ASSESSMENT OF WATER QUALITY AND SOIL PROPERTIES FOR IRIGATION IN THE HORTICULTURAL CROPS PRODUCING AREAS OF ALHEGAINA, NORTH KORDOFAN STATE SUDAN

ADAM HAMED MOHAMMED IBRAHIM

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DECLARATION

This thesis is my original work and has not been presented for a Degree in any other University.

Signed ……………………………..…… DATE: …………………..

Adam Hamed Mohammed Ibrahim (A103/13624/09)

Department of Agriculture Resource Management

SUPERVISORS

We confirm that the work reported in this thesis, was carried out by the candidate under our supervision as university supervisors.

Signed ………………………….. DATE ……………………..

Prof. Dr. Benson Evans Mochoge

Department of Agriculture Resource Management

Kenyatta University, **KENYA**

Signed ………………………….. DATE ……………………….

Dr. Abdelmoneim A.I. Elgubshawi

Department of Soil and Water Sciences

Faculty of Natural Resources and Environmental Studies

University of Kordofan

ELOBEID, **SUDAN**

DEDICATION

This thesis is dedicated to my:

parents Hamed Mohammed Ibraahim and Hawa Ibrahim Ahmed

and my brothers and sisters those who are surviving and those whose souls rest in Allah.

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TABLE OF CONTENTS

APPENDIX II: Table 14 for the comparison of water samples were collected in dry and wet season 64

List of Tables

List of figures

ABBREVIATIONS AND ACRONOYMS

DS/M	DECISIEMENS PER METER
EC	ELECTRICAL CONDUCTIVITY
ESP	EXACHANGEBLE SODIUM PERCENTAGE
GIS	GEOGRAPHICAL INFORMATION SYSTEM
GPS	GLOBAL POSITIONING SYSTEM
TH	TOTAL HARDNESS
NDV	NOT DETECTED VALUE
NKS	NORTH KORDOFAN STATE
MEQ/L	MILLIEQUIVALENTS PER LITER
MG/L	MILLIGRAMS PER LITER
MMHO/CM	MILLIMHOS PER CENTIMETER
µS/C	MICROSIEMENS PER CENTIMETER
PI	PERMEABILITY INDEX
PPM	PARTS PER MILLION
PVC	POLYVINYL CHLORIDE
RSBC	RESIDUAL SODIUM BI-CARBONATE
SAR	SODIUM ADSORPTION RATIO
SSP	SOLUBLE SODIUM PERCENTAGE
TDS	TOTAL DISSOLVED SOLIDS
T/fed	TON PER FEDDANS (Feddan = 1.038 acre)

ABSTRACT

Sudan is a large country with a great diversity of climatic and agro-ecological zones. The horticultural acreage in the Sudan is estimated at 273,000 hectares, representing about 3% of the total crop area. The area under horticultural crops is on the increasing for it is fetching good money for the farmers. Horticultural crops comprise the groups of vegetables,fresh legumes, fruit trees, ornamental plants, plantation crops, medicinal and aromatic plants and spices. The present study was conducted in Alhegaina area, North Kordofan-Sudan,with an aim of assessing the quality of water used for irrigation and soil properties for the production of horticultural crops mainly onions and tomatoes. The data of the study were obtained from two sources, from soil and water samples analysis, and from a questionnaire which was prepared to assess the farmers' perception on the factors affecting horticultural crops production in Alhegaina. Soil samples were taken from depths 0-15, 15-30 and 30-40 cm and were collected from 10 small scale farms, in which 5 farms used surface water while the other 5 farms used ground water for irrigation. Six water samples were collected during dry and wet seasons, three from surface sources (dams) and the other three from sub-surface normal wells. The sampled soil and water were analyzed for various parameters in the laboratory. Using the questionnaire, fifty six small garden holders (10%)were interviewed randomly. For data analysis, statistical mean comparisons based on T-test using Excel and SPSS packages were used. The results of the study indicated that water sources, that is from sub-surface and surface sources did not differ significantly and that their chemical values were within the limits acceptable for irrigation and crop production. However, the concentrations of the bi-carbonates were somewhat high (between 50-135mg/L) while for other chemicals, the concentrations (Na, Ca ,Mg, K and even EC and TDS) were fairly within the permissive limits for use. For example, EC of water and that of soil extracts were between 0.03-0.1 for water and 0.38-0.01 dS/m for soil extracts. Surface water pH was slightly alkaline (7.38 – 7.68) while that from sub-surface was slightly acidic (6.98-6.69). The soils generally were of low soil fertility with very low values of N and P, and in some cases K. With the farmers' perception on horticultural crops production, farmers were generally poorly informed, have low education and rarely use fertilizer inputs in crop production. There is need therefore to improve their knowledge on crop management and production. The Government has to come up with a policies on farmers' education,on inputs usage especially fertilizers and on credit facilitation to farmers.

CHAPTER ONE

1.0 INTRODUCTION

1.1 General Background Information

Sudan is a large country with a great diversity of climatic and agro-ecological zones. The country is rich in plant genetic resources. However, these plant genetic resources are subjected to erosion due to the expansion of mechanized agriculture in the rainy lands of Central, Eastern and Western Sudan. Of about 84 million ha of arable land (with reasonably fertile soils), 1.63, 8.21 and 7.93 million ha respectively were under irrigated agriculture, traditional rain-fed cultivation and mechanized farming in the 1994/95. Forests and woodlands cover about 64.36 million ha while rangelands are estimated to cover 24 million ha (Zaroug, 1996). Horticultural crops comprise the groups of vegetables, fresh legumes, fruit trees, ornamental plants, plantation crops, medicinal and aromatic plants and spices. The horticultural acreage in the Sudan is estimated at 273,000 hectares, representing about 3% of the total crop area, and contributes 12% to national production compared to 21% for food grains and 8% for oil seeds (Ahmed, 2002). Horticultural crop growers share many of the same management concerns of other producers. Although horticultural crops vary substantially, they all require skilled management to produce a high product. These crops rely heavily on high management of soil, water, nutrient resources and pest populations. Water availability is the most serious limitation to agricultural quality production in Western Sudan. This study was carried out in Alhegaina area-North Kordofan State to assess the soil and water resources which are used to produce horticultural crops (vegetables and fruits) by farmers.

1.2 Statement of the Problem

North Kordofan State does not have sufficient supply of horticultural products but always imports some from the neighbouring states. However, yields per unit area are low compared with international standards or with neighbouring countries. Local yields are in the order of 4 t/fed for vegetables, 4-5 t/fed for potatoes, 4 t/fed for tomato and 6 t/fed for onion as compared with respective yields of 26, 12-15, 18 and 13 t/fed for the same crops in Egypt. This is an illustration of the big productivity gap and the high potential for improvement (Ahmed, 2002). This can be as a result of poor water quality and soil infertility in the area. For example, the excess salts affect the uptake of nutrients from the soil. In irrigation, poor water quality with excess salts affect plants in many ways, but the most common problems are caused by salts which influence the osmotic relationship between roots and soil moisture (Malash et al., 2005).

1.3 Justification and significance of the study

In North Kordofan area the water which is used by small scale farmers for producing horticultural crops such as vegetables and fruits, has the influence on onion and tomato production be it from its supply or quality. Soil also has the same effect like that of water in the crops due to its salt contents and poor agricultural practices. There is a need to assess the water quality from various sources such as surface and ground water which is used to irrigate different horticulture crop in the area . Equally important will be the sustainability assessment of soil in terms of salts and their effects on horticultural crops. This study is useful to shed light on water quality and soil productivity on horticultural crops production in the area. The production of both vegetables and fruits is flourishing, providing cash to farmers, forming an important component of the human diet and holding good promise for export. There is a need to increase yield per unit area and improve quality to meet the country's strategic goals of improving export earnings and producing adequate quantities for fresh consumption and processing.

1.4 Research objective

The general objective of the this study is to assess the quality of water used for irrigation and soil properties for the production of onion and tomato in ALhegaina -North Kordofan State, Sudan, while the specific objectives are:

1- To assess the chemical properties of water and their effects on horticultural crop production.

2- To assess the physical-chemical properties of soils that are used by farmers on crop production

3- To compare the chemical properties of water sources for irrigation (ground and surface water) on the soil properties.

4- To assess the farmer's perception on onion and tomato production in relation to water sources used for irrigation and other inputs.

1.5 Research hypothesis

1- The chemical properties of water used for irrigation have effects on most horticultural crops production

2- The soil quality in terms of chemical and physical properties, affect the performance of crops differently.

3- The chemical properties of water sources (ground and surface water) affect soil properties differently

4- Famers have little knowledge on horticultural crops' production in relation to water use for irrigation and other inputs.

1.6 Conceptual Framework

Low yield of crops especially horticultural in Alhegaina area could be due to poor water quality used for irrigation, or low soil fertility and/or lack of knowledge to farmers on horticultural crops production. Tomato and onion are sensitive crops to salinity. This requires, therefore, regular monitoring of water used for irrigation and the soils for their chemical properties in order to avoid or limit excess salinity in the soil. Farmers knowledge on the management and production of horticultural crops is vital in order to be aware of the inputs required, timing and water application for increased crop yield.

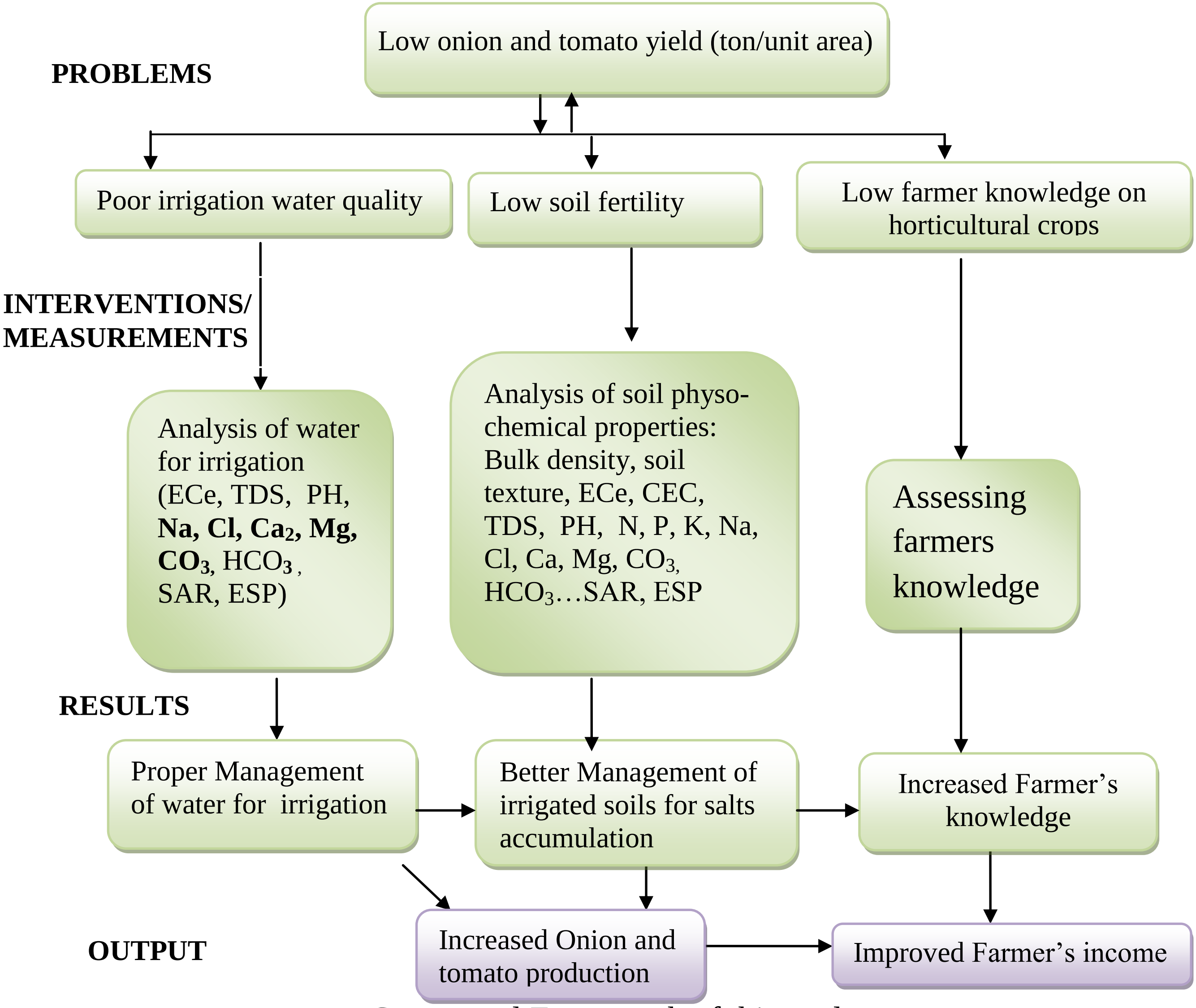

Figure 1: Conceptual Framework of this study

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Water quality for irrigation

Understanding knowledge of irrigation water quality is critical to the management of water for long-term productivity. Irrigation water quality is related to its effects on soils and crops and its management. High quality crops can be produced only by using high-quality irrigation water keeping other inputs optimal. Characteristics of irrigation water that define its quality vary with the source of the water (APHA,2005). There are area differences in water characteristics, based mainly on geology and climate. There may also be great differences in the quality of water available on a local level depending on whether the source is from surface water bodies such as rivers and ponds or from groundwater aquifers with varying geology, and whether the water has been chemically treated (Ayers &Westcot,1994; Nahid et al.,2008). The chemical constituents of irrigation water can affect plant growth directly through toxicity or deficiency, or indirectly by altering nutrient availability to the plants (Ayers and Westcot, 1985; Rowe *et al.,* 1995; Islam and Shamsad,2009).

