UNIVERSITY OF CAPE COAST

FARMERS' PERCEIVED SUSTAINABILITY OF COTTON PRODUCTION UNDER THE GEZIRA SCHEME IN SUDAN

BY

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Thesis submitted to the Department of Agricultural Economics and Extension, School of Agriculture, College of Agriculture and Natural Sciences, University of Cape Coast in partial fulfilment of the requirements for award of Master of Philosophy degree in Agricultural Extension

AUGUST 2015

DECLARATION

Candidate's Declaration

I hereby declare that this thesis is the result of my own original work and that no part of it has been presented for another degree in this University or elsewhere.

Candidate's Name: Omer Ali Mohammed Adbdalla

Signature ………....…………… Date…..……………..................

Supervisors' Declaration

We hereby declare that the preparation and presentation of the thesis were supervised in accordance with the guidelines on supervision of thesis laid down by the University of Cape Coast.

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ABSTRACT

Cotton production plays an important role in farmers' livelihood in the Gezira State in the Sudan. Cotton is the main cash crop produced in the scheme. However, sustainability of cotton production in the Gezira Scheme has been an interesting issue, especially, after the noticeable deterioration of the cotton industry in the last few years. This study determined the environmental and economic sustainability of cotton production in the Gezira Scheme as perceived by farmers who are the direct beneficiaries of the scheme. Data was collected from farmers using interview schedule. The data was analysed with descriptive statistics including frequency, percentage, mean and standard deviation and the inferential statistic Spearman's rank correlation. The results showed that majority of the respondents were above the productive age set by the United Nations. The majority of the farmers had access to formal education and had an average farm size of 8.4 hectares with about 22.33% of it under cotton cultivation. The level of sustainability of cotton production was found to be moderate or fairly sustainable. There were positive relationships between farmers' education level, farm size and sustainability, the relationship between farmers' age, family size and sustainability was negative. The study found adequacy of irrigation water, availability of farm inputs and mechanization of agricultural practices as the main contributing factors to the sustainability of cotton production in the Gezira Scheme. The study recommends that the Ministry of Agriculture and the Gezira Scheme Management should promote the use of organic fertilizers, educate the farmers on soil conservation practices and negotiate with the actors along the cotton value chain to reduce the price of production inputs to affordable levels and increase the price of the outputs.

ACKNOWLEDGEMENTS

I greatly acknowledge the strong commitment of my supervisors Prof. Ernest Laryea Okorley (principal supervisor) and Mr. Samuel Akuamoah Boateng (co-supervisor) who have patiently guided, supported, and closely supervised me to come up with this thesis.

I want to express my gratitude to all staff of the Department of Agricultural Economics and Extension, School of Agriculture especially, the Head of Department, Prof. Festus Annor-Frempong for not only being supportive but also, providing me with worthy contributions and academic basis that enabled me undertake this study.

I owe unlimited appreciation to the INTRA-ACP Mobility Scheme and SHARE Programme for granting me the rare privilege and financial support to undertake the M.Phil programme that led to this thesis. At this juncture, I have to mention SHARE coordinator in the University of Gezira, Sudan, Dr. Muna Mohammed Elhaj and also, the SHARE coordinator in the University of Cape Coast, Ghana, Prof. Paa Kobina Turkson, for their unlimited support and encouragement.

My sincere gratitude goes to all my classmates, in particular, Chimkanma Chimenem Wigwe and Joaquim Bucuane for their support and advice that helped to improve this research work. Special thanks go to Francisca Deepu for assisting me with language editing throughout the write up of this thesis.

DEDICATION

To my mother Shabak Elnour Mohammed and to the memory of my late father Ali Mohammed Abdalla

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LIST OF ACRONYMS

ARC	Agricultural Research Corporation
DAE	Department of Agricultural Engineering
EPAR	Executive Programme for Agricultural Revival
EPI	Environmental Performance Index
EU	European Union
FAO	Food and Agriculture Organisation of the United Nations
GDP	Gross Domestic Product
ICAC	International Cotton Advisory Committee
IFAD	International Fund for Agricultural Development
IIED	International Institute for Environment and Development
IMF	International Monetary Fund
OECD	Organisation for Economic Cooperation and Development
SGB	Sudan Gezira Board
UN	United Nations
UNCTAD	United Nations Conference on Trade and Development
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
WHO	World Health Organisation

CHAPTER ONE

INTRODUCTION

This chapter is the introductory chapter which provides information on sustainable cotton production in the Gezira Scheme of Sudan. The chapter provides the background to the study, statement of the problem, research objectives, research questions, research hypothesis, significance of the study, delimitation of the study, limitations of the study, definition of terms and organization of the study.

Background to the Study

Cotton is an indispensable commodity in sub-Sahara African countries. It is an important component in economic development and remains a key source of livelihood of the most citizens of West African countries (Sahel and West African Club Secretariat & OECD, 2005). More than two million rural households in Africa rely on cotton production to earn their living (Baffes, as cited in Lorenzetti, 2013). Lorenzetti also reported that, in some African regions, cotton is the only cash crop and as such it represents the most important economic activity. For instance, the cotton sector's share in the total merchandise export in West and Central Africa (WCA) ranges from 25 to 45 percent and also, contributes 4-6% to the Gross Domestic Product (GDP). According to International Cotton Advisory Committee (ICAC) (n.d.), employment in the cotton sector in Africa is estimated at about 20 million people, but economic dependency on cotton as the only cash crop for most families would involve far more number of employees in the sector. ICAC also concluded that cotton is the largest employer in countries such as Burkina Faso, Chad, Mali and Togo. In Mali, direct employment in the cotton sector is estimated at 3 million whilst 13 million is estimated to be economically dependent on cotton. In Zambia, about 250,000 families with 14 million people representing 13% of the national population are directly dependent on the cotton industry for part or all of their livelihoods. In Mozambique, an estimated 1.5 million rural citizens earn cash directly from cotton (Lorenzetti, 2013).

