization of alfalfa (Medicago satival).Plant regenerated from selected Na Cl –tolerant cell lines. Plant Cell Retorts 6.31-34.

Mustafa, H., ELgoni, M.A. and Idris, M. (2000) Manual for Range Management and Improvement. Dry land Husbandry Project, Sudan 2000.

Nachtengaele, F.O.F. (1976). Studies on Saline and Sodic Soil in Sudan Soil Survey Adm.Wad Medani. Technical Bulletin NO. 24.

Olsson, G.W., (1981).Soil and the Environment: A guide to soil surveys and Application .Chapman and Hall, New York, N.Y.200pp.

Osman, H.M., (2005).Land reclamation and rural Development: policies strategies and practices in Sudan.

RAP, (1990). Range and Pasture Administration Report, 1990. R.A.P., Khartoum.

RAP, (1993). Range Reseeding Programmer annual Report, Range and Pasture Administration. Khartoum.

Reitemeier, R.F.,(1943). Semi Micro Analysis of Saline Soil Solutions. Indus and Engine. Chem., Analyst. Ed.15:393-402 illus.

Rhodes, J .D. (1990).Soil Salinity: causes and control. In: Goude A.S.(Ed.)Techniques for Desert Reclamation *pp.109-129*.John Wiley Sors. 217pp

Rible, J. M. and Quick, J. (1960). Method S-19.0. In: Water soil plant tissue. Tentative methods of analysis for diagnostic purposes. Davis, University of California Agricultural Experiment Service. Mimeographed Report.

Richards, A. (1954). Diagnosis and Improvement of saline and alkali soils. Hand book60. USDA.

Saeed A.M. (1969). The soils of Khartoum District .The Agricultural Magazine, 10.28-31.

Salih .E. M. (1996). The Geographical Extent of desertification in Sudan. ALBuHUTH J. vol. 5 pp. 18-33.

Salih .E. M. (2005).Application of Remote Sensing and GIS for Monitoring the Desert Margin Zone in Sudan. Regional Workshop Scientific Research and National Research Plans for Combating Desertification. UNESCO chair of Desertification, Sudan.

SAS. (1994). JMP Statistical and Graphics Guide. Version 3. SAS Institute, Cary, North Carolina.

Soil Survey Admin. (SSA),(1976).Report, Soils of Sudan.

Spooner,R.,(1989). Desertification: The Historical significance .In: Africa foods systems in crisis. Part one: micro perspective. Hess Ashmore and Katz. S.O (eds). Gordon and Breach, New York, P.111-162.

Stebbing,E.P., (1953) .The Creeping Desert in the Sudan and Elsewhere in Africa ,Mc Corquodale & Company (Sudan ) LTD.

UNCCD,(1994).United Nations Convention to Combat Desertification in Those Countries Experiencing Serious Drought and /or Desertification, particularly in Africa.

UNCED, (1992). Agenda 21: Programmer of Action for Sustainable Development. Rio de Janerio, United nations.

UNEP,(1977).United Nations Environment Program,29 Aug11st -9 September1977.World map of Desertification at scale of 1:25.00.000 A/CONE.14/2 prepared by FAO,UNESCO and WMO.

UNEP/ISRIC (GLASOD), (1990) World Map of Status of Human-induced Soil Degradation. Nairobi: UNEP.

U.S. Salinity Laboratory Staff. (1954). pH reading of saturated soil paste. p. 102. In: L. A. Richards (ed.) Diagnosis and improvement of saline and alkali soils. USDA Agricultural Handbook 60. U.S. Government Printing Office, Washington, D.C.

U.S. Salinity Laboratory Staff.(1954). Choice of determinations and interpretation of data. p. 26. In: L. A. Richards (ed.) Diagnosis and improvement of saline and alkali soils. USDA Agric. Handb. 60. U.S. Government Printing Office, Washington, D.C.

WHO, (1984).Chemical and Physical Aspects and Microbiological Aspects. Guidelines for drinking water.1:19, 53, 79.

Wilcox, (1951).A method for calculating the saturation percentage from the weight of a known volume of saturated soil paste. *Soil Sci.* 72: 233- 237. illus.

Williams, M.A.and Adamson, D.(1976).The origin of the soil between the Blue and White Nile Rivers. Central Sudan, with some agricultural and climatologically implication. Economic and Social Research Council, National Council for Research, Khartoum.

Worral, G.A. (1957a).Features of some semi-arid soil in the district of Khartoum, Sudan.1. The high level dark clays of *Soil Sci.* 8.pp 193-302.

World Bank, (2001). Reaching the Rural Poor.

Younis, M.G.A., (1977).A study of the Effect of well waters on some physical chemical and physical properties of El –Rawakib soils.

Younis, M.G.A., (1985). Emirates and Sudan investment CO.LTD. Agricultural Scheme, Jubel Aulia – Khartoum province, VOL (1)

## المراجـع العـربيـة


المنظمة العربية للتنمية الزراعية ، البرنامج الوطني لمكافحة التصحر في جمهورية السودان ، الخرطوم ابريل ، 2002.