Analytical procedures for the laboratory determinations of water quality have been given in several publications (USDA Handbook 60 by Richards, 1954; FAO Soils Bulletin 10 by Dewis and Freitas1970; APHA,2005). Table 1 shows the guidelines for interpretations of water quality for irrigation as given by Ayers and Westcot (1985).The chemicals guidelines given in Table 1 act as the management tools and practical guidelines that have been used successfully in general irrigated agriculture for evaluation of the common constituents in surface water, ground water, drainage water, sewage effluent and waste water. They are the first step in pointing out the quality limitations of the water supply. Also shown in Table 1 is the degree of restriction of chemical parameters on the use of irrigation water. A restriction on use indicates that there may be a limitation in choice of crop or special management need to maintain full production capability. However, a “restriction on use” does not indicate that the water is unsuitable for use.

Table 1: Guidelines for interpretations of water quality for irrigation

Potential Irrigation Problem				Units	Degree of Restriction on Use		
					None	Slight to Moderate	Severe
Salinity							
	EC_w			dS/m	< 0.7	0.7 – 3.0	> 3.0
	(or)						
	TDS			mg/l	< 450	450 – 2000	> 2000
SAR	= 0 – 3	EC_w	=		> 0.7	0.7 – 0.2	< 0.2
	= 3 – 6		=		> 1.2	1.2 – 0.3	< 0.3
	= 6 – 12		=		> 1.9	1.9 – 0.5	< 0.5
	= 12 – 20		=		> 2.9	2.9 – 1.3	< 1.3
	= 20 – 40		=		> 5.0	5.0 – 2.9	< 2.9
Specific Ion Toxicity							
	Sodium (Na)						
	surface irrigation			SAR	< 3	3 – 9	> 9
	sprinkler irrigation			me/l	< 3	> 3	
	Chloride (Cl)						
	surface irrigation			me/l	< 4	4 – 10	> 10
	sprinkler irrigation			me/l	< 3	> 3	
	Boron (B)			mg/l	< 0.7	0.7 – 3.0	> 3.0
	Nitrogen (NO_3 - N)			mg/l	< 5	5 – 30	> 30
	Bicarbonate (HCO_3)						
	pH				Normal Range 6.5 – 8.4		

Ayers & Westcot (1985)

2.2 Effect of Water quality on the soil properties and crop production

2.2.1 Effect of Water quality on crop production

Irrigation water whether of good quality or not, can have effect on plant growth, for example poor irrigation water quality with excess salt can damage plants in various ways, but the most common problems are caused by salts effecting osmotic relationship between the root and the soil moisture (Malash *et* al. ,2005).Water with high amount of salts can hinder the conversion of ammonium salts to nitrate by nitrifying micro-organisms in soil when used for irrigation.Furthermore, most of tomato plants are more sensitive to salt during seed germination, seedling growth and when flowering or fruiting. (Breckle, 1995). According to Breckle (1995) the seed and seedling stages are vulnerable not only because the plant structures are immature and delicate, but also because tiny roots system draw moisture and nutrients from the soil surface where salts tend to concentrate. A severe reduction in water infiltration rate due to water quality is usually related to either very low water salinity or to a high sodium adsorption ratio (SAR). In either case, the calcium content of the water may be at a relatively low concentration. If the calcium in the soil-water taken up by the crop is less than 2 me/l, there is a strong probability that the crop yield will be reduced due to a calcium deficiency (Rhoades, 1982).

Salinity is a measure of the total amount of salt in the water. When the salt levels are too high, a salinity hazard may exist. Salts in soil and/or water can reduce water availability to the crop to such an extent that yield can be affected. Electrical conductivity or Total Dissolved Solids (TDS) tests are two means of measuring salinity. Electrical conductivity is a useful and reliable index for the measurement of water salinity or TDS in water. Electrical conductivity in water is due to ionization of dissolved inorganic solids (minerals, salts, elements both cations and anions). The total amount of TDS should be used together with SAR. TDS levels below 700 mg/L and SAR below 4 are considered safe; TDS levels between 700 and 1,750 mg/L and SAR levels between 4 and 9 are considered slightly safe, while levels above these are considered hazardous to any crop. The properties of the soil, the ground water and the landscape interact with the salinity of the irrigation water to either increase or decrease the salinity hazard (Peterson, 1999).

2.2.2 Effect of water quality on soil properties

The normal pH range for irrigation water is from 6.5 to 8.4. Abnormally low pHs may cause accelerated irrigation system corrosion where they occur. High pH's above 8.5 are often caused by high bicarbonate (HCO_3^-) and carbonate (CO_3^{2-}) concentrations, known as alkalinity. High carbonates cause calcium and magnesium ions to form insoluble minerals leaving sodium as the dominant ion in solution. According to Mass (1990), this alkaline water can intensify sodic soil conditions. While EC_w is an assessment of all soluble salts in a sample, sodium hazard is defined separately because of sodium's specific detrimental effects on soil physical properties (see section 2.5.2). The SAR index quantifies the proportion of sodium (Na^+) to calcium (Ca^{++}) and magnesium (Mg^{++}) ions in a sample. Calcium will flocculate (hold together), while sodium disperses (pushes apart) soil particles. This dispersed soil will readily crust and have water infiltration and permeability problems. General classifications of irrigation water based upon SAR values calculated using Equation 1, are

presented in Table 2.

$$SAR = \frac{Na^+_{meq/L}}{\sqrt{\frac{(Ca^{++}_{meq/L}) + (Mg^{++}_{meq/L})}{2}}}$$

Equation 1.Equation used to calculate SAR

Where

meq/L = mg/L divided by atomic weight of ion divided by ionic charge (Na^{+}=23.0 mg/meq, Ca^{++}=20.0 mg/meq, Mg^{++}=12.15 mg/meq)

Table 2: Classification of sodium hazard of water based on SAR values.

SAR values	Sodium hazard of water	Comments
1-9	Low	Use on sodium sensitive crops must be cautioned.
10-17	Medium	Amendments (such as gypsum) and leaching needed.
18-25	High	Generally unsuitable for continuous use.
≥26	Very High	Generally unsuitable for use.

Mass (1990)

Sodium in irrigation water can also cause toxicity problems for some crops, especially when sprinkler is used. However, crops vary in their susceptibility to sodium toxicity damage (Mass, 1990).

2.3 Effect of water sources for irrigating crops

According to Biernbaum (1994) both irrigation water quality and proper irrigation management are critical to successful crop production. In addition, the quality of the irrigation water may affect both crop yields and soil physical conditions, even if all other conditions and cultural practices are favourable or optimal. Different crops require different irrigation water qualities, therefore, testing the irrigation water prior to selecting the site and the crops to be grown is critical (Shahinasi and Kashuta,2008). The quality of some water sources may change significantly with time or during certain periods such as in dry or rainy seasons (Islam et al.,2009). So it is recommended to have more than one sample taken, in different time periods. Growth of plants is frequently limited by imbalances in electrical conductivity (EC), alkalinity, sodium (Na), and boron (B). High EC levels inhibit the germination of seeds, the rooting of cuttings, and root growth of some established crops. Akalinity directly influences the pH of the root medium; as alkalinity in irrigation water increases, so does root medium pH. High levels of Na can antagonize the uptake of potassium (K), calcium (Ca),and magnesium (Mg). Leaf necrosis occurs when high levels of boron are present in irrigation water. Other potential irrigation water contaminants that may affect suitability for agricultural use include heavy metals and microbial contaminants (Bauder et al., 2007).

2.3.1 Ground water effect on crop production

Ayers & Westcot, (1994) found that the quality of well water may vary with the season and/or climate. For example, solutes tend to be dilute in rainy years, and concentrated in dry years. The environment also impacts the quality of pond water, during dry periods, the concentration of the solutes increased as water evaporated. Also WHO (1984) reported that groundwater is slightly acidic to slightly alkaline with pH values from 6.5 to 8.3.

Bicarbonate is an important ion in the evaluation of irrigation water quality. Bicarbonate is responsible for alkalinity of the groundwater. According to Eaton (1950), irrigation water having residual sodium carbonate (RSC) values greater than 5 meq/L are considered harmful to the growth of plant, while irrigation waters with RSC value around 2.5meq/L is safe for irrigation, a value between 1.25 and 2.5 meq/L is of marginal and a value of more than 2.5 meq/L is unsuitable for irrigation (Hem, 1970). When sodium concentration is high in irrigation water, sodium ion is absorbed by the clay particles and the soil reduces the permeability and this results in soil with poor internal drainage and therefore the air and water circulation is restricted during the wet condition and such a soil is usually hard when dry (Collins and Jenkins, 1996)

2.3.2 Effect Surface water quality for crop production

For irrigation, the quality of water determines if optimum return from the soil can be obtained as the quality affects soil, crop and water management. Nearly all water contain dissolved salts and trace elements, many of which result from the nature weathering of the earth's surface. In most irrigating situations, the primary water quality concern is salinity levels, since salt can affect both soil structure and crop yield. Surface water contributes the major share of irrigation coverage (Nahid, et al, 2008). In classifying water for irrigation, Sodium Adsorption Ratio (SAR) is an important parameter in determining the suitability of irrigation water, which is found normal in surface water according to Rughunath, (1990). Good proportion of Ca^{2+} and Mg^{2+} is favourable for good permeability problem. According to Raghunath, (1990) and Wilcox, (1955) classifying water for irrigation is determined considering the combined effects of SSP, EC and boron contents.

The surface water is fresh and good and moderately hard in respect with the classification of TDS, permeability Index (PI) and Total Hardness (Ht)(Freeze and Cherry, 1979). According to Michael (1992).the range of pH in surface water is found slightly alkaline to practically neutral. Surface water is also suitable for most plants provided that moderate amount of leaching takes place or that plants with moderate salinity tolerance are grown. Shaki and Adeloe (2006) using both surface and sub-surface water for irrigation, concluded that surface water has no salinity or toxicity problem and thus, is suitable or almost excellent for being used for irrigation.

2.4 Soil Salinity effect on crops production

The salinity effects are generally evidenced by reducing transpiration rates and proportionally related growth, and producing smaller plants. The salinity also alters the soil ability to retain nutrients, thus suppressing plant growth (Goudie, 1991).

Alan (1994) reported that Plants vary in their response to soil salinity. Salt tolerant plants (plants less affected by salinity) are better able to adjust internally to the osmotic effects of high salt concentrations than salt-sensitive plants. Salt-tolerant plants are more able to absorb water from saline soils, while salt-sensitive plants have limited ability to adjust and are injured at relatively low salt concentrations. Many horticultural and field crops are classified as sensitive or moderately sensitive to soil salinity as shown in Table 3 (Bauder et al., 2007)

Table 3: Relative tolerance of selected crops to salinity of irrigation water and salt tolerance

High (8-12 mmhos/cm)	**Medium (3-8 mmhos/cm)**	**Low (1-3 mmhos/cm)**
FIELD CROPS		
Cotton	Rye, wheat, oats, sorghum, corn, and soybeans	Field beans, peanuts
FORAGE CROPS		
Bermudagrass	Sweet clover, dallisgrass, sudan grass, alfalfa, fescue, wheat and oats for hay, vetch	White clover and landino clover
VEGETABLE CROPS		
Garden beets, kale, asparagus, and spinach	Tomato, broccoli, cabbage, peppers, cauliflower, lettuce, sweet corn, potatoes, carrots, onion, peas, squash, and cucumbers	Radishes, celery, and green beans

FRUIT CROPS		
	Figs, grapes, and cantaloupes	Pears, apples, oranges, plums, apricots, and peaches

Whereas Table 3 shows relative tolerance of selected crops to salinity, Table 4 shows yield potential of salt-tolerance classes of horticultural and landscape plants to soil salinity levels as formulated by Alan (1994). Baunder et al., (2007) reported that quality of water for plants in soil solution decreases dramatically as EC increases

Table 4: Soil salinity levels and yield potential of salt-tolerance crops

Relative salt	**Expected loss of relative growth yield (%)**			
Tolerant class	**0**	**25**	**50**	**100**
	-------------------------- Soil salinity (ECe dS/m---------------------------------- -----			
Sensitive	<1.3	1.4 - 2.7	2.6 - 4.2	>8.0
Moderately sensitive	<3.0	2.7-6.3	4.2 - 9.5	>16.0
Moderately tolerant	<6.0	6.3-10.5	9.5-15.0	>24.0
Tolerant	<10.0	10.5-15.5	15.0-21.0	>32.0

Alan (1994)

2.5 Effect of salts and individual ion toxicities in soils on crop production

2.5.1 Salinity hazard

Ayers, (1997) reported that most water quality guidelines on crop productivity are mainly on the water salinity hazard as measured by electrical conductivity (EC_w). The primary effect of high EC_w on crop productivity is the inability of the plant to compete with ions in the soil solution for water. This is usually referred as physiological drought for plants.. The higher the EC, the less water is available to plants, even though the soil may appear wet. Because plants can only transpire "pure" water, usable plant water in the soil solution decreases dramatically as EC increases. A soil high in exchangeable sodium is very undesirable for agriculture as it causes flocculation resulting in impermeable crust. Table 5 shows the criteria for irrigation water use based upon conductivity

Table 5: Suggested criteria for irrigation water use based upon Electrical Conductivity

Classes of water	**Electrical Conductivity**
	(dS/m)*
Class 1, Excellent	≤0.25
Class 2, Good	0.25 - 0.75
Class 3, Permissible[1]	0.76 - 2.00
Class 4, Doubtful[2]	2.01 - 3.00
Class 5, Unsuitable[2]	≥3.00

Ayers, (1997)
*dS/m at 25ºC = mmhos/cm
[1]Leaching needed if used.
[2]Good drainage needed and sensitive plants will have difficulty obtaining stands.