In Sudan, cotton is one of the most important cash crops, with more than 300,000 families depending on it for their livelihoods. In addition to farm families, several other thousands of Sudanese are engaged in cotton related activities. Before oil production started in 1999, cotton was Sudan’s main foreign exchange earner. Currently, cotton contributes 1.8 % to the country’s agricultural GDP (Sudan Cotton Company, 2013). Cotton is grown in Sudan under various topographical and environmental conditions. Various methods of irrigation and different applications of chemical inputs are used in the cotton industry. Cotton is cultivated in clay soil in Gezira, Rahad, New Halfa, Suki, Blue Nile and White Nile schemes, in silt soil in Tokar delta of Eastern Sudan and in heavy clay soil in Nuba Mountains area of Western Sudan (Sudan Cotton Company, 2011). A major and an important cotton production scheme in the Sudan is the Gezira Scheme.

The Gezira Scheme started in the early years of the Anglo-Egyptian rule of the Sudan with a pilot project for growing cotton as a cash crop in 1911 in the central part of Gezira State (Salman, 2010). Salman also asserted that the scheme was designed to be a large farm for growing cotton as a cash crop to support the Anglo-Egyptian government in Sudan with, income for defraying part of the cost of administration of Sudan, and to help with the economic development of the Gezira area, and the Sudan as a whole. The Gezira Scheme also contributes to national food security and forms the basis of the livelihoods of about 2.7 million people who live within the Scheme (Al Naiem, as cited in Mahgoub, 2014). The intensive labour demand in cotton farming and cotton–based industries provides employment, reduces poverty, improves lives and encourages settlement in rural areas (Ahmed, 2010).

Despite the roles attributed to the Gezira Scheme in the socio-economic development of Sudan, there is the argument that the Scheme has not had the needed impact on the people. The assertion is that the irrigated cotton sub-sector has generated the smallest income multiplier for rural households compared to two other main sub-sectors in Sudanese agriculture (semi-mechanized and traditional farming) (Salman, 2010). According to Salman (2010), the Gezira Scheme is uneconomic from the national and tenant point of view. The problem of uneconomic production comes mainly from low productivity and high production costs. The interaction of high production costs and lower yields of cotton resulted in an under proportional income shift (Ahmed, Suliman & Mohd, 2012). Productivity comparisons for recent years reveal that Sudan's cotton yield forms an average of about 50% of those in Egypt, 30% of Syria's cotton, and from time to time is lower than productivity in West African countries that mostly grow rain-fed cotton (Faki, 2006). The present pattern of escalating cost of production and stagnating low yields may question the economic feasibility of growing cotton in the Gezira Scheme.

Due to the observed low output of the agricultural sector in Sudan and the Gezira Scheme, the Government of Sudan, as part of its strategic orientation to accelerate agricultural development, issued some programmes such as the Green Mobilization Programme and the Executive Programme for Agricultural Revival (EPAR). The agricultural revival programmes gave support to the cotton production sub-sector and much concern is being given to the low cotton productivity and the challenges for its improvement (Sudan Cotton Company, 2013). Also, the Management of the Gezira Scheme, in collaboration with Agricultural Research Corporation, introduced several technologies and inputs under the policy of agricultural intensification in order to solve the problem of low productivity and raise the income of the agricultural households. These inputs include improved seed varieties, chemical fertilizers, pesticides and different types of agricultural machineries.

The mechanization and intensification of agriculture in the Gezira Scheme involving intensive use of pesticides, fertilizers, dam construction and irrigation have brought environmental concerns and doubts about the sustainability of the Scheme (Moghraby, as cited in Gbenga, 2008). Gbenga reported that the canalization for the Gezira Scheme which is about ten thousand kilometre was launched in the country without consideration for environmental impact, deforestation, population movements and water related diseases after the implementation of the project. Moreover, it is argued that in developing countries conventional farming is far from sustainable with demonstrated heavy pesticide resulting in negative impacts on the environment and people (Kooistra, Pyburn & Termorshuizen, 2006). As in most developing countries, there are some challenges facing the agricultural system in Sudan, such challenges include soil deterioration, insect unbalance due to irrational use of insecticides, crop diversification and intensification under dilapidated infrastructure and emergency crop rotations (UNEP, n.d). The problem of soil compaction, deforestation and pollution due to inappropriate use of pesticides coupled with sand dune movements are believed to be contributing to serious ecosystem degradation and desertification in the Sudan (Suliman, as cited in Gbenga, 2008). Consequently, these are said to be having serious negative impact on crop yields and the livelihoods of the poor, particularly, those that depend on livestock and agriculture. The World Development Report (2010) estimated that Sudan's agricultural yields are expected to decline by 56% in 2080, which is the steepest decline in the world.

For cotton production to be sustainable in a more holistic sense, the social, economic and environmental sustainability concerns have to be addressed (Kooistra, Pyburn & Termorshuizen, 2006). The Government of Sudan claims to be aware of the sustainability concerns and thus has established some agencies and policies especially, with regard to agricultural pesticides, desertification, land degradation, water pollution, soil erosion, deterioration of biodiversity and the growth of commercial mechanized agriculture for the production of cotton (IMF, 2013). The government of Sudan has also initiated the Gezira Scheme's Act of 2005 with the aim of ensuring sustainable development of the Scheme's area (Sudan Cotton Company, 2013). The outcomes of these initiatives are yet to be assessed.

Statement of the Problem

The Anglo-Egyptian government in Sudan initiated the Gezira Scheme for cotton production in 1925 to provide income to defray part of the cost of the administration of Sudan, and to help with the socio-economic development of the Gezira area, and the Sudan as a whole (Salman, 2010). The Gezira Scheme has played an important role in economic development and poverty reduction among the people in Gezira State since its establishment (Ahmed, 2010).