المنظمة العربية للتنمية الزراعية، مشروع منطقة جنوب الخرطوم – جمهورية السودان الديمقراطية, دراسة الجدوى الفنية والاقتصادية لاستصلاح الأراضي المتأثرة بالملوحة والقلوية والنهوض بإنتاجيتها, الخرطوم 1974.

صلاح الدين عبد الله العبيد، حالة التصحر في السودان، ورقة مقدمة إلي الدورة التدريبية حول تنمية الموارد البشرية وبناء القدرات في مجال مكافحة التصحر، الكويت 2000.

# Appendices

**Appendix (1): Soil SP ANOVA**:

| Source of variation | Degree of freedom | Sum of squares ($S^2$) | Mean square (M.S) | F. value | Pr > F |
|---|---|---|---|---|---|
| Block | 4 | 15893.746 | 3973.437 | 44.53 | 0.0001 |
| Treatment | 2 | 2961.074 | 1480.537 | 16.59 | 0.0001 |
| Error | 128 | 11331.322 | 89.223 | | |
| Total | 134 | 30.186.143 | | | |

**Appendix (2): Soil pH ANOVA:**

| Source of variation | Degree of freedom | Sum of squares ($S^2$) | Mean square (M.S) | F. value | Pr > F |
|---|---|---|---|---|---|
| Block | 4 | 10.319 | 2.579 | 16.01 | 0.0001 |
| Treatment | 2 | 0.278 | 0.139 | 0.86 | 0. 0423 |
| Error | 128 | 38.018 | 0.161 | | |
| Total | 134 | 48.616 | | | |

**Appendix (3): Soil ECe ANOVA:**

| Source of variation | Degree of freedom | Sum of squares ($S^2$) | Mean square (M.S) | F. value | Pr > F |
|---|---|---|---|---|---|
| Block | 4 | 331.00 | 82.751 | 6.13 | 0.0002 |
| Treatment | 2 | 271.25 | 135.62 | 10.04 | 0.0001 |
| Error | 128 | 1729.28 | 13.51 | | |
| Total | 134 | 2331.54 | | | |

**Appendix (4): Soil Na ANOVA:**

| Source of variation | Degree of freedom | Sum of squares ($S^2$) | Mean square (M.S) | F. value | Pr > F |
|---|---|---|---|---|---|
| Block | 4 | 25682.040 | 6420.51 | 8.18 | 0.0001 |
| Treatment | 2 | 7664.96 | 3832.48 | 4.88 | 0.0090 |
| Error | 128 | 100466.70 | 784.89 | | |
| Total | 134 | 133813.70 | | | |

**Appendix (5): Soil Mg ANOVA:**

| Source of variation | Degree of freedom | Sum of squares ($S^2$) | Mean square (M.S) | F. value | Pr > F |
|---|---|---|---|---|---|
| Block | 4 | 135.972 | 33.99 | 5.09 | 0.0006 |
| Treatment | 2 | 163.818 | 81.909 | 12.26 | 0.0001 |
| Error | 128 | 1576.975 | 6.682 | | |
| Total | 134 | 1876.765 | | | |

**Appendix (6): Soil K ANOVA:**

| Source of variation | Degree of freedom | Sum of squares ($S^2$) | Mean square (M.S) | F. value | Pr > F |
|---|---|---|---|---|---|
| Block | 4 | 0.189 | 0.047 | 11.14 | 0.001 |
| Treatment | 2 | 0.061 | 0.030 | 7.22 | 0.009 |
| Error | 128 | 0.998 | 0.004 | | |
| Total | 134 | 1.248 | | | |

**Appendix (7): Soil SAR ANOVA**:

| Source of variation | Degree of freedom | Sum of squares ($S^2$) | Mean square (M.S) | F. value | Pr > F |
|---|---|---|---|---|---|
| Block | 4 | 12495.342 | 3123.835 | 41.62 | 0.0001 |
| Treatment | 2 | 1880.881 | 940.440 | 12.53 | 0.0001 |
| Error | 128 | 17711.387 | 75.048 | | |
| Total | 134 | 32087.610 | | | |

**Appendix (8): Soil $HCO_3$ ANOVA:**

| Source of variation | Degree of freedom | Sum of squares ($S^2$) | Mean square (M.S) | F. value | Pr > F |
|---|---|---|---|---|---|
| Block | 4 | 10.999 | 2.249 | 1.70 | 0. 150 |
| Treatment | 2 | 15.041 | 7.520 | 4.60 | 0.010 |
| Error | 128 | 381.110 | 1.614 | | |
| Total | 134 | 407.151 | | | |