The amount of water transpired through a crop is directly related to yield. Therefore, irrigation water with high EC_w reduces yield potential (Tables 4 and 6). Water with an EC_w of only 1.15 dS/m contains approximately 2,400 kilograms of salt for every 30 cm depth of water. Crop growth reductions because of dissolved substances in the soil are similar to drought-stressed effects. An osmotic gradient on salty soils is formed. Water uptake by plant roots is increasingly restricted as the concentration of soil salts increases. Because of this, as soil salts build up in the soil, more frequent irrigation is necessary to help flush out salts and reduce water stress. Crop species differ in their abilities to withstand salt stress (Baunder et al.2007).

Table 6: Potential yield reduction from saline water for selected irrigated crop

	% yield reduction			
Crop	**0%**	**10%**	**25%**	**50%**
	EC_w[2]			
Barley	5.3	6.7	8.7	12
Wheat	4.0	4.9	6.4	8.7
Sugarbeet[3]	4.7	5.8	7.5	10
Alfalfa	1.3	2.2	3.6	5.9
Potato	1.1	1.7	2.5	3.9
Corn (grain)	1.1	1.7	2.5	3.9
Corn (silage)	1.2	2.1	3.5	5.7
Onion	0.8	1.2	1.8	2.9
Beans	0.7	1.0	1.5	2.4

Ayers (1997)

2ECw = electrical conductivity of the irrigation water in dS/m at 25Co. 3Sensitive during germination. ECw should not exceed 3 dS/m for garden beets and sugarbeets

2.5.2 Sodium hazard

Sodium hazard (or alkalinity hazard) in the use of water for irrigation is determined by the absolute and relative concentration of sodium (Na+) to calcium (Ca++) and magnesium (Mg++) ions in a water sample and it is expressed as Sodium Adsorbed

Ratio (SAR) which is the measure of sodium hazard in irrigation water (Siamak and Srikantaswamy,2008 ; Silva,2004). Excess sodium in water produces undesirable effects on soil properties and reduces soil permeability (Dhirendra et al.,2009).Sodium when replacing adsorbed calcium and magnesium, becomes hazardous as it causes damage to the soil, making it to be compact and impervious, especially the soil structure, resulting in the formation of crusts ,water-logging, reduced aeration and infiltration rate. Excess of Na+ ions in soil may be also toxic to certain types of crops (Tiwari and Manzoor, 1988; Nata et al., 2009 ; Ogunfowokan et al., 2009 &2013). Classification of Na+ ions effects on crops have been given on Table 2 ,section 2.2.2 .

2.5.3 Chlorides

Although chloride is an essential element to plants in very low amounts, it can cause toxicity to sensitive crops at high concentrations. Like sodium, high chloride concentrations cause more problems when applied with sprinkler irrigation (Mass,1990).Table 7 shows the effect of chlorides on plants and its classification in irrigation water. Leaf burn under sprinkler from both sodium and chloride can be reduced by night time irrigation or application on cool, cloudy days. Drop nozzles and drag hoses are also recommended when applying any saline irrigation water through a sprinkler system to avoid direct contact with leaf surfaces. (Mass, 1990). Working with faba bean(Vicia faba), Ehsan et al.,(2010) reported reduced growth of faba bean at high concentrations of Cl- than that of Na+. They observed that increasing the concentrations of NaCl in the soil increased the concentrations of Cl-more than that of Na+ probably due to Na+ ions interaction with bicarbonates. Similar results had been reported by Hajrasulha (1980).In another experiment with tomato plants, Sara et al.,(2007 reported great inhibition of tomato plant growth at high concentration of chorides.

Table 7: Chloride classification of irrigation water and its effect on plants.

Chloride (ppm)	Effect on Crops
Below 70	Generally safe for all plants.
70-140	Sensitive plants show injury.
141-350	Moderately tolerant plants show injury.
Above 350	Can cause severe problems.

Mass (1990)

3.5.4 Boron

Boron is another element that is essential in low amounts, but toxic at higher concentrations as shown in Table 8. According to Mass, (1990) Boron toxicity can occur on sensitive crops at concentrations less than 1.0 ppm and it is advised that irrigation water specifically from ground water should be analyzed of boron before used to crops (Mass, 1990).

Table 8: Boron sensitivity of selected plants in mg/L

Sensitive		Moderately Sensitive	Moderately Tolerant	Tolerant
0.5 - 0.75	0.76 - 1.0	1.1 - 2.0	2.1 – 4.0	4.1 – 6.0
Peach	Wheat	Carrot	Lettuce	Alfalfa
Onion	Barley	Potato	Cabbage	Sugar beet
	Sunflower	Cucumber	Corn	Tomato
	Dry Bean		Oats	

Mass(1990)

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2.5.5 Sulphate

The sulphate ion is a major contributor to salinity. However, toxicity is rarely a problem, except at very high concentrations where high sulphate may interfere with uptake of other nutrients. Exceptions are sandy fields with less than1 percent organic matter and less than 10 ppm SO^4-S in irrigation water (Mass, 1990).

2.5.6 Nitrogen

Nitrogen (N) in irrigation water is largely a fertility issue. The nitrate ion often occurs at higher concentrations than ammonium in irrigation water. Waters high in N can cause quality problems in crops such as barley and sugar beets and excessive vegetative growth in some vegetables. However, these problems can usually be overcome by good fertilizer and irrigation management.

2.6 Horticultural crops production in Sudan

2.6.1 Distribution and production of fruits and vegetables

Most of horticultural crops production in Sudan is under irrigated farming system, along valleys and streams in the western states except in the south areas with high rainfall (Horticultural Sector, Ministry of Agriculture and Forest, HS, 2009). According to Elbashir and Imam (2010). Many types of cultivars of fruits and vegetable can be produced almost all the year round due to the climatic variations plus available land and water. This large potential could supply both local and export markets. However, horticultural crops represent about 12% of the national agricultural income compared to 17% for cotton and 29.6% for cereals and oil seeds. According to annual horticultural sector which cultivated Onion and tomatoes in Sudan during years 2005 to 2009, average production of onion was about 894 tons which came from a cultivated area of 50 hectares, which translates to 17.9 tons per hectare. Whereas the average production of tomatoes from year 2005 to 2009 was 434.2 tons produced from a cultivated area of 32.6 ha which translates to 13.3 tons per hectare of tomatoes.

2.6.2 Major constrains in fruits and vegetable production in Sudan.

The major constraints of fruits and vegetables production in Sudan are summarized as follows: lack of sufficient improved management technology, inadequate financial and credits facilities, land fragmentation, poor vegetables seed production, limitation to application of agricultural research finding due to inadequate extension services, low productivity due to poor and traditional cultural practices, high cost and improper local transportation, weeds, and pests and disease (Elbshir and Imam, 2010)**.** In addition to the diseases and pests, land degradation is a major land problem in the Sudan resulting from desert creep, water and wind erosion, sodicity effect and loss of fertility. These factors, among others, lead to the observed decline in agricultural productivity in the main rain-fed and irrigated areas. Due to the very expensive and tedious land reclamation practices, it becomes necessary to develop knowledge on soil classification and soil characteristics for a sustainable use of this resource. It is also imperative to protect this important resource through the development of suitable technologies such as land preparation, irrigation and fertilizer use to boost agricultural production (Agricultural Research Corporation, Sudan, 2013).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Study Area

The sampling of water, soil samples and socioeconomic data collection were carried out in Alhegaina area, along Um Tagargar stream which Pass through Alhegaina and Alrahad in North Kordofan State. Alhegaina area lies between latitudes 12^{o}- 42^{-} _12^{o} 52^{-} N and longitudes 30^{o} 30^{-} and 30^{o} 45^{-}E and occupies about 32 Km^{2} (ministry of agriculture north kordofan,1999). North Kordofan State is divided into four agric-ecological zones which include: Semi desert/ Arid zone;Semi arid zone/Sahel ;Low rainfall Savanna and Moderate / High Rainfall savanna. The semiarid zone is further classified into sandy semi-arid and clayey semi-arid subzones. North Kordofan State lies within the desert and semi-desert climatic zones at the northern edge of the savanna belt (Merzouk, 2004) as shown in Fig. 1

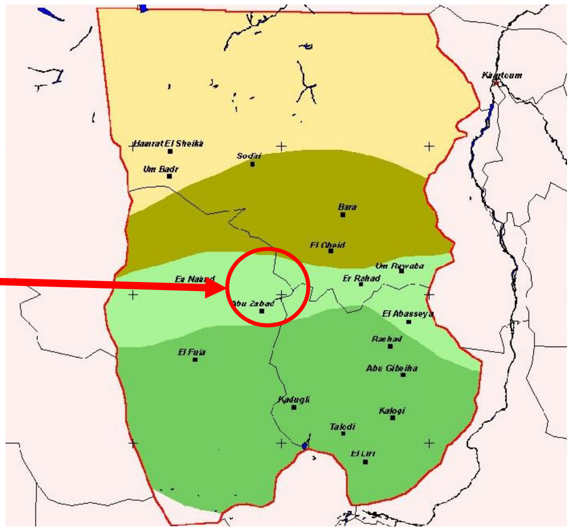

Figure 2: North Kordofan map, Sudan **Kordofan agric-ecological zones**
Sorce (Merzouk,2004)

Semi desert/ arid zone Semi arid zone/ Sahel

Low rainfall savanna Moderate/ high rainfall savanna

3.2 Climate of North Kordofan

Average maximum monthly temperatures range from 29.9°C in January to 39.6°C in May with average value of 34.5°C. The minimum average monthly temperatures vary from 13.3°C, in January, to 24.7°C in June with an average value of 20.3° C for the same period.

Rainfall is low normally around 386mm and is unequally distributed. The rainy season normally extends from June/July to September/October. However, the period between the first and last useful rains is limited to 70 to 90 days only (James, 1982).

3.3 Geological and Soil of North Kordofan

The geological formations of North Kordofan State consist of the Basement Complex, the Nubian Sandstone, the Um Rawaba sedimentary formation and the superficial deposits of which sands are the dominant fraction. Following the formation of basement complex rocks, the region was subjected to prolonged erosion and later invaded by shallow seas depositing the Nawa Formation (Devonian- Carboniferous). The Middle Miocene continental seas had covered the whole region depositing the thick horizontally bedded Nubian Sandstone formation (Mohamud *et* al., 2007).In north Kordofan sandy soils (Qoz) cover 70 percent of the area, and Qoz soil have very low CEC and poor in nutrient holding capacity. Rapid drying of surface zone in Qoz soils appear to be major causes of seeding failure, and also these soils are more susceptible to the wind erosion. Gardud soils (non cracking soils), the second most extensive soil type in northern Kordofan, is difficult to very hard to till and cultivation is done using traditional hand tools. Water infiltration in Gardud soils is very low. As a result, much of the rainwater from Gardud lands is lost as runoff. The surface of Gardud soils is highly eroded and stoney (James, 1982). Alhegaina area is covered with sandy soils which are stabilized sand dunes known as sand pedi-plain and the soil type is characterized by high water permeability, poor holding capacity and low nutrient content. The soil is easy to cultivate but has low production potential. Also, the clay soils are found along Khor um Tagargar. They have high production potential and high water holding capacity and relatively low productivity. Labor requirement for field operation is much higher compared to Qoz soils (Elkhalil,2006).The water sources are mainly wells, and some reservoirs (hafirs),in the rainy season (Mohamud *et* al., 2007). The study was carried out along Khor Um Tagargar(Um Tagargar stream) which passes through Alhegaina and Alrahad areas,located to the eastern part of Alhegiana along UM Tagargar,which is the catchment reservoir as well as the source of sub-surface and surface water from where farmers get water to irrigate crops.

3.4 Vegetation cover in Alhigaina

The study area falls within the low rainfall savannah on sandy soil (Qoz).The dominat vegetation is mainly composed of *Acacia senegal* (hashab),*Balanites aegyptiaca* (higlig), *Ziziphus spina-christi* (sidir), *Adansonia digitata* (tabaldi). The area is characterized by high density of *Bocscia seneglensis* (korsan), and *Calotropis procera* (Ushar). Among them, there are fruit trees such as (higlig , tabadi, sidir) which contribute significantly to the income of farmers in Alhegaina area since they do not require inputs other than labor cost of gathering and marketing (Ministry of Agriculture ,1999).

3.5 Soil Sampling and analysis

3.5.1 Soil sampling procedure

The study assessed soil properties used by farmers for the production of tomato and onion crops in the area. The soil samples were collected from 10 small scale farmers' fields, that is 5 farms which used surface water (Alrahad catchment), and 5 farms which used ground water for irrigation. Soil sampling was done at different depths (0-15)cm,(15-30)cm and (30-45)cm, using an auger.Simple random sampling techniques was used for collecting soil samples. The soil samples collected were kept in containers then transported to the laboratory for drying and analysis.

3.5.2 Soil Samples analysis

Initial physical and chemical soil analyses were carried out after drying the samples in the laboratory and preparing them for analysis, i.e grinding and sieving then using a 2mm sieve. The physical characteristics analyzed included bulk density and soil texture (sand, silt and clay). Bulk density was determined by core ring method (Mehlich *et al.*,1962; Hinga *et al.*, 1980). Soil texture was determined by a hydrometer method (Bouyoucos, 1951). The chemical Properties that were analyzed included pH**,** EC, TDS, N, P, K, Ca, Mg, Cl, Na and HCO_3,CO_3, $CaCO_3$, and B. From the chemical data obtained, sodium adsorbed ratio(SAR) and exchangeable sodium percentage (ESP%) were calculated. The pH was measured using a hydrogen selective electrode (schofield, R.K. and A.W. Taylor.1955); and ECe was determined using electric conductivity meter (Wilcox, 1966). Ca and Mg were determined by titration using EDTA, and Cl was determined by titration using $Ag.No_3$, K, Na used flame photometer, and nitrogen(N) Kjeldahl method, CO_3 and HCO_3 were determined by titration using hydrochloric acid and phosphorus (p) was determined using spectrophotometer according to Hesse (1971).