To improve the productivity of cotton, agricultural technologies such as pesticides, fertilizers and machineries have been used extensively in the cotton industry under the Gezira Scheme. Despite the lack of accurate data on types and quantities of inputs used, it is concluded that water, machineries, inorganic fertilizer and pesticide use have caused significant environmental problems in cotton production systems (Faki, 2006).

Interestingly, the sustainability of cotton production in Gezira Scheme has not been assessed. To formulate relevant policies and strategies for sustainable production of cotton in Sudan it will require an understanding of the sustainability of the Gezira Scheme cotton production system. In the light of the above situation, the problem investigated in this research was to determine the sustainability of cotton production in the Gezira Scheme as perceived by farmers who are the direct beneficiaries of the Scheme.

Objectives of the Study

General Objective

The general objective of this study was to determine farmers' perceived sustainability of cotton production under the Gezira Scheme in Sudan.

Specific Objectives

The specific objectives of the study were to:

1. Describe farmers' socio-demographic and farm related characteristics in terms of age, sex, level of education, family size, years of experience, farm size, and off-farm activity.
2. Determine farmers' perceived environmental and economic sustainability of cotton production under the Gezira Scheme in Sudan.
3. Examine the relationship between the farmers' characteristics (socio-demographic and farm related) and their perceived sustainability of cotton production.

Research Questions

The research questions were:

1. What are the socio-demographic and farm-related characteristics of cotton farmers in terms of age, sex, level of education, family size, years of experience, farm size, and off-farm activity?
2. What is the perceived environmental and economic sustainability of cotton production under the Gezira Scheme in Sudan?
3. What is the relationship between the farmers' characteristics (socio-demographic and farm-related) and the perceived sustainability of cotton production in the Gezira Scheme of Sudan?

Research Hypotheses

H_0: There is no significant relationship between farmers' farm size and the perceived level of sustainability of cotton production.

H_1: There is significant relationship between farmers' farm size and the perceived level of sustainability of cotton production.

H_0: There is no significant relationship between farmers' age and the perceived level of sustainability of cotton production.

H_1: There is significant relationship between farmers' age and the perceived level of sustainability of cotton production.

H_0: There is no significant relationship between farmers' education level and the perceived level of sustainability of cotton production.

H_1: There is significant relationship between farmers' education level and the perceived level of sustainability of cotton production.

H_0: There is no significant relationship between farmers' family size and the perceived level of sustainability of cotton production.

H_1: There is significant relationship between farmers' family size perceived level of sustainability of cotton production.

H_0: There is no significant relationship between farmers' experience and the perceived level of sustainability of cotton production.

H_1: There is significant relationship between farmers' experience perceived level of sustainability of cotton production.

Significance of the Study

Sustainability of plant production systems is recently receiving special attention. In Sudan, sustainability of cotton production is of high concern after the noticeable fluctuation in area under cotton cultivation and the productivity of cotton especially, in the Gezira scheme which is regarded as the main cotton producing area in the country. It is expected that information from this study will draw the attention of stakeholders to specific indicators that have considerable influence on sustainability of cotton production in the study area. This will make stakeholders focus on the indicators and devote efforts in order to enhance sustainable cotton production in the Gezira Scheme. The study has generated information on sustainability of the production of cotton which is the main cash crop in Sudan. Therefore, this information can be adopted for policy formulation toward achieving sustainable development in the Sudan. Also, the study serves as basis for further studies on sustainability of plant production systems in Sudan.

Delimitation of the Study

The study concentrated on measuring cotton farmers' perceived sustainability of cotton production, taking into consideration economic and environmental sustainability. The study determined environmental sustainability based on farmers' perception, using indicators such as use of fertilizers, use of pesticides, availability of adequate irrigation water, soil conservation practices and use of farm machinery. Variables such as availability and level of prices of farm inputs, level of mechanization of agricultural practices and sufficiency of loans were taken into consideration to determine the economic sustainability.

Limitations of the Study

One of the limitations of this study was that the researcher had a short period of time and limited resources to collect data from the 355 respondents. Due to logistical problems within the six weeks, the researcher and his assistants were able to collect reliable data from 315 cotton farmers out of the 355 sample size. The remaining 40 potential respondents could not be reached because the field survey was done during the rainy season during which most of the roads to the farmers locations were not motorable. The study employed non-probabilistic sampling, which has restriction on generalisation of the findings to all cotton farmers in the Gezira Scheme in Sudan.

Definition of Terms

In the context of this research, the following terms are defined:

Sustainability of cotton production: The capacity to maintain the process of cotton production overtime

Sustainable cotton production: A system for cotton production that can maintain high levels of production with minimal environmental impact and can provide maximum social and economic benefits for producers and their communities

Environmental sustainability: Environmental sustainability requires maintaining natural capital as a provider of economic inputs and an absorber of economic outputs

Economic sustainability: Economic sustainability implies a system of production that satisfies present consumption levels without compromising future needs

Mechanization of agricultural practices: Using tractor to perform agricultural tasks such as ploughing, sowing, weeds control, spraying pesticides, fertilization and harvesting.

Organisation of the Study

The study is structured into five chapters which include introduction, literature review, methodology of the study, results and discussions and summary, conclusions and recommendations.

Chapter one presents the introduction which consists of background to the study, statement of the problem, objectives of the study: general objective and specific objectives, research questions, research hypothesis, significance of the study, delimitations, limitation of the study, definition of key terms and organisation of the study.

In chapter two, the literature is reviewed to describe the earlier researchers' efforts on the topic of this study. Particularly, historical background on cotton production in Sudan and the Gezira Scheme, concept of perception, theory of sustainability and models of sustainability, sustainable agriculture, socio-demographic and farm-related characteristics of farmers which may influence sustainability of agricultural crop production, economic sustainability of plant production, environmental sustainability of plant production and cotton production sustainability were reviewed in this chapter.

The methodology of the study is presented in chapter three. In this regard, the chapter provides explanation on research design, the study area, population of the study, sampling procedure and sample size, instrumentation, data collection and data analysis procedures. The chapter ends with the analytical framework showing variables of the study and their methods of analysis.