**Appendix (9): Soil $SO_4$ ANOVA:**

| Source of variation | Degree of freedom | Sum of squares ($S^2$) | Mean square (M.S) | F. value | Pr > F |
|---|---|---|---|---|---|
| Block | 4 | 7699.130 | 1924.782 | 10.63 | 0.0001 |
| Treatment | 2 | 16497.279 | 8249.639 | 45.54 | 0.0001 |
| Error | 128 | 42749.57 | 181.14 | | |
| Total | 134 | 66945.984 | | | |

**Appendix (10): Soil B.D ANOVA**:

| Source of variation | Degree of freedom | Sum of squares ($S^2$) | Mean square (M.S) | F. value | Pr > F |
|---|---|---|---|---|---|
| Block | 4 | 0.206 | 0.052 | 32.38 | 0.0001 |
| Treatment | 2 | 0.006 | 0.003 | 1.77 | 0.1734 |
| Error | 128 | 0.376 | 0.002 | | |
| Total | 134 | 0.588 | | | |

**Appendix (11): Soil CEC ANOVA**:

| Source of variation | Degree of freedom | Sum of squares ($S^2$) | Mean square (M.S) | F. value | Pr > F |
|---|---|---|---|---|---|
| Block | 4 | 9835.025 | 2458.75 | 46.52 | 0.0001 |
| Treatment | 2 | 1034.030 | 3196.01 | 9.78 | 0.0001 |
| Error | 128 | 12474.564 | 52.858 | | |
| Total | 134 | | | | |

**Appendix (12): Soil ESP ANOVA:**

| Source of variation | Degree of freedom | Sum of squares ($S^2$) | Mean square (M.S) | F. value | Pr > F |
|---|---|---|---|---|---|
| Block | 4 | 11311.103 | 2827.775 | 47.33 | 0.0001 |
| Treatment | 2 | 806.097 | 403.048 | 6.75 | 0.0014 |
| Error | 128 | 14099.205 | 59.742 | | |
| Total | 134 | 26216.405 | | | |

**Appendix (13): Soil Sand ANOVA:**

| Source of variation | Degree of freedom | Sum of squares ($S^2$) | Mean square (M.S) | F. value | Pr > F |
|---|---|---|---|---|---|
| Block | 4 | 12444.071 | 3111.017 | 37.89 | 0.0001 |
| Treatment | 2 | 98.960 | 49.480 | 0.60 | 0.5482 |
| Error | 128 | 19543.031 | 82.114 | | |
| Total | 134 | 32086.236 | | | |

**Appendix (14): Soil Silt ANOVA:**

| Source of variation | Degree of freedom | Sum of squares ($S^2$) | Mean square (M.S) | F. value | Pr > F |
|---|---|---|---|---|---|
| Block | 4 | 37.055 | 9.263 | 3.23 | 0.0133 |
| Treatment | 2 | 79.396 | 39.698 | 13.82 | 0.0001 |
| Error | 128 | 677.885 | 2.872 | | |
| Total | 134 | 794.337 | | | |

**Appendix (15): Soil Clay ANOVA:**

| Source of variation | Degree of freedom | Sum of squares ($S^2$) | Mean square (M.S) | F. value | Pr > F |
|---|---|---|---|---|---|
| Block | 4 | 9337.725 | 2334.432 | 41.26 | 0.0001 |
| Treatment | 2 | 576.899 | 288.449 | 5.10 | 0.0068 |
| Error | 128 | 13353.894 | 56.584 | | |
| Total | 134 | 23268.521 | | | |

**Appendix (16): Water pH ANOVA:**

| Source of variation | Degree of freedom | Sum of squares ($S^2$) | Mean square (M.S) | F. value | Pr > F |
|---|---|---|---|---|---|
| Treatment | 3 | 0.15543 | 0.0518084 | 88.81 | 0.0001 |
| Error | 8 | 0.004667 | 0.00583 | | |
| Total | 11 | 0.16009 | | | |

**Appendix (17): Water SAR ANOVA:**

| Source of variation | Degree of freedom | Sum of squares ($S^2$) | Mean square (M.S) | F. value | Pr > F |
|---|---|---|---|---|---|
| Treatment | 3 | 1.31320 | 0.43773 | 56.90 | 0.0001 |
| Error | 8 | 0.05846 | 0.00731 | | |
| Total | 11 | 1.3717 | | | |

**Appendix (18): Water EC ANOVA:**

| Source of variation | Degree of freedom | Sum of squares ($S^2$) | Mean square (M.S) | F. value | Pr > F |
|---|---|---|---|---|---|
| Treatment | 3 | 0.1358 | 0.04529 | 41.18 | 0.0001 |
| Error | 8 | 0.0088 | 0.0011 | | |
| Total | 11 | 0.1446 | | | |

**Appendix (19): Water RSC ANOVA:**

| Source of variation | Degree of freedom | Sum of squares ($S^2$) | Mean square (M.S) | F. value | Pr > F |
|---|---|---|---|---|---|
| Treatment | 3 | 3.0033 | 1.0011 | 46.21 | 0.0001 |
| Error | 8 | 0.1733 | 0.0216 | | |
| Total | 11 | 3.1766 | | | |