3.6 Water Sampling and analysis

3.6.1 Water sampling procedure

The water samples were collected from ground and surface water sources as used by farmers there. The water samples were collected during dry and wet season. At least 6 water samples were collected, three collected from the dams (Alrahad torda) and the other three from sub-ground normal wells which are used to irrigate tomato and onion crops in the area. The samples collected were kept in containers that were thoroughly washed to avoid any contamination.

3.6.2 Water samples analysis

The water samples collected were analyzed for pH, EC, TDS, Na, Ca, Mg, Cl, SO_{-4}, $NO_{3,}$ NO_2, B, CO_3 and HCO_3. All this elements were determined accordingly to international standards of laboratory analysis as stated in section 3.6.1.

3.7 Questionnaire formulation, data collection and data analysis

3.7.1 Questionnaire formulation

The researcher used open and closed-ended questionnaires for the data collection. As shown in appendix I.

3.7.2 Data collection

The study involved in the collection of data on water and soil usage by farmers in the area. Besides,other relevant information were gathered using structured questionnaire where 56 respondents (small gardens holders) out of 560 small garden holders in Alhegaina area were randomly sampled and interviewed for the collection of socio-economic data.

3.7.3 Questionnaire data analysis

After obtaining the required information from the questionnaire, (Appendix 1) the data was coded and analyzed. This was done by analying closely the information given by each respondent in each questionnaire. The data was put in tables, for easy of interpetation. The questionnaire data was analyzed in frequency and percentages. Descriptive statistics was followed to analyze the data collected using SPSS software,version 18.

3.8 Statistical, data analysis

Soil physical and chemical data obtained were subjected to statistical analysis. This was presented in tables and descriptive statistics to get the means, standard deviations, coefficient variances, and minimum and maximum values as calculated using SPSS statistical software version 18. Means comparison was done using t-test to find out whether there was any significant difference, at 95% confidence interval, between the calculated means.

CHAPTER FOUR

4.0: RESULTS AND DISCUTION

This chapter presents the results and discussion of the study in three broad sections. That is section 4.1 water chemical properties, section 4.2 soil chemical and some physical properties and section 4.3 on the analysis of farmer's perception on the challenges of horticultural production in Alhegaina.

4.1 Water samples analysis:

Water samples were collected from subsurface wells and surface sources in dry and wet seasons in Alhegaina area and were analyzed for various chemical properties as shown in Tables 9 and 10 for dry season and Tables 11 and 12 for wet seasons

4.1.1 Chemical analysis of subsurface water sampled in dry and wet seasons

The result shown in Table 9 are measurements of chemical analysis of sub-surface water from Alhegaina sampled in the dry season. The results show the minimum, maximum values, and their means and standard deviations for each parameter analyzed. The chemical analysis of this sub-surface water sampled during the dry season was slightly alkaline according to the pH (7.15-7.54) and bicarbonate (95-180 mg/L) contents were found to be relatively high. The total dissolved solids (34.1-84.4 mg/L) with a mean value of 54.6 mg/L were found to be within the acceptable limits of irrigation water quality for tomato and onion production (Ayers and Westcot,1985, APHA,1990,Dewis and Freitas,1970, and Baunder et al,2010; Waskom and Davis,2010). However, continued use of this water for irrigation, may increase soil alkalinity due to its rich content in bicarbonate(135 mg/L) and relatively high soluble Ca and Mg elements which may precipitate as insoluble carbonates in soil and thus increase sodium content in soil solution (Mass,1990).

Table 9: Chemical analysis of sub-surface water sampled in dry season (Alhegaina)

Location	Season	parameters	Sample size	Minimum	Maximum	Mean	Std. Deviation
Al Hegaina	Dry	pH	3	7.15	7.54	7.38	.21
		EC ds/m	3	0.05	0.12	0.08	0.037
		TDS Mg/l	3	34.07	84.37	54.62	26.38
		Cl Mg/l	3	9.94	24.57	17.66	7.35
		Na Mg/l	3	13.48	23.26	18.91	4.98
		Ca Mg/l	3	28.16	54.40	43.13	13.51
		K Mg/l	3	5.26	9.72	8.00	2.40
		Mg Mg/l	3	18.60	115.12	67.25	48.26
		Co_3 Mg/l	3	0	0	.00	.00
		HCO_3 Mg/l	3	95	180	135.00	42.72
		NO_3 Mg/l	3	.10	1.00	.43	.49
		SO_4 Mg/l	3	19.70	26.80	23.63	3.61

4.1.2 Sub-surface water analysis from Alhegaina area during wet season:

The chemical analysis of water samples from sub-surface wells in Alhegaina area during wet season is shown in Table 10. In comparison with Table 9,where sampling was done in dry season, the pH of the water in wet season was slightly acidic, with a mean reading of 6.48.The sulphate, nitrates and magnesium contents were also slightly elevated above those in the dry season with means of 37.1, 2.8 and 78.9 mg/L, respectively. However, for bicarbonates, the values were lower(111.7 mg/L) by nearly 17% than those analyzed during the dry season (135.0mg/L).This would suggest that rain water was slightly acidic due to the presence of sulphur and nitrogen oxides in the precipitate and probably from the dissolved anions from the underlying rocks during percolation(William Ocampo-Dugue et al.,2006;Richard et al.,1987).Richard et al.,(1987) working on US rivers for water quality concluded that terrestrial and atmospheric oxides had great influence on sub-surface and surface water quality. Like water sampled during the dry season, this water also could have no negative effects on soil properties and on horticultural crops. Therefore, it can be used for irrigation without any tangible problems (Westcot,1985 and WHO,1984).

Table 10: Sub-surface water analysis sampled in wet season in Alhegaina area

Location	Season	Parameter	Sample size	Minimum	Maximum	Mean	Std. deviation
Alhegaina	Wet	pH	3	6.20	6.71	6.48	0.26
		EC ds/m	3	0.07	0.10	0.08	0.018
		TDS Mg/l	3	46.90	70.00	55.53	12.60
		Cl Mg/l	3	10.30	16.33	12.54	3.29
		Na Mg/l	3	19.20	21.38	20.57	1.19
		Ca Mg/l	3	27.36	46.88	38.35	9.98
		K Mg/l	3	9.67	10.82	10.24	0.58
		Mg Mg/l	3	54.24	104.12	78.92	24.94
		Co_3 Mg/l	3	0	0	.00	.000
		HCO_3 Mg/l	3	10	175	111.67	88.93
		NO_3 Mg/l	3	1.60	3.90	2.57	1.19
		SO_4 Mg/l	3	20.00	61.30	37.13	21.53

4.1.3. Surface water analysis sampled in dry and wet seasons from Alrahad

From the results shown on Tables 11 and 12, that is the chemical analysis of water sampled from surface source in dry and wet seasons, indicate that the levels of data obtained were generally within the recommended rates for good quality water for irrigation. This is according to Westcot (1985) as indicated on Table 3. However, the data obtained in dry and wet seasons differed slightly in pH (7.53 and 6.60), TDS (24.33 and 32.90mg/L), Mg^{2+}(27.60mg/L), Ca^{2+} (10.80 and 18.37mg/L), and bicarbonates (75.0 and 50.0 mg/L) in dry and wet season, respectively. In wet season, the values of TDS and Ca were higher by 26 and 41%, respectively compared to those analyzed in dry season whereas values for pH (7.53) and HCO_3 (75) were higher by 12.4 and 33.3%, respectively during dry season as compared to those in wet season. Although the values of data analyzed in wet and dry season look generally good for irrigation, if used continuously, more especially that from dry season with high pH (7.53) and high bicarbonates(75.0mg/L), and fairly reasonable magnesium and calcium ions, may elevate further the soil pH due to precipitation of magnesium and calcium carbonates which are insoluble. This leaves sodium ions dominant in soil solution which could affect crop performance due to nutrient antagonism (Ca^{2+} and K^+) during nutrient uptake. It could also affect soil physical fertility in terms of dispersion of soil structure due to build up of sodium (Rhodes,1982; Mass,1990; Goude,1991; Malash et al.,2005 and Nahid et al.,2008). Mass (1990) concluded that high Na+ activity in soil in relation to other cations can intensify sodic soil conditions.

Table 11: Surface water analysis sampled in dry season (Alrahad)

Location	Season	Parameter	N	Minimum	Maximum	Mean	Std. deviation
Al rahad	Dry	pH	3	7.40	7.70	7.53	0.15
		EC ds/m	3	0.03	0.04	0.03	0.01
		TDS Mg/l	3	19.47	29.20	24.34	4.87
		Cl Mg/l	3	4.26	6.39	5.33	1.07
		Na Mg/l	3	14.13	14.39	14.26	0.13
		Ca Mg/l	3	9.60	12.00	10.80	1.2
		K Mg/l	3	7.58	7.82	7.70	.12
		Mg Mg/l	3	24.40	30.80	27.60	3.2
		CO_3 Mg/l	3	0	0	.00	0.00
		HCO_3 Mg/l	3	75	75	75.00	0.00
		NO_3 Mg/l	3	.00	.00	.00	0.00
		SO_4 Mg/l	3	.00	.00	.00	0.00

Table 12: Surface water analysis sampled in wet season (Alrahad)

Location	Seasons	Parameter	N	Minimum	Maximum	Mean	Std. deviation
Rahad	Wet	pH	3	6.52	6.73	6.60	0.12
		EC ds/m	3	0.03	0.07	0.05	0.02
		TDS Mg/l	3	23.80	50.40	32.90	15.16
		Cl Mg/l	3	4.97	5.33	5.21	.20
		Na Mg/l	3	12.09	12.43	12.26	.17
		Ca Mg/l	3	11.76	27.80	18.37	8.38
		K Mg/l	3	5.84	6.41	6.13	.29
		Mg Mg/l	3	10.80	23.04	18.84	6.97
		CO_3 Mg/l	3	0	0	.00	.00
		HCO_3 Mg/l	3	35	65	50.00	15.00
		NO_3 Mg/l	3	0.00	0.00	0.00	.00
		SO_4 Mg/l	3	0.00	0.00	0.00	0.00

4.1.4 Comparison of chemical properties from the water sources and seasons

From the results obtained from the two water sources and seasons as recorded in Tables 9-12 and Appendix II it shows clearly that there were no significance differences in pH, EC, TDS, HCO3 and NO3 data, in both seasons. However, some of the parameters had significant differences in the wet season but not in dry season, for examples Na, K, Mg, in the dry season while other parameters had significant differences in both seasons for example, Cl, Ca and SO4. This could be a reflection of water source origin as influenced by the weathering of parent materials, and differences in seasonal depositions from the atmosphere (Nahid et al.,1950). The differences are made clearer in Fig. 2 where the concentrations of bicarbonates were extremely high in both seasons and from the two sources, followed by magnesium and total dissolved salts (TDS).Chemicals with least concentrations were nitrates ,potassium and chlorides in that order.

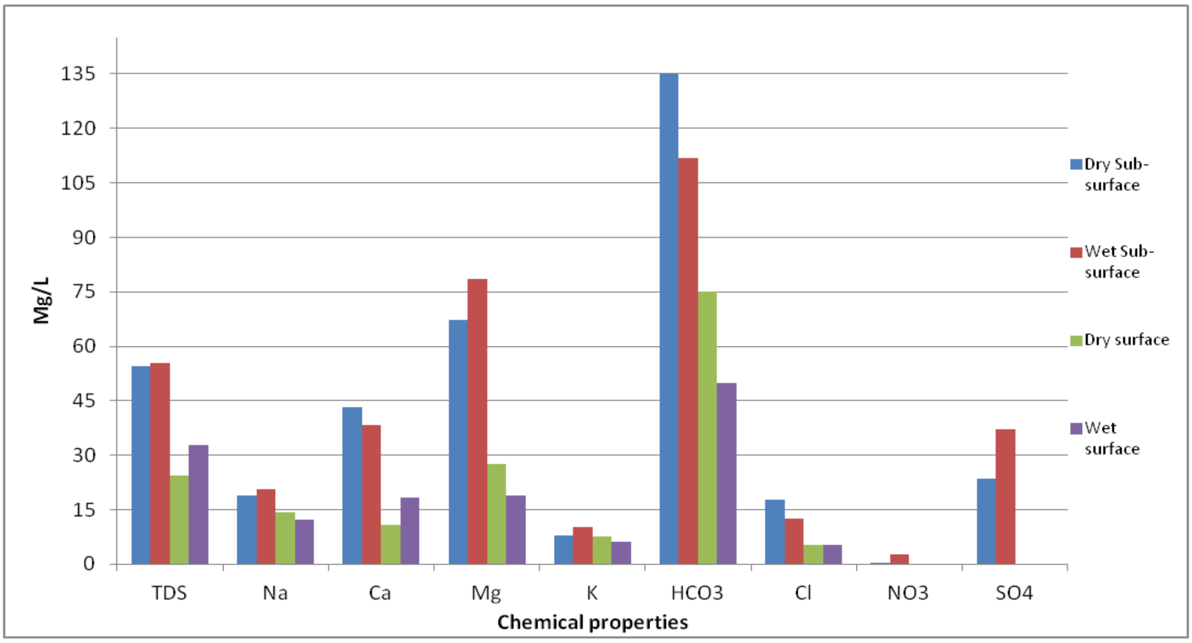

Figure 3: Water quality analysis from sub-surface(Al hegaina) and surface (Al rahad) water sources in dry and wet seasons

4.2 Chemical and some physical properties of soils sampled in dry and wet seasons from farms using sub-surface water for irrigation.

Soil chemical and physical properties analyzed from soils sampled from Algehania during dry and wet seasons are shown in Tables 13 and 14.