The results and discussions are presented in chapter four. The chapter presents the key findings of the study in line with the objectives of the study. In chapter five, the summary of the study is presented and this is followed by conclusions and recommendations.

CHAPTER TWO

LITERATURE REVIEW

This chapter reviews existing theoretical and empirical studies that informed this research. Thus the review covers historical background on cotton production in Sudan and the Gezira Scheme, concept of perception, sustainability theory, models of sustainability, farmers' characteristics that may influence sustainability of crop production on the farm, environmental sustainability of crop production systems and set of indicators for measuring environmental sustainability. The chapter also presents review on economic sustainability of crop production systems and set of indicators for measuring economic sustainability of agricultural crops.

Historical Background of Cotton Production in Sudan

The Sudan Cotton Company (2013) stated that the agricultural sector in Sudan dominates the economy and provides the livelihood for over 80% of the population. It accounts for about 34.5% of GDP and also provides a big share of inputs for the country's agro-industries (African Economic Outlook, 2014). Most of the cotton grown is on large state-managed farming tracts, with a small percentage grown by private farmers. Cotton makes up a sizeable portion of Sudan's exports; some cotton is used domestically in textile factories (Foreign Language Centre, 2012).

According to Faki and Taha (2007) the introduction of cotton in central Sudan (Gezira) in 1925 was preceded by the establishment of the cotton-based

Agricultural Research in Shambat in 1904 and in Medani in 1918. The research institute made available basic scientific information on agricultural environment, varieties, cultural practices and crop protection. Up to the 1980s, cotton was the predominant research area of ARC due to the government priority and full support for commercial cotton production at that time.

Cotton is considered as one of the most important cash crops produced in Sudan. It was the main foreign exchange earner contributing considerably to foreign exchange proceeds. More than three hundred thousand families in Sudan are still depending on cotton for their livelihood while several other thousands are engaged in cotton related activities (Faki, 2006). The intensive labour demand along the cotton value chain provides employment opportunity for the youth, reduces poverty, improves lives and encourages settlement in rural areas in Sudan.

Although cotton had been grown as a commercial crop in Sudan since 1905, the Gezira Scheme helped make cotton one of Sudan's most significant cash crops (Foreign Language Centre, 2012).

History and Development of the Gezira Scheme

Gezira Scheme is the oldest and largest in terms of the area of irrigated schemes in the history of Sudan, and it is considered the most important development project. It is also used to be the biggest irrigation system under one administration in the world (Mahgoub, 2014).

The Gezira Scheme is situated in the triangular plains between the Blue Nile and the White Nile south of Khartoum. The scheme extends southward close to the cities of Sennar on the Blue Nile, and Kosti on the White Nile, about 400 kilometres from Khartoum. In fact "Gezira" is the Arabic word for “peninsular.” The Scheme started in the early years of the Anglo-Egyptian rule of the Sudan with a pilot project for growing cotton as a cash crop in the central part of Gezira in 1911(Salman, 2013). Salman also explained that a number of reasons helped in the success of the pilot project from the very beginning. The flat and featureless plains of Gezira, with a general slope of about 15cm per one kilometre, can be irrigated from the Blue Nile and drained by gravity thus, minimizing considerably the cost of irrigation. The impermeable clay and rich soil of Gezira decreased significantly the loss of irrigation water through seepage and minimized the need for fertilizers. The people of Gezira have practiced rain-fed farming for centuries, and were expected to adapt easily to irrigated agriculture. Moreover, Gezira is close to Khartoum, the capital and to Port Sudan, the major port of the country, through which cotton would be exported.

Following the success of the pilot project in 1912, preparations for the larger scheme started. An agreement was reached with Egypt on the use of the Nile waters for the Scheme for which the Sennar Dam was constructed on the Blue Nile for a maximum area of 126,000 hectares. The Anglo-Egyptian administration was able to obtain a loan from the British government to cover part of the cost of the Sennar Dam. However, the preparatory work was interrupted by the First World War, and the dam was finally completed in July 1925, to commence the Scheme officially. The dam is situated on the Blue Nile about 260 km southeast of Khartoum, and has a total storage capacity of 930 million cubic meters. The Scheme was designed to be a large farm for growing cotton as a cash crop to provide the Anglo-Egyptian government in Sudan with income for defraying part of the cost of administration of the Sudan, and to help with the economic development of the Gezira area, and the Sudan as a whole.

An agreement was reached with the Sudan Plantation Syndicate, a British company registered in London to manage the Scheme. The production relationship involved the government, the syndicate and the cotton growers. The government owned the dam, the irrigation infrastructure and part of the land, initially about half of the 126,000 hectares (Salman, 2010). Salman, further asserted that the other half of the land of the Scheme was privately owned, and in 1927 the government issued the Gezira Land Ordinance which gave the government the authority to compulsorily rent the land from its owners for forty years. Both the government-owned and compulsorily leased lands were rented to the growers with average size of the farm rented to each tenant called Hawasha is generally being about 8.4 hectares, although there have been variations up and down.

The Gezira Scheme has grown in size over the years. According to the conclusion of the Nile Waters Agreement between Egypt and Britain in 1929, the share of the Sudan of the Nile waters gradually increased to four billion cubic meters. This allowed a concomitant expansion of the Gezira Scheme from 126,000 hectares in 1925 to close to 420,000 hectares by 1950. The latter part of the Nile Waters Agreement between Egypt and Sudan in 1959 allowed the construction of the Roseiris Dam on the Blue Nile, about 250 kilometres upstream from the Sennar Dam, and about 106 kilometres downstream from the Ethiopian borders. The Dam is 60 meters in height and has a storage capacity of about three billion cubic meters, more than three times that of the Sennar Dam. As a result, Sudan was able to irrigate the Managil extension of the Gezira Scheme with a size of 336,000 hectares when the Dam was completed in 1966. Consequently, the total area under irrigation in the Gezira Scheme reached 756,000 hectares (Mahgoub, 2014).