4.2.1 Soil chemical and some physical properties sampled in dry season

The chemical and physical soil properties for different depths are shown in Table 13.The data showed that there was no danger of salinity since all the values were below the standard ranges of salinity(Table 5) (Ayer,1997).The soil pH was slightly basic and increased with depth (7.11, 7.30 and 7.50).The bicarbonates similarly increased with depth where mean values ranged between 13.52 and 22.0 Me/g. In terms of SAR and ESP, the values were low, between 0.96 and 2.32 for SAR and between 5.11 and 5.82 for ESP. The Ec of the soil extract was extremely low with values lying between 0.18 and 0.33 dS/m, which indicates lack of danger of dissolved solids in this soil. The soil texture class was sandy clay with bulk densities of between 1.38 and 1.42 g/cm. The concentrations of available N and P as plant nutrients, were extremely low with mean values of 0.02% for nitrogen and between 2.06 and 1.49 mg/kg soil for phosphorus which decreased down the soil profile. The low values of nitrogen and phosphorus in this soil could have contributed to the poor crops performance rather than salinity effect which was suspected. In term of K content in this soil, the soil was well supplied.

Table 13:. Chemical and physical properties of soil sampled in dry season from farms which used sub-surface(wells) water for irrigation(Alhegaina)

	Sample No	Dry Season											
		Depth 0-15				Depth 15-30				Depth 30-45			
Parameters		Min	Max	mean	Sd	Min	Max	mean	Sd	Min	Max	Mean	Sd
PH	5	7.03	7.19	7.11	0.06	7.07	7.48	7.30	0.15	7.32	7.68	7.50	0.13
EC ds/m	5	0.20	0.40	0.30	0.10	0.10	0.24	0.18	0.07	0.12	0.70	0.33	0.22
Cl mg/k	5	35.46	63.83	48.23	12.69	28.37	78.01	56.74	18.76	35.46	56.74	43.97	9.25
Na mg/k	5	2.57	9.65	6.09	2.56	1.83	7.35	4.11	2.03	3.13	6.09	4.83	1.10
Ca mg/k	5	12.00	20.00	16.40	4.10	12.00	20.00	16.00	3.74	8.00	12.00	10.40	2.19
Mg mg/k	5	50.40	84.00	67.12	13.73	26.80	64.80	52.16	14.88	24.00	58.40	47.20	14.39
CO_3 mg/k	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hco_3 mg/k	5	12.20	18.50	13.52	2.79	6.10	24.40	17.12	7.96	12.20	30.50	22.00	6.93
N %	5	0.01	0.03	0.02	0.01	0.01	0.03	0.02	0.01	0.01	0.03	0.02	0.01
P mg/k	5	0.27	3.23	2.06	1.11	1.35	2.23	1.93	0.36	0.86	2.34	1.47	0.62
K mg/k	5	13.76	22.64	17.38	3.60	10.31	16.18	13.04	2.21	11.80	41.07	24.24	11.64
CaCO3 %	5	5.50	8.50	6.96	1.10	5.00	6.70	5.94	0.70	5.90	8.50	7.70	1.07
SAR	5	0.38	1.54	0.96	0.43	0.32	1.55	0.74	0.47	0.55	4.72	2.35	1.65
ESP	5	2.33	9.43	5.82	2.73	2.33	11.10	5.11	3.46	3.72	6.89	5.22	1.54
Sand %	5	43.65	63.65	57.35	7.89	58.65	66.15	61.40	3.33	51.15	67.65	59.34	6.76
Slit %	5	2.00	18.50	9.80	5.99	6.00	10.00	7.88	2.17	3.50	8.50	6.69	2.21
Clay%	5	25.35	39.35	32.88	5.73	24.35	35.35	30.73	4.71	28.85	32.85	31.48	1.80
Bulk Den	5	1.30	1.40	1.38	0.04	1.30	1.50	1.42	0.11	1.30	1.40	1.38	0.04

4.2.2 The chemical and physical properties of soils sampled in wet season

The data for soil samples collected in wet season are shown on Table 14.The data are given in ranges and means,for the three depths, i.e 0-15,15-30 and 30-45 cm. Like the soil sampled in the dry season on Table 13, the data here also were low and with similar trend. However, the pH of the soil during the wet season was slightly acidic ranging between 6.75 and 6.85. Again here, the N and P nutrients were extremely low, almost traces and most likely the cause of low soil productivity. Noticeable also is the amount of cations, especially Ca, Mg and K which were lower than those in soils collected during dry season. This could be due to dilution effect as a result of improved soil solution in the wet season where nutrients were more in the soil solution for plant uptake than during dry season when soils were rather dry (Ayers and Westcot,1994). In the case of SAR and ESP, the values in wet season were higher than those in the dry season but within the normal range of salinity in soils. Therefore, neither the dry season nor the wet season were the soils here in danger of salinity and its effects on crops (Ayer,1997).

Table 14: Chemical and physical properties of soils sampled in wet season from farms which used sub-surface water for irrigation

	Sample No	Wet Season											
		Depth 0-15				Depth 15-30				Depth 30-45			
Parameter		Min	Max	mean	Sd	Min	Max	mean	Sd	Min	Max	Mean	Sd
PH	5	6.65	7.04	6.82	0.16	6.54	7.05	6.75	0.22	6.63	7.02	6.85	0.15
EC ds/m	5	0.02	0.07	0.04	0.02	0.01	0.03	0.02	0.01	0.01	0.09	0.03	0.03
Cl mg/k	5	35.46	63.83	46.81	11.87	21.28	49.64	35.46	13.27	35.46	56.74	42.55	8.69
Na mg/K	5	4.91	6.74	5.35	0.78	3.56	5.87	4.46	0.85	3.43	4.96	4.17	0.66
Ca mg/k	5	12.00	16.00	14.40	2.19	8.00	16.00	10.40	3.58	8.00	16.00	12.00	2.83
Mg mg/k	5	22.59	65.18	43.10	17.22	28.16	37.03	33.65	4.05	16.73	30.59	23.65	5.41
CO_3mg/k	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hco_3mg/k	5	12.20	18.30	15.86	3.34	12.20	24.40	15.86	5.46	6.10	24.40	13.42	7.95
N %	5	0.01	0.02	0.02	0.00	0.01	0.10	0.03	0.04	0.01	0.02	0.01	0.00
P mg/k	5	0.70	2.56	1.52	0.83	0.19	2.02	0.74	0.76	0.28	1.41	1.04	0.46
K mg/k	5	4.15	12.79	8.25	3.25	2.80	5.89	4.47	1.22	3.17	6.28	4.12	1.24
CaCO3%	5	6.70	8.00	7.32	0.51	5.60	7.30	6.56	0.71	5.50	9.00	7.56	1.28
SAR	5	1.04	1.86	1.40	0.35	0.91	1.98	1.55	0.42	1.05	2.69	1.71	0.66
ESP	5	5.81	9.94	7.78	1.70	7.08	11.30	8.45	1.64	7.92	11.44	9.74	1.36
Sand %	5	43.65	63.65	57.35	7.89	58.65	66.15	61.40	3.33	51.15	67.65	59.34	6.76
Slit %	5	2.00	18.50	9.80	5.99	6.00	10.00	7.88	2.17	3.50	8.50	6.69	2.21
Clay %	5	25.35	39.35	32.88	5.73	24.35	35.35	30.73	4.71	28.85	32.85	31.48	1.80
Bulk Den	5	1.30	1.40	1.38	0.04	1.30	1.50	1.42	0.11	1.30	1.40	1.38	0.04

4.2.3 Chemical and physical properties of soils sampled from farms that used surface water for irrigation in dry season.

Table 15 shows the chemical and physical properties of soils sampled from the farms that used water from the dams or surface water sources to irrigate crops. The pH of the soil was slightly alkaline which ranged between 7.38 and 7.68, and increased with depth. The values of EC, N and P were extremely low in this soil while those of cations (Ca,,K and Na) were somewhat low when compared to Mg which was slightly high (ranged between 49.76 – 43.52mg/L) and decreased with depth. The behavior of pH increasing with depth could be due to Ca concentration which increased also with depth accompanied with a fairly reasonable concentrations of bicarbonates. The low levels of nitrogen, phosphorus and potassium which are important plant nutrients in this soil could be probably as a result of repeated cropping of horticultural crops season to season without enough fertilizers application and improper crop rotational pattern or sequence.

Table 15: Soil chemical and some physical properties for soils sampled in dry season from farms which used surface water for irrigation

	Sample No	Dry Season											
		Depth 0-15				Depth 15-30				Depth 30-45			
Parameter		Min	Max	mean	Sd	Min	Max	Mean	Sd	Min	Max	mean	Sd
pH	5	7.12	7.53	7.38	0.16	7.43	7.69	7.54	0.10	7.34	7.96	7.68	0.23
EC ds/m	5	0.30	0.50	0.38	0.08	0.10	0.20	0.14	0.04	0.10	0.50	0.23	0.17
Cl mg/kg	5	28.37	63.83	43.97	13.64	42.55	42.55	42.55	0.00	49.64	78.01	58.15	11.65
Na mg/kg	5	5.52	9.91	6.80	1.85	4.90	7.91	6.20	1.09	6.30	8.44	7.10	0.97
Ca mg/kg	5	8.00	20.00	16.80	5.02	18.00	20.00	18.80	1.10	18.00	20.00	19.20	1.10
Mg mg/k	5	39.60	63.20	49.76	10.45	33.20	58.80	46.48	10.08	39.60	50.40	43.52	4.43
CO_3 mg/k	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hco_3mg/k	5	12.20	18.50	15.98	3.45	12.20	18.50	15.98	3.45	12.20	18.50	14.72	3.45
N %	5	0.00	0.03	0.02	0.01	0.01	0.03	0.02	0.01	0.01	0.02	0.02	0.01
P ppm	5	0.52	1.41	0.90	0.33	0.95	1.96	1.48	0.36	1.40	1.95	1.80	0.23
K ppm	5	9.62	15.80	12.32	2.38	6.30	10.82	8.35	1.73	8.48	9.87	9.21	0.49
$CaCO_3$%	5	7.20	8.30	7.54	0.45	7.00	8.50	7.66	0.63	6.40	8.00	7.10	0.66
SAR	5	0.86	1.60	1.27	0.30	0.91	1.33	1.09	0.17	1.18	1.98	1.43	0.33
ESP	5	5.55	9.67	7.96	1.64	6.20	9.39	7.76	1.44	8.41	9.65	8.96	0.60
Sand %	5	47.15	57.65	52.65	5.05	51.15	52.68	51.92	0.77	46.15	47.15	46.48	0.58
Slit %	5	8.50	22.50	17.75	6.60	19.50	20.97	20.23	0.74	14.50	20.00	16.33	3.18
Clay %	5	26.35	33.85	29.60	3.28	26.35	29.35	27.85	1.50	32.85	39.35	37.18	3.75
Bulk Den	5	1.50	1.60	1.53	0.06	1.30	1.40	1.37	0.06	1.50	1.50	1.50	0.00

4.2.4 Chemical and physical soil properties from farms which used the surface water for the irrigation in wet season

Results of soil properties, both chemical and physical, sampled during wet period from farms that used surface(dam) water for irrigation are shown in Table 16.The pH of the soil was slightly acidic ,ranging between 6.98 and 6.81 within the profile. Compared to the results of Table 15, the Ec as well as N and P were lower in this season than in dry season. Similar trend was seen with the cations (Na, Ca, Mg and K) whose concentrations were lower than those in dry season, more especially that of K. However, for SAR and ESP, in the wet season they were higher than those of dry season while concentrations of bicarbonates were approximately the same. The observed differences between dry and wet seasons data values especially of cations could have resulted from rains in wet season which might have facilitated leaching and uptake of nutrients in the soil solution (Nahid et al.,2008 and Ayers and Westcot,1994).

4.2.5 Comparison of the soil chemical properties of soil samples collected from the farms that used subsurface and surface water to irrigate the crops

In this section, the T-test or T-value was used as a separation of means of the soil properties with an aim to see whether there were any significant differences between the parameters in both dry and wet season from the farms which used water from subsurface wells and surface water source to irrigate the tomato and inions as shown in Tables 16 and 17.

4.2.5.1 Comparison of the soil properties from farms that were irrigated with sub-surface and surface water in dry season

Table 16: Comparison of the soil properties of soil samples collected from the farms that used surface and subsurface water for irrigation in dry season

Depth /Cm	0-15				15-30				30-45			
Location	Sub-surface	surface			Sub-surface	surface			Sub-surface	surface		
Parameter	Mean	mean	T-value	P-value	mean	mean	T-value	P-value	Mean	mean	T-value	P-value
pH	7.11	7.38	3.5	0.01	7.30	7.54	2.9	0.02	7.49	7.68	1.55	0.16
EC ds/m	0.30	0.38	1.3	0.22	0.18	0.14	0.85	0.41	0.33	0.23	0.75	0.47
Cl mg/k	48.22	43.97	0.51	0.62	56.74	42.55	1.69	0.12	43.97	58.15	2.1	0.06
Na mg/k	6.09	6.80	0.50	0.63	4.11	6.19	2.0	0.07	4.83	7.10	3.47	0.01
Ca mg/k	16.40	16.80	0.13	0.89	16.00	18.80	1.6	0.14	10.40	19.20	8.03	0.00
Mg mg/k	67.12	49.76	2.25	0.05	52.16	46.48	0.70	0.50	47.20	43.52	0.55	0.60
HCO_3 mg/k	13.52	15.98	1.2	0.25	17.12	15.98	0.28	0.77	22.00	14.72	2.10	0.60
N %	0.02	0.02	0.76	0.47	0.02	0.02	0.34	0.74	0.02	0.02	1.24	0.25
P ppm	2.06	0.99	2.24	0.06	1.93	1.48	1.98	0.08	1.47	1.79	1.09	0.31
K mg/k	17.38	12.32	2.62	0.03	13.04	8.35	3.73	0.06	24.24	11.63	2.88	0.02
$CaCO_3$ %	6.96	7.54	1.09	0.31	5.94	7.66	4.08	0.00	7.70	7.1	1.06	0.32
SAR	0.96	1.27	1.33	0.22	0.74	1.09	1.55	0.15	2.35	1.43	1.22	0.25
ESP	5.82	7.96	1.51	0.17	5.11	7.76	1.58	0.15	5.22	8.95	5.6	0.00

The comparison of soil chemical data from the farms that used sub-surface and surface water during dry season (Table 16) using T-test as a he comparison of soil chemical data from the farms that used sub-surface and surface water during dry season (Table 16) using T-test as a separation of means, show that highly significant differences ($p<0.01$) were with pH while K and Mg were significant at $p<0.05$ in 0-15cm soil depth when pH and $CaCO_3$ in 15-30cm depth , and Na, K and ESP in 30-40 cm depth were all highly significant ($p<0.01$).This means that sub-surface and surface water used for irrigation had significant influence in the parameters mentioned above in soils. However, as already discussed above, the soil chemical values of the soil, irrespective of the water source in the dry season, were within acceptable limits of salinity for crop use without serious danger to the crops even to the sensitive ones, such as onions and tomatoes (Ayer,1997).

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4.2.5.2 The soil chemical properties from farms that used sub-surface and surface water for irrigation in the wet season

Table 17: Comparison of the soil properties of soil samples collected from the farms that used surface and subsurface water for irrigation in Wet Season

Depth /Cm	0-15				15-30				30-45			
Location	Sub-surface	surface			Sub-surface	surface			Sub-surface	surface		
Parameter	Mean	mean	T-value	P-value	mean	mean	T-value	P-value	Mean	mean	T-value	P-value
pH	6.82	6.98	1.60	0.15	6.75	6.81	0.53	0.61	6.85	6.86	0.02	0.98
EC ds/m	0.04	0.38	0.59	0.57	0.02	0.03	1.25	0.24	0.03	0.02	0.94	0.38
Cl mg/k	46.81	45.39	0.24	0.80	35.45	49.64	1.49	0.17	42.55	36.87	0.87	0.41
Na mg/k	5.35	5.56	0.76	0.52	4.46	5.51	2.7	0.03	4.16	5.30	2.1	0.06
Ca mg/k	5.35	12.00	1,50	0.17	10.40	11.20	0.32	0.76	12.00	11.20	0.41	0.69
Mg mg/k	43.10	29.16	1.67	0.13	33.65	36.05	1.03	0.33	23.65	31.25	1.94	0.08
HCO_3 mg/k	15.86	17.08	0.44	0.67	15.86	18.30	1.00	0.35	13.42	15.86	0.63	0.54
N %	0.02	0.01	0.11	0.92	0.03	0.02	0.86	0.42	0.01	0.01	0.30	0.77
P ppm	1.52	0.50	2.62	0.03	0.74	1.01	0.55	0.59	1.04	0.83	0.56	0.63
K mg/k	8.25	2.64	3.84	0.01	4.47	3.64	1.27	0.24	4.12	2.69	1.27	0.24
$CaCO_3$ %	7.32	7.86	0.70	0.50	6.56	7.18	1.05	0.32	7.56	8.04	0.66	0.53
SAR	1.40	2.20	3.7	0.01	1.54	3.18	2.28	0.05	2.35	1.71	0.84	0.42
ESP	7.78	11.49	4.10	0.00	8.45	9.89	1.59	0.15	7.94	10.69	0.67	0.47

Comparing the soil chemicals results of the wet season (Table 17) with properties of the dry season, as discussed above on Table 16,the results in the wet season were slightly different in values and showed statistical differences. The highly significant differences ($p<0.01$) using the T-test as a separation of means, were observed with K, ESP and SAR, and at $p<005$ for P, in the depth 0-15cm ,while in the depth 15-30cm ,were Na and SAR .In the depth 30-45cm, there were no significant differences observed with all parameters. This could be due to low effect of the irrigation water percolation at this depth. Like in the dry season, the source of water significantly affected some soil parameters in the wet season. However, the different farming practices in the area (e.g cropping systems), and the dissolution of underlying rocks by rainfall and irrigation water could have also contributed to the distribution and concentration of nutrients in the soil (Breckel,1995,Colling and Jenkins,1996).

4.3 Farmers' perception on Horticultural Crops Production in Alhegaina

4.3.1 General overview and presentation of the section

The response on farmers perceptions as to the factors affecting horticultural crops production in Alhegaina area were obtained from a questionnaire as formulated in Appendix I. The questionnaire considered the knowledge and educational level of farmers in horticultural crops production mainly tomato and onion production, training of farmers by extension service, factors affecting crop yields as understood by farmers, methods of cultivation, source of water for irrigation and the kind of fertilizers farmers use for horticultural crops production.A study sample of 56 respondents were used in the study, accounting for 10% of the farmers in the area.

4.3.2 Education level

Fig.4 shows the educational level of small-scale farmers in Alhegaina who were interviewed. The majority of the farmers (58.9%) had attained primary educational level, followed by illiterates (16.1%),intermediate(14.3%) and lastly by those with secondary and above (10.7%). At primary level of education in Sudan, there are no agricultural courses taught, but at secondary level and above. This shows that most farmers have low knowledge on agricultural practices and this contributes a lot to poor agricultural performance in the area and more especially on horticultural crops production. Similar conclusions have been reported by others (Haq,2012,Knight et al.,2003 and Haq et al.,2004).However, in his study, Haq (2012) found that the returns to education showed even from primary schools which is not the case in Sudan.

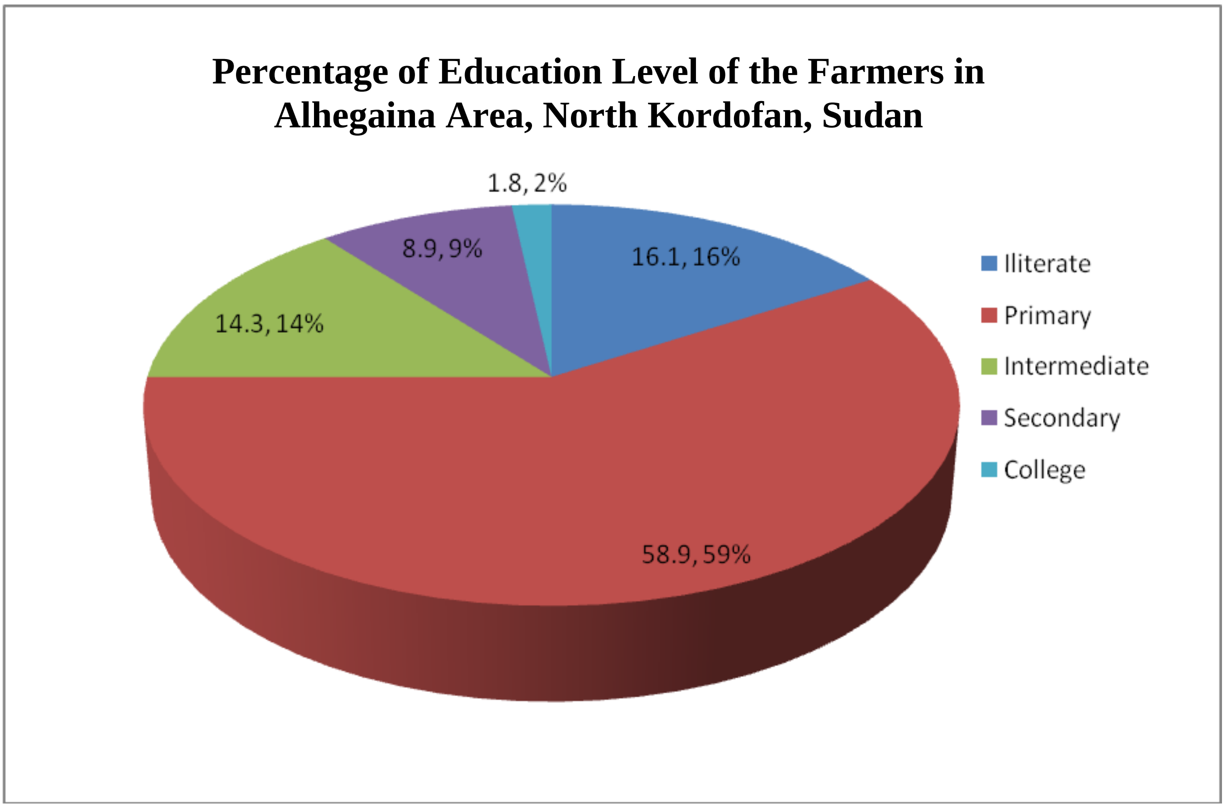

Figure 4: Educational level of the farmers in Alhegaina area, North Kordofan, Sudan

4.3.3 Type of horticultural crops that are grown in alhegaina

Most farmers in Alhegaina grow both vegetables and fruits and at the same time as shown in Table 18, majority (55.1%) of the farmers surveyed were found to grow both vegetables and fruits whereas 41.1% were growing vegetables alone and 3.6% were growing fruits. The vegetables included onions, tomatoes, potatoes, wide leaf and carrots, while the fruits included mango, guava, and lemon. This shows the importance of vegetables in the area compared to that of fruits. The people of the area grow vegetables mostly because they get good money to add to the family income. Many types of cultivars of fruits and vegetable can be produced almost all the year round due to the climatic variations plus available land and water. This large potential could supply both local and export markets (Elbashir and Imam, 2010). The results shown on Figs. 5 and 6 show that 92.8% of the farmers grow tomatoes whereas 25% grow onions in the area.

Table 18: Type of horticultural crops which are cultivated in Alhegaina

Kind of horticultural crop	Frequency	percent
Vegetables	23	41.1
Fruits	2	3.6
Both	31	55.1
Total	56	100

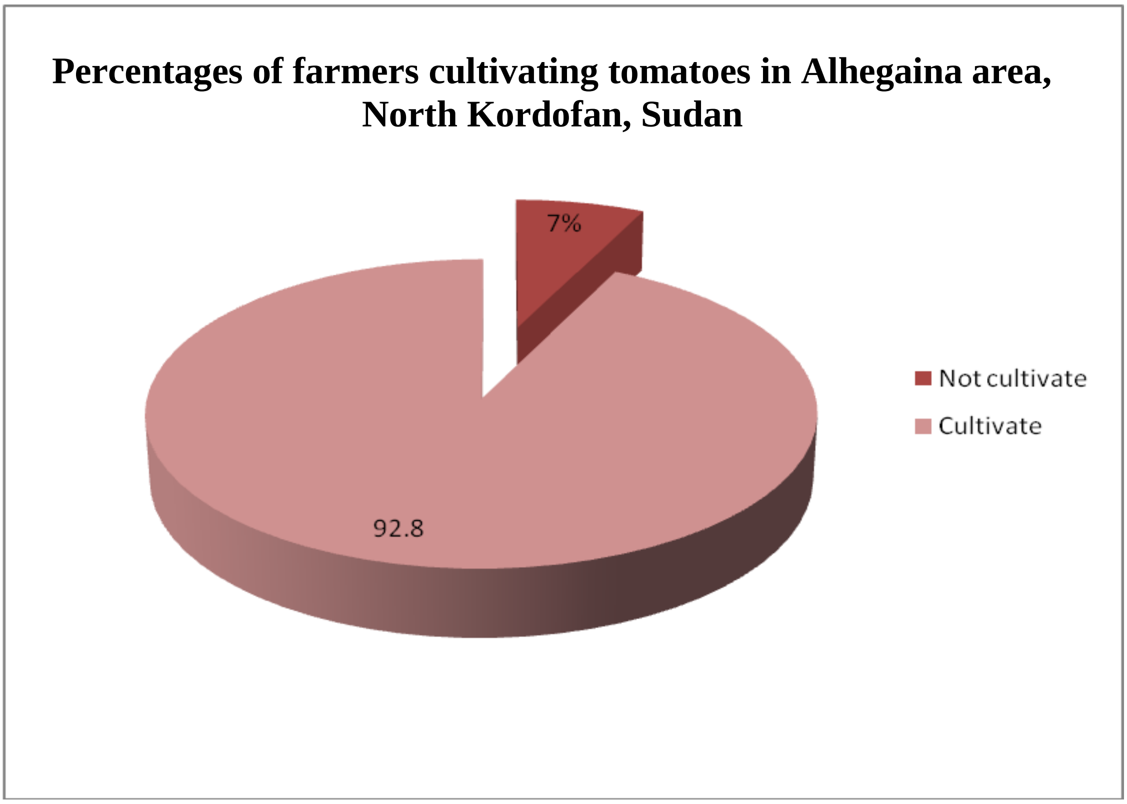

Figure 5: Percentages of farmers cultivating tomatoes in Alhegaina area, North Kordofan, Sudan