Over the years, the Gezira Scheme continues to play an important role in the socio-economic development of the Gezira area and the national economy of Sudan. While irrigated agriculture contributes about 13 % on average to Sudan's GDP and about 33 % to agricultural GDP, the share of the Gezira Scheme's contribution to national and agricultural GDP is estimated at 3% and 7%, respectively (Eldaw, 2004). In terms of its physical contribution, the Gezira Scheme has contributed significant proportions to the country's agricultural production during the past decades. Thus, about two thirds of Sudan's cotton exports and about 70%, 30% and 12% of total production of wheat, groundnuts and sorghum, respectively, in Sudan originate from the Gezira Scheme (Eldaw, 2004).

Concept of Perception

Like most concepts within the social science disciplines, perception has been defined in a variety of ways since its first usage. Van den Ban and Hawkins (1996) defined perception as the process by which people receive information or stimuli from the environment and transform it into psychological awareness. Lacing, Phillipson, and Lee as cited in Jayaratne (2001) observed that people develop perceptions on the basis of the subjective experience and not on the objective-physical stimulus pattern. They conceptualized perception as a psychological process which has different cognitive stages.

From the lay man’s perspective, perception is defined as an act of being aware of “one’s environment through physical sensation, which denotes an individual’s ability to understand (Chambers Dictionary as cited in Unumeri, 2009). Perception has less central role to play in the conceptualizations that emphasize the action aspects of scientific knowledge (Jayaratne, 2001). Jayaratne further explained that there are three fundamental pathways to knowledge, namely: logical-illogical thinking pathway, universal idiosyncratic symbolizing pathway, and perception-misperception sensing pathway.

Demuth (2013) argued that most relevant theories and explanations of perception as a process of acquiring and processing of information may be divided into two basic groups according to the direction of information flow. The first is a group of theories which suggest using only bottom-up processes when acquiring and processing sensory data. Demuth further asserted that bottom-up processes start at the lowest sensory levels, at the most distant levels of cognitive apparatus, and then they gradually lead to more complicated and complex processes which take place in higher structures which are responsible for more global and abstract ways of thinking. On the contrary, the top-down theories suppose that, in the process of discrimination, mainly when processing sensory stimulus, we start by “feeling” sensory data on receptors, but their processing presumes a downward influence of higher cognitive contents which organize and later determine them. Such influence we can be called the top-down effect. The core of this approach is the fact that, in order to process sensory stimulus, one needs to have prior experience or knowledge, or other influences which help to organize and form cognitive contents (Demuth, 2013).

Perception can be used to obtain reliable information on the physical world and, therefore, it can be used to assess sustainability. Many scholars used perception to evaluate sustainability and sustainable development (Trotman, 2007; and Cattenazzo, D'Urso & Fragniere, 2008). The EU (2008) employed perception to evaluate perceived sustainability and compared it with measured sustainability. The assertion is that the primary goal of perceptual categorization is to estimate the statistical structure of the physical world and most experts assume that perception estimates true properties of an objective world (Hoffman, n.d)

Theory of Sustainability

Theories of sustainability attempt to prioritize and integrate social responses to environmental and cultural problems. An economic model of sustainability looks to sustain natural and financial capital. An economically sustainable system must be able to produce goods and services on a continuous basis to maintain manageable levels of government and external debt, and to avoid extreme sectors imbalances which damage agricultural or industrial production (Harris, 2000). An ecological model looks to sustain biological diversity and ecological integrity while a social model looks to sustain social systems that realize human dignity (Jenkins, 2010).

In its literal rudiments, sustainability means a capacity to maintain some entity, outcome, or process over time. Agriculture, forest management, or financial investment might be deemed sustainable, meaning that the activity does not exhaust the material resources on which it depends (Jenkins, 2010). Jenkins further asserted that, in its increasingly common use, the concept of sustainability frames the ways in which environmental problems jeopardize the conditions of healthy economic, ecological, and social systems. Also, sustainability, in its essence, refers to the ability of something to endure over time. Sustainability of cotton production basically implies its ability to continue in the future and operate at the current or increased levels. In order to be sustainable, cotton production should be profitable and economically viable, environmentally sound, socially just and culturally acceptable (FAO, 2007).

Models of Sustainability

To explain the models of sustainability, Jenkins (2010) suggested the question of 'What must we sustain?' And tried to provide answers to that question based on what he called "strong" and "weak" approaches to sustainability. "Strong sustainability" gives priority to the preservation of ecological goods like the existence of species or the functioning of particular ecosystems. A "weak sustainability" disregards specific obligations to sustain any particular good, espousing only a general principle to leave future generations no worse off than we are. In terms of protecting old-growth forests, for example, a strong argument might be made for protection, even if it requires foregoing development that would increase opportunities for future generations. A weak view would take into account the various benefits old-growth forests provide, and would then attempt to measure the future value of those benefits against the values created by development.

Environmental Model of Sustainability

Environmental sustainability' requires maintaining natural capital as both a provider of economic inputs called 'sources' and an absorber called 'sinks' of economic outputs called 'wastes' (World Bank, as cited in Basiago, 1999). In practical terms, the theory of 'environmental sustainability' suggests a planning process that allows human society to live within the limitations of the biophysical environment (Goodland, 1995).

An environmentally sustainable system must secure a stable resource base, avoiding over-exploitation of renewable resource systems or environmental sink functions and depleting non-renewable resources only to the extent that investment is made in adequate substitutes (Harris, 2003). This includes maintenance of biodiversity, atmospheric stability, and other ecosystem functions not ordinarily classed as economic resources (Harris, 2000).

Economic Model of Sustainability

The economic model of sustainability aims to sustain opportunity, usually in the form of capital (Harris, 2003). According to the classic definition formulated by the economist, Robert Solow, we should think of sustainability as an investment problem in which we must use returns from the use of natural resources to create new opportunities of equal or greater value. Social spending on the poor or on environmental protection, while perhaps justifiable on other grounds, takes away from this investment and so competes with a commitment to sustainability. With another view of capital, however, the economic model might look different if we do not assume that "natural capital" is always interchangeable with financial capital. Herman (1996) and other proponents of ecological economics argued that sustaining opportunity for the future requires strong conservation measures to preserve ecological goods and to keep economies operating in respect of natural limits. These considerations complement an ecological model. From a different perspective of the relation between opportunity and capital, spending on the poor might be regarded as a kind of investment in the future.

Economic sustainability' implies a system of production that satisfies present consumption levels without compromising future needs. The sustainability that economic sustainability seeks is the sustainability of the economic system itself.

Social Model of Sustainability

In the most basic sense, social sustainability implies a system of social organization that alleviates poverty. In a more fundamental sense, however, social sustainability establishes the nexus between social conditions such as poverty and environmental decay (Basiago, 1999). As cited in Goodland (1995), Redclift claims that poverty reduction is the primary goal of sustainable development, even before environmental challenges can be fully addressed.

The meaning of social sustainability lies in the definition of social values which the majority of the scientific community calls it social capital (Widok, 2009). The question is what has to be protected for future generations and how this can be done. Following common definitions, social capital consists of shared knowledge and related organizational networks (e.g., governments, judiciaries, militaries, healthcare systems, banking systems, education systems, charities, etc.) that enhance the potential for effective individual and collective action in human social systems (Widok, 2009). Values like transparency, fairness, balance, equality, well-being, health and safety arise in this context. Social sustainability can therefore be defined as a way to achieve the protection, promotion, and preservation of these values for future generations. This includes human rights, preservation of diversity, protection and promotion of health and safety, intra and intergenerational equity, among many others. However, it is concluded that social sustainability aims to sustain social systems that realize human dignity. Concerned with the way in which local and global environmental problems jeopardize human dignity, this model focuses on sustaining the conditions of a fully human life (Jinkins, 2010).

Sustainable Agriculture

The term sustainable agriculture has been defined in different ways. According to USDA, as cited in Jayaratne (2001) sustainable agriculture is a farming system that is economically profitable, environmentally sound, and socially responsible. It emphasizes on methods and processes that improve soil productivity while minimising harmful effects on the climate, soil, water, air, biodiversity and human health. Moreover, sustainable agriculture ensures that basic nutritional requirements of current and future generations are met in both quantity and quality terms such that agriculture can also generate additional long-term jobs, adequate income, equal working and living conditions for everybody involved in agricultural value chains. It also seeks to reduce the agricultural sector’s vulnerability to adverse natural conditions such as climatic and socio-economic factors (Wörner & Krall, 2012). According to Earles (2005), sustainable agriculture looks at both social and economic aspects in addition to environmental issues. That is agriculture that follows the principles of nature to develop systems for raising crops and livestock which are self-sustaining as nature is. Earles further asserted that sustainable agriculture is also the agriculture of social values, one whose success is indistinguishable from vibrant rural communities, rich lives for families on the farms, and wholesome food for everyone.

Sustainable agriculture addresses environmental and social concerns, and also offers innovative and economically viable opportunities for growers, labourers, consumers, policymakers and many others in the entire food system (Onduru, De Jager, Hiller & Van den Bosch, 2012).

Sustainability of Cotton Production Systems

Sustainable cotton production system involves a system for production that can maintain high levels of production with minimal environmental impact and can provide maximum social and economic benefits for producers and their communities (Ferrigon & Lizarraga, 2009).

FAO (2006) reported that the conditions under which cotton is grown and the issues associated with its cultivation vary enormously due to the differing environmental, agro-ecological, climatic, socio-economic and political conditions. These different conditions mean that the cultivation of the same crop may result in significantly different social and environmental impacts, and that there are significantly different options and capabilities available to address these impacts. An assessment of the impacts of cotton growing and development of the best options for managing impacts should therefore only be done with reference to the specific context being assessed.

However, despite these highly variable conditions, and the site-specific nature of appropriate responses, the impacts of cotton growing are often considered globally. Both the cotton industry, and cotton as a raw material are assessed either generically, or based on the averaging of information from different countries without reference to the specific production location. Access to comprehensive, site-specific, robust and uniform data is necessary to ensure that this ‘globalisation’ of the impacts of cotton farming portrays the actual impacts as accurately as possible (FAO, 2006).

One of the responses to the impacts of cotton production has been the establishment of programmes or initiatives working with farmers to improve the sustainability of growing cotton. FAO (2006) asserted that development programmes promoting sustainable intensification of agriculture to protect and enhance the livelihoods of producers and the environment have long been working in cotton, and there has been an increasing regulatory interest in resource management by agricultural producers, leading to the implementation of production risk management systems focused on responsible natural resource stewardship. In recent years, there has been an emergence of initiatives aimed at promoting sustainability in cotton production that involve the downstream supply chain for cotton. These include in particular, large retailers with a growing interest in improving their own overall footprint to provide customers with greater confidence in the integrity of their products. As a result, there are an increasing number of production standards and systems that claim to promote the objectives of sustainable farming.

Measuring Sustainability of Plant Production Systems

The idea of sustainable development has gained importance in the past decades. Moreover, the concept of sustainable development has become a leading paradigm for policy makers and researchers. However, sustainability proved to be a remarkably difficult concept to define and to apply in practice. Measurement of sustainability is fraught with difficulties of principles and practice (Van Passel, Mathijs & Van Huylenbroeck, 2006).