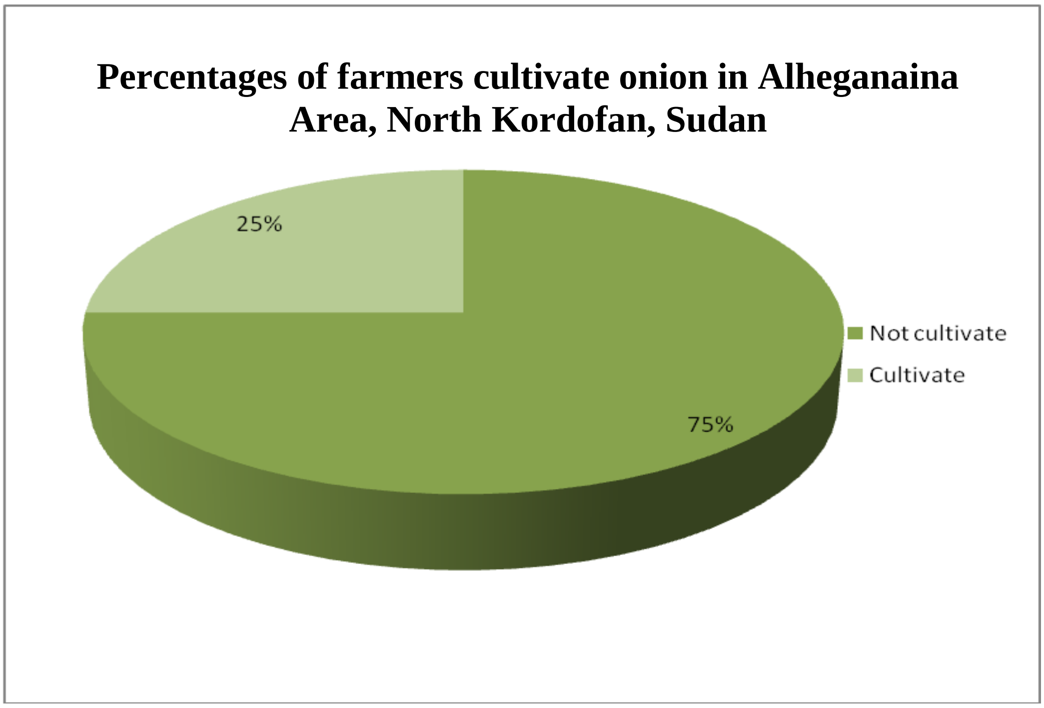

Figure 6: Percentages of farmers cultivate onion in Alhegaina area, North Kordofan, Sudan

4.3.4 .Tomato and Onion cultivation and performance in Alhegania

Fig, 6 show the number and percentage of farmers cultivating onions and tomatoes at Alhegaina area respectively. Fig, 7 shows the yield production of the crops per feddan. Majority of farmers grow tomatoes (92.8%) as compared to onions (25%). Production yield levels of tomatoes is still low, less than 6 tonnes /feddan, attained by 57.1% of the farmers while only 35.1% the farmers attain yields above 6 tonnes / feddan. In the case of onions, 17.9% of the farmers produce less than 6 tonnes /feddan and only 7.1% produce more than 6tonnes / feddan. From the results shows that majority of farmers 75% not cultivate onions. The major constraints of fruits and vegetables production in Sudan are summarized as follows: lack of sufficient improved management technology, inadequate financial and credits facilities, land fragmentation, poor vegetables seed production, limitation application of agricultural research findings due to inadequate extension services, low productivity due to poor and traditional cultural practices, high cost and improper local transportation, weeds, and low control of pests and diseases (Elbshir and Imam, 2010).

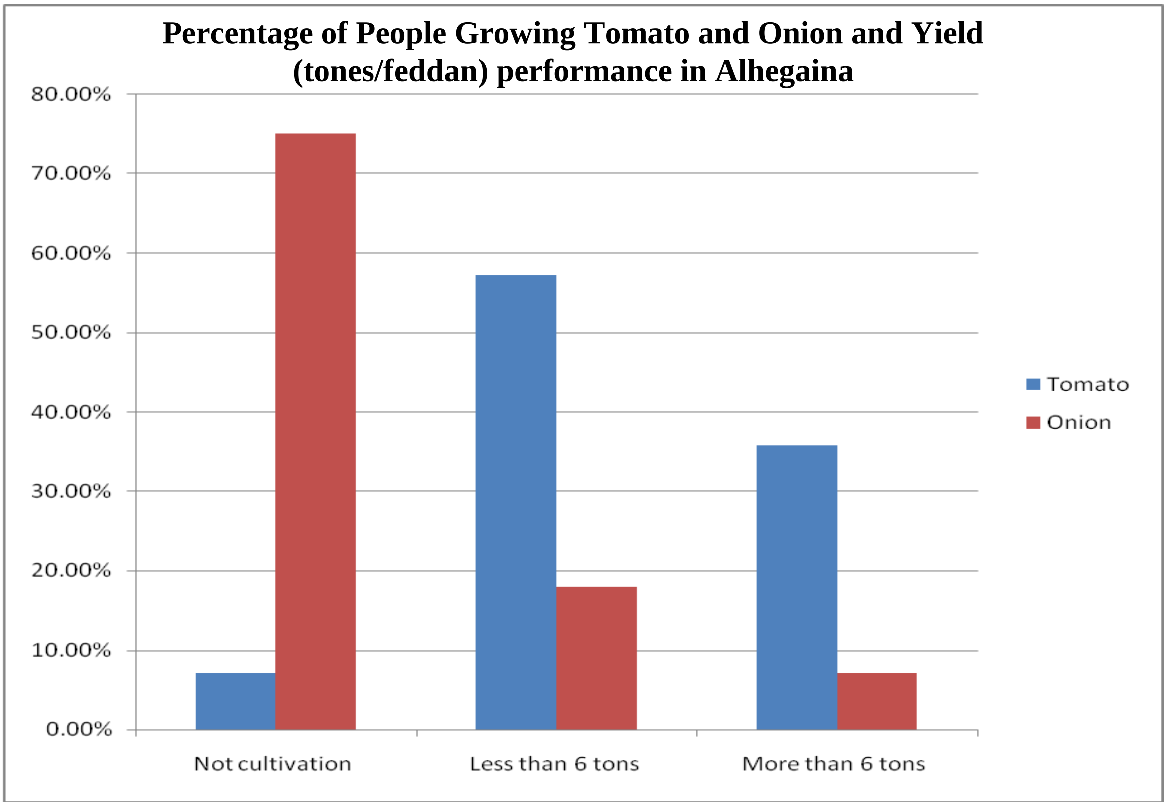

Figure 7: People growing Tomato and Onion and Yield (tonnes/feddan) performance in Alhegaina

4.3.4. Farmers receiving training and funding

From the result shown on Fig 8 means farmers who received neither training nor funding, whereas "Yes" means the farmers who received training and funding. Of the farmers interviewed, 94.6% did not received any training whereas 92.9% received no funding at all. Out of 56 farmers, only 5.4% received some training, and 7.1 received some funding. Considering that horticultural crops production requires at least people with some knowledge and skills in agriculture, it therefore means that the level of horticultural crops production will continue to be low in Alhegaina unless the Government takes the initiative of training such farmers or regularly train them in short courses. This also goes with funding to boost production which is very necessary for small scales horticultural crops' farmers. Credits facilities should be extended to these farmers as well (Elbshir and Imam, 2010).

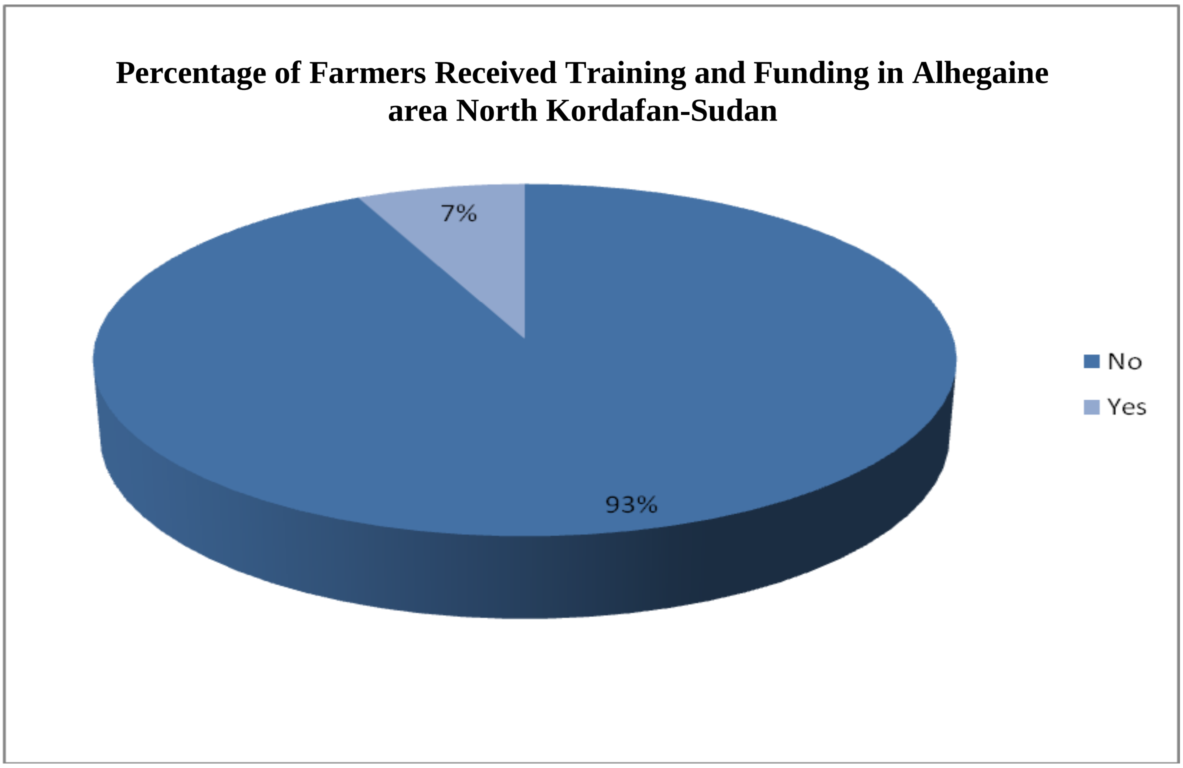

Figure 8: Percentage of Farmers Received Training and Funding in Alhegaine area North Kordafan-Sudan

4.3.6 Low yield related to the soil and water sources

Information gathered from farmers indicated that soil fertility and water quality are some of the factors perceived contribute to low yields of crops in the area (Table 19).The table shows that 39.3% of the respondents attributed low yield to water source whereas 33.9% felt that the problem was on soil fertility. The remaining group, that is 21.4% put the blame on both soil fertility and water source while a small percentage of the people interviewed (5.4%) did not have any clue. According to the findings of this study as discussed in sections 4.1 and 4.2, the main cause of low productivity of the area is the soil fertility and to a small extent water. The levels of N and P, the major nutrients for crop productions, were found to be very low in the soils of Alhegaina. Good yields can only be realized if N and P inorganic fertilizers are applied. In the side of water quality, both from surface and sub-surface was found to be acceptable for use for its salinity level was fairly low.

Table 19: Soil fertility and water quality as factors affecting crops yields

low yield related to these factors	Frequency	Percent
none of them	3	5.4
Soil fertility	19	33.9
Water sources	22	39.3
Both	12	21.4
Total	56	100

4.3.7 Method of irrigation and water sources used for irrigation

Questioned about the water source for irrigation and the method used to irrigate, 58.9% of the farmers said that they use sub-surface water, mainly from the wells while 41.1% use surface water from dams show table 20. On irrigation method, the results show that 98.2% of farmers used surfarce methods for irrigation as shown on Table 21, and only 1.8% use modern methods. Farmers use engines to pump water from surface or sub-surface(wells) sources to distributed randomly on to the farm fields using furrows. Only 2% of the farmers were found to use sprinkler system of irrigation.

Table 20: Sources of water used for irrigation

Kind of sources	Frequency	Percent
Surface	23	41.1
Subsurface well	33	58.9
Total	56	100

Table 21: Kind of irrigation used in alhegaina area

Type of irrigation	Frequency	Percent
Flooding surface	55	98.2
Sprinkler	1	1.8
Total	56	100

4.3.8 Tillage equipments used by farmers

Table 22 shows the type of equipments used for land preparation by farmers at Alhegaina. About 98% of the farmers use disk plough for preparing the land, whereas only 2% use disk and harrow. It should be noted that these machines for tillage are not owned by the farmers but hired or borrowed for use. This is another expense to the poor farmers.

Table 22: Type of machines used for tillage

Type of machine used in tillage	Frequency	Percent
Disk	55	98.2
Disk and harrow	1	1.8
Total	56	100

4.3.9 Farmers using fertilizers and types

When farmers were asked whether they use fertilizers in growing crops in the area, almost 100% responded positively, that they use some fertilizers in horticultural crop production. However, when asked on the rates they use and how they apply the fertilizers, a few farmers responded that sometime using fertilizer during farm season, while the majority had no knowledge of fertilizer use and even the rates required by various crops. On the types of fertilizers to be used, most farmers did not know the kind of fertilizers to be applied, how much and at what time, and for what crop. They applied whatever fertilizer was available in the market. This is made clearer on Fig. 9 which shows the different types of fertilizers used by farmers in Alhegaina. Of the farmers who use fertilizers, 39% use urea, 32% use urea plus leaf mulch residues and 21% use urea with organic fertilizer, mainly cattle and sheep wastes. The rest of the farmers either use animal wastes alone (3.6%) or a combination of urea, leaf residues and animal wastes(1.8%) or urea with phosphate fertilizers (1.8%).

As mentioned above, while most farmers are applying fertilizers for crop production, there is great need to be educated on fertilizer use, type for each crop and when and how to apply. This will not only improve yields and farmers' knowledge but also improve fertilizer use efficiency and cost effectiveness of fertilizer to the farmers. Parts of the farmers using fertilizers there another factors effecting agricultural crops. Land degradation is a major land problem in the Sudan resulting from desert creep, water and wind erosion, sodicity effect and loss of fertility. These factors, among others, lead to the observed decline in agricultural productivity in the main rain-fed and irrigated areas (Agricultural report, 2013).

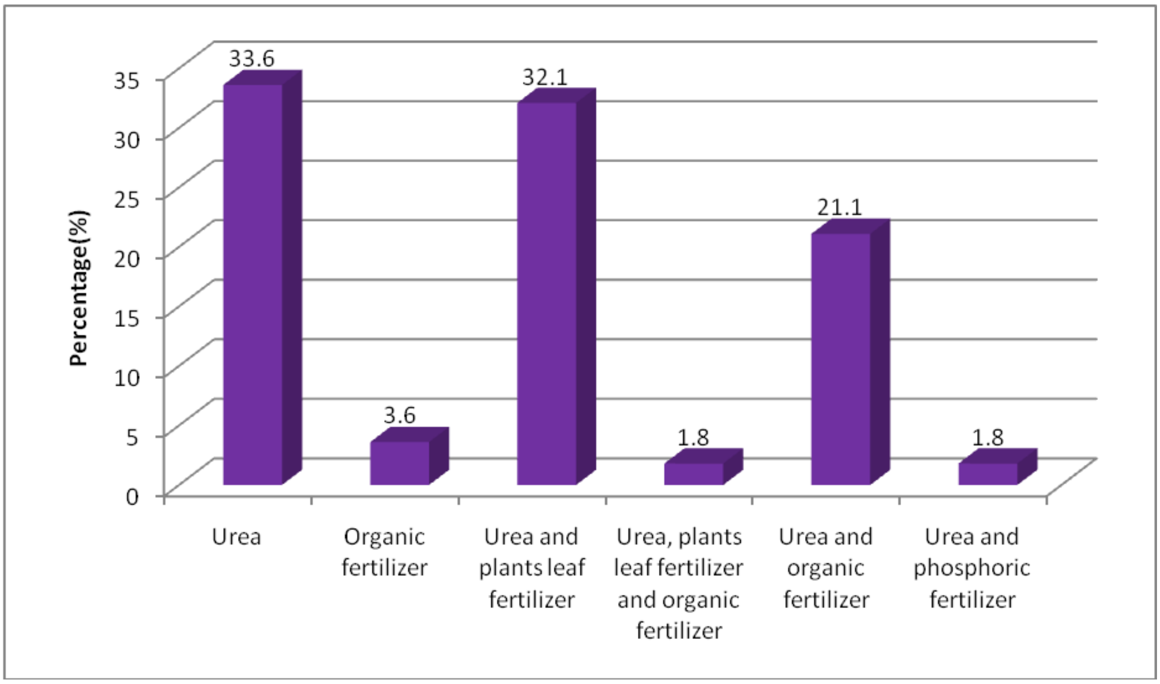

Figure 9: Types of fertilizers used by farmers in alhegaina area

CHAPTER FIVE

5.0 Conclusion and Recommendations

5.1 Conclusion

The objectives of this study were to assess the suitability of water used for irrigation in the production of horticultural crops as drawn from sub-surface and surface sources in dry and wet seasons, effect of this water on soil chemical properties, and farmers' perception on onion and tomato production in relation to water source for irrigation and crop yields. From the results of this study, the following conclusions were reached:

- That the chemical properties of water used for irrigation both from sub-surface and surface sources did not differ significantly and that their chemical values were within the limits acceptable for irrigation and crop production. However continuous use of this water especially that from sub-surface, in dry season may lead to sodicification of the soil.
- That the seasonal water application had some slight influence on soil chemical properties, more especially in the wet season where concentrations of cations (Na,Ca,Mg,K)were slightly lower than those in the dry season. Soils in the dry season, however, exhibited higher pH and bicarbonates than those in the wet season.
- That soils generally were of low soil fertility with very low values of N and P, and in some cases K.
- Perception of farmers in horticultural crops production was found to be very low both in terms of inputs usage, knowledge in farming, and poorly facilitated in terms of funding and extension service.

5.2. Recommendations

- Regular check up of water used for irrigation for chemical properties is very necessary in order to monitor its salt contents
- Use of inorganic and organic fertilizers to this very poor soil is mandatory in order to increase its productivity.
- The Government and as well as NGOs must come up with a policy/programme of educating farmers on modern farming methods through extension service to reach as many farmers as possible and to advise them accordingly to increase horticultural crops production.
- Extension service to horticultural crops growing farmers to be strengthened.
- Government to assist farmers in credit procurement in order to boost crop production
- More research to be carried out especially in the farmers'fields as away of educating farmers on the good practices of horticultural crops production.

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APPENDICES

APPENDIX I: Questionnaire

To investigate the factors which has relation with lack of horticultural crop production in alhegina area North Kordofan –sudan

A - General questions :

1. i- Sex ………………….. ii- Age …………………

iii) Level of education

University [ ] Middle level College [ ] Secondary [ ]

Intermediate [ ] Primary [ ]

2. For how long have you been practicing horticulture:

………………………………………..

3.- How many acres of land do you have for farming: ……………….

4. Which type of horticultural crop do you plant: 1- onion [ ] 2- tomato [ ] 3- both[ ]

5- After harvesting horticultural crop do you get?

1- High yield (more then 6 ten/fed)[ ] 2- Low yield(low than 4 ten/fed) [ ]

6. If low yield, what are the reasons?

……………………………………………………………………………………………

……….

ix – Have you ever received any training concerning horticultural crops production: yes [ ] no[ ]

If yes, who is providing the training?. The government [ ] NGOs [ ]

x- Have you ever received some amount of money from any agencies as GOs and NGOs yes [ ] no[ ]

If yes, did you spend it on horticultural crop production? No [ ] yes [ ]

B- Data which is related with soil and water

a - Do you think low yield has relation with: soil fertility [ ] water sources [ ]   both [ ]

b-   Kind of water sources used for irrigation : is it from water surface[ ] ground surface[ ] both [ ]

c- Type of irrigation method used :traditional irrigation [ ] modern irrigation [ ] both [ ]

C- Data that relations with agricultural activities:

a- did you use tillage in planting: yes [ ]   no [ ]

If yes, specify…………………………………………………………………..

b- have you ever used fertilizer :   yes [ ][no [ ]

If yes specify the type of fertilizer……………………………………………

APPENDIX II: Table 14 for the comparison of water samples were collected in dry and wet season

Season	Dry season						Wet season					
Location	Subsurface	Surface	Sub-surface	Surface	T-test		Sub-surface	Surface	Sub-surface	Surface	T-test	
Parameter	mean	mean	SD	SD	T-value	p-value	mean	Mean	SD	SD	T-value	P-value
pH	7.38	7.53	0.21	0.15	1.013	0.368	6.48	6.60	0.26	0.11	0.69	0.53
EC ds/m	0.078	0.035	0.038	0.006	1.956	0.122	0.079	0.047	0.018	0.022	1.99	0.12
TDS mg/l	54.62	24.34	26.37	4.87	1.956	0.122	55.53	32.90	0.013	0.015	1.99	0.12
Cl mg/l	17.65	5.33	7.35	1.07	2.877	0.04	12.54	5.21	3.30	0.21	3.85	0.02
Na mg/l	18.91	14.26	4.97	0.13	1.618	0.181	20.57	12.25	1.19	0.17	11.94	0.00
Ca mg/l	43.13	10.80	13.50	1.20	4.130	0.01	38.34	18.37	9.99	8.38	2.65	0.06
K mg/l	8.00	7.70	1.20	2.40	0.219	0.83	10.24	6.13	6.13	0.53	11.11	0.00
Mg mg/l	67.25	27.60	48.26	3.20	1.42	0.23	78.92	18.84	24.94	6.97	4.02	0.02
HCO_3mg/l	135.00	75.00	42.72	0.00	2.433	0.07	111.67	50.00	88.93	15.00	1.08	0.30
NO_3 mg/l	0.43	0.00	0.49	0.00	1.522	0.20	2.57	0.00	1.19	0.00	3.73	0.02
SO_4 mg/l	23.63	0.00	3.61	0.00	11.334	0.00	37.13	0.00	21.53	0.00	3.99	0.04

Degree of freedom (df) = 4, SD = standard deviation

APPENDIX III soil chemical and some physical properties sampled in wet season from farms which used surface water for irrigation

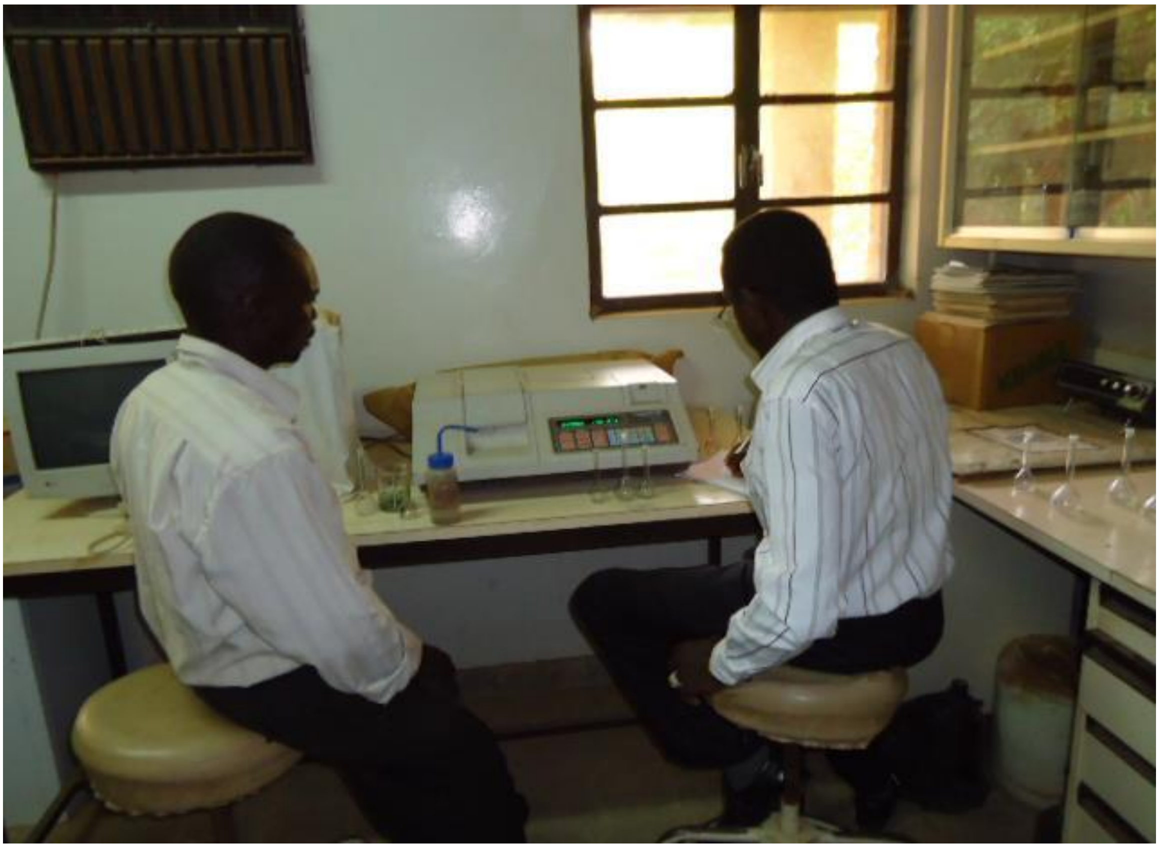
	Sample No	Wet Season											
		Depth 0-15				Depth 15-30				Depth 30-45			
Elements		Min	Max	mean	Sd	Min	Max	mean	Sd	Min	Max	mean	sd
PH	5	6.82	7.14	6.98	0.15	6.61	7.04	6.81	0.16	6.69	7.13	6.86	0.17
EC ds/m	5	0.02	0.05	0.03	0.01	0.01	0.05	0.03	0.01	0.01	0.03	0.02	0.01
Cl mg/kg	5	35.46	49.64	45.39	6.34	28.37	63.83	49.64	16.63	28.37	56.74	36.88	11.65
Na mg/kg	5	5.10	6.57	5.65	0.60	5.36	5.76	5.51	0.17	4.26	6.87	5.30	0.99
Ca mg/kg	5	8.00	16.00	12.00	2.83	4.00	16.00	11.20	4.38	8.00	16.00	11.20	3.35
Mg mg/k	5	22.59	39.46	29.17	7.01	34.59	41.89	36.05	3.26	22.59	41.89	31.25	6.88
CO_3 mg/k	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hco_3mg/k	5	12.20	24.40	17.08	5.10	18.30	18.30	18.30	0.00	12.20	18.30	15.86	3.34
N %	5	0.01	0.02	0.02	0.00	0.01	0.03	0.02	0.01	0.01	0.02	0.01	0.01
P ppm	5	0.17	0.75	0.50	0.25	0.21	2.29	1.01	0.80	0.30	2.21	0.83	0.80
K ppm	5	2.17	3.02	2.65	0.31	2.38	4.38	3.64	0.78	1.28	3.72	2.70	0.95
CaCO3%	5	6.00	9.50	7.86	1.64	6.00	8.60	7.18	1.11	6.50	9.20	8.04	0.99
SAR	5	1.64	2.44	2.20	0.33	1.79	5.79	3.18	1.55	1.21	2.71	2.07	0.68
ESP	5	9.85	12.80	11.50	1.10	8.31	11.59	9.90	1.18	7.36	13.24	10.69	2.45
Sand %	5	47.15	57.65	52.65	5.05	51.15	52.68	51.92	0.77	46.15	47.15	46.48	0.58
Silt%	5	8.50	22.50	17.75	6.60	19.50	20.97	20.23	0.74	14.50	20.00	16.33	3.18
Clay %	5	26.35	33.85	29.60	3.28	26.35	29.35	27.85	1.50	32.85	39.35	37.18	3.75
Bulk D	5	1.50	1.60	1.53	1.06	1.30	1.40	1.37	0.06	1.50	1.50	1.50	0.00

APPENDIX IV PICTURES

Alrahad resevoir(catchment)

Soil Samples In Alhegaina Area

PH Meter



Phosphorious meter (Spectorinic meter)