A large number of indicators have been developed and used in order to assess agricultural sustainability. However, there is no unified theoretical basis for the creation of a scientifically substantiated system of indicators, especially for data collection, analysis, scale and final goal. In this regard, whilst environmental sustainability is measured with the consideration of intensity and type of agricultural inputs such as fertilizer, machinery operation, pesticide applications, soil conservation practices and irrigation water concerns, economic sustainability is measured based on availability of farm inputs, farm financial resources, level of mechanisation and economic viability as represented by yield, gross agricultural value and gross agricultural margin (Dantsis, Douma, Giourga, Loumou & Polychronaki, 2010).

Demographic and Farm Related Characteristics of Farmers

Some social indicators measure farmers' self-reliance (Pretty, as cited in Dantsis, Douma, Giourga, Loumou & Polychronaki, 2010) which may contribute to the retention of the agricultural population in the countryside as the main pre-condition of sustainability. The retention of a skilled workforce in rural areas and having an appropriate rural community infrastructure, will affect the capacity of farmers to adjust and manage their enterprises to changing economic and environmental conditions and the sustainability of agriculture (OECD, 2001).

The following socio-demographic and farm-related characteristics were found in the literature and they may have influence on sustainability of crop production system.

Age of the Farmer

Most literature found that farmers' age is associated with their education level, attitudes, managerial features, commitment to farming and size of farming operation (Dantsis, Douma, Giourga, Loumou & Polychronaki, 2010). Schur as cited in OECD (2005) found that in a survey of German farmers, young farmers were more educated, used advisory services more and attributed a greater importance to the management practices those services advocated. Furthermore, a younger, well-educated workforce is more likely to be able to respond rapidly to changing economic and environmental conditions leading to the sustainability of agriculture (OECD, 2001). Also, Van Passel, Mathijs and Van Huylenbroeck (2006) advocated that age has a significant negative effect on farm sustainability and the best sustainability scoring farms have a younger and better educated farm manager. Also, farms with a high sustainable efficiency have more children on the farm and the farm manager and/or partner receive(s) more off-farm earnings.

Level of Education

According to the OECD (1999), a farmer's educational level and effective farm management as well as timely adoption of environmentally friendly management practices are positively correlated. Level of education is measured as the years of education of the farmer. Abdel Rahman and Hamid (2013) conducted a study on farmers in the Gezira area and found that most farmers were literate, indicating that 34.44% of them had secondary education and only 11% were illiterate.

Off-farm Activity

This indicator describes the off-farm activities (non-agricultural) of the farmer or any member within the agricultural household, representing the importance of non-agricultural activities in the rural areas (Dantsis, Douma, Giourga, Loumou & Polychronaki, 2010). Farmers that agriculture is not the main source of their livelihood can have different attitudes towards farming and risk, and consequently may be more likely to take environmental quality into account in their farm management decisions. At the same time, part-time farmers may substitute farm chemicals for labour, which can have adverse environmental effects (OECD, 2001)

Family Size

In Sudan, the average household size is 6 persons per household with 71 percent of the population living in households of 4-9 members (Sudan Central Bureau of Statistics, 2010). The number of family members may give significant information on the structure of agricultural household and it highlights the trend of the retention of farm population in the countryside. It can also bring about diversifying sources of income of the agricultural household (Burton, as cited in Dantsis, Douma, Giourga, Loumou & Polychronaki, 2010). Although, household size determines the availability of cheap family labour compared to hired labour, when household size is small, there is great opportunity and need for hired labour to meet up with challenges of use of sustainable agricultural management practices, which may lead to increase in crop production variable cost (Simon, Garba & Bunu, 2013).

Farm Size

OECD (2001) reported that the trend toward increasing farm size usually entails field consolidation with the loss of boundary features, and intensification as capital replaces labour and the use of inputs per hectare increases. The more sustainable farms are bigger in the size unit, (Van Passel, Mathijs & Van Huylenbroeck, 2006). A larger size of agricultural land increases yield and may represent potentially higher sustainability efficiency (Dantsis, Douma, Giourga, Loumou & Polychronaki, 2010). The farm size is measured as the mean size of holdings (ha). The sale value or farm size can be used to classify farmers into small or large-scale farmers. However, there are an estimated 450 million small-scale farms worldwide defined by IFAD as farms of two hectares or less of land (Murphy, 2012).

Years of Farming Experience

Experience plays an important role in sustainability of agricultural plant production systems. It influences farmer's decision to use, discontinue use or reject farm innovations (Simon, Garba & Bunu, 2013).

Environmental Sustainability and Its Indicators

The earth system is an integral component of human enterprise. This ever changing system provides a multitude of valuable services to humans, and these include a liveable climate, provision of clear air and water, and the production of food and fibre (Kates, Parris & Leiserowitz, 2005).

Sustainable land use in agricultural regions means using land assets in a way that maintains or enhances productivity, protects the potential of natural resources, prevents degradation, meets increasing demands for fresh and healthy food, maintains the economic viability of agricultural production, and accomplishes all of the aforementioned in a manner acceptable to society (Liu & Zhang, 2013).

There can be trade-offs in implementing environmentally sound management practices. Reducing soil erosion, for example, whereby farmers adopt no-tillage in crop production can be achieved if weeds are controlled with herbicides (OECD, 2001). An environmental side-effect of these practices is a likely change in water movement in the soil, with no-tillage leading to increase in infiltration and percolation of nutrients compared with conventional tillage. In addition, the increase in herbicide use may cause pesticide leaching. Thus, the objective of lowering soil erosion through no-tillage may lead to some negative environmental effects.

Farm management indicators have the potential to help policy makers take into account the linkages between different management practices and their impact on the environment including: whole farm management involving the overall farming system; and farm management aimed at specific practices related to nutrients, pests, soils, and irrigation (OECD, 2001). Conservation tillage is currently a method with potential to minimise soil erosion. With the method, conventional ploughing is usually reduced or even eliminated. Additional benefits are a reduction in weed populations and reduced tillage costs. According to a report by the cotton foundation in the USA, 78% of US cotton farmers who have adopted conservation tillage practices since 1997 have done so specifically because herbicide-resistant cotton varieties had made it more feasible (Kooistra, Pyburn & Termorshuizen, 2006).

Concerning whole farm management indicators, the share of farms with environmental whole farm plans is increasing. Also, the share of agricultural area under organic farming is considered. Many countries now encourage conversion to organic farming by providing financial compensation to farmers for any losses incurred during conversion (OECD, 2001).

Fertilizer Usage and Its Impact on the Environment

Common synthetic fertilisers used for cotton are typically combinations of nitrogen (N – usually in the form of ammonium or nitrate), Phosphorus (P), and Potassium (K). Airborne N2 is the source of ammonium and nitrate, and phosphorus and potassium are mined. Much of the world's phosphate rock originates from the US, China, Russia's Kola Peninsula and smaller deposits are found throughout North Africa and in the oceans (e.g. near the coast of South Africa). Phosphate present in guano plays a minor role in terms of worldwide supply(Kooistra, Pyburn & Termorshuizen, 2006).

Livestock manure is the key nitrogen (N) fertiliser for organic farming. In addition, legumes cropped in mixture or in rotation with cotton contribute to soil N-fertility and serve in many cases as feed for animals. Manure and legumes are both options for maintaining plant nutrition in subsistence farming for which synthetic fertilisers are too expensive. Over the past several decades, widespread availability of synthetic nitrogen fertiliser in many nations has resulted in a major decrease in legume cultivation. Manure is applied to the field in either a raw (fresh or dried) or composted state (Kooistra, Pyburn & Termorshuizen, 2006). In conjunction with this, supplying nutrients to the crop, livestock manure contributes to soil organic matter, which in turn stimulates soil biological processes, soil structure, root penetrability and water retention.

In the context of plant production systems sustainability, fertilizer usage reflects the specialisation and intensification of cropping practices (OECD, 2001). As a direct indicator that could potentially estimate the environmental loading from fertilization, the total quantity of nitrogen (N), phosphorus (P) and potassium (K) applied per unit of agricultural land area is used.

To determine the effectiveness on crop growth and the environmental impact of fertiliser use, the most important factors to consider are: rainfall patterns, types and levels of fertiliser used, and timing of fertiliser application. Organic fertilisers include animal manure, green manure crops (usually legumes) and compost. Apart from nourishing the crop, the goal of these organic fertilisers is to maintain organic matter content in the soil (Hansen et al., as cited in Kooistra, Pyburn & Termorshuizen, 2006). Kooistra, Pyburn and Termorshuizen went further to explain that the disadvantage of using animal manure as a primary source of nitrogen is that organic nitrogen must first decompose microbial to ammonium and nitrate before it can be taken up by plants. Therefore, losses may happen via volatilisation (in the case of ammonia) or leaching to deeper soil layers (for nitrates). By contrast, synthetic fertiliser can be taken up instantaneously by a plant and if an amount is applied according to the plant's needs, virtually no fertiliser will be lost to the environment. Nitrogen losses associated with the use of organic sources must be balanced against the positive effect of carbon additions to the soil that maintain or increase organic matter in the soil and against the negative effects of synthetic nitrogen fertiliser. However, soil nutrients may be depleted as a result of continuous cultivation, poor fertilizer practices or due to leaching by heavy rainfall (Nwachukwu & Onwuha, 2011). Nwachukwu and Onwuha (2011) further asserted that the application of appropriate chemical fertilizer to ensure crop growth will minimise nutrient depletion after such crops are harvested and care must be taken to ensure application at the specified rates and at the recommended stages of growth of the plant.

Uri, as cited in Kooistra, Pyburn and Termorshuizen (2006) estimated that 50-70% of nitrogen and phosphorus found in surface or groundwater originate from fertiliser applications. Nitrate moves with water and leaches easily to surface and groundwater.

Moreover, for the production of nitrate and ammonium, much energy is needed, which contributes to global warming. Mining phosphorus and potassium may cause environmental impacts including changes in the landscape, water contamination, excessive water consumption and air pollution. The impact on a single farm is, however, negligible and therefore not generally taken into account when estimating the environmental impact of farming systems (Kooistra, Pyburn & Termorshuizen, 2006).

Pesticide Usage and Its Impact on the Environment

Pesticides contribute to agricultural productivity but also pose potential risks to human health and the environment. The risk variations depend on pesticide's inherent toxicity and exposure. Exposure to a pesticide depends on the way it is applied and its mobility and persistence in the environment. Pesticide indicators are potentially a useful tool to help policy makers monitor and evaluate policies and also provide information concerning human and environmental pesticide risks (OECD, 2001).The main impact of pesticides is on the environment, most notably on humans (Kooistra, Pyburn & Termorshuizen, 2006). The environmental effects of pesticides include damage to agricultural land, fisheries and fauna and flora, increased mortality and morbidity of humans due to exposure to pesticides are also recorded especially in several developing countries (Wilson & Tisdell, as cited in Budak & Budak, 2006).

Pesticides have contributed greatly to increased agricultural productivity and crop quality, but once in the environment, pesticides can accumulate in soil and water and damage flora and fauna as concentrations in food-chains become high enough to harm wildlife. Pesticide residues also impair drinking water quality, contaminate food for human consumption, cause adverse health effects from direct exposure to farm workers, while some pesticides contain bromide compounds which, when volatised, convert into stratospheric ozone-depleting gases (OECD, 1999). In the present study, the number of replications of herbicides, insecticides and fungicides application per growing season is used as an indicator of pesticide use (Dantsis , Douma, Giourga, Loumou & Polychronaki, 2010).

Pesticide use can be measured in tonnes of active ingredients with the chronic and acute potential and cumulative risk indicators. Chronic risk indicator reveals the potential human health risk from a chronic exposure to pesticides, reflecting the long-term effect (safety and toxicity) of pesticides to humans (OECD, 1999).

Faki and Taha (2007) concluded that there are some challenges facing the agricultural system in Sudan such as insect unbalance due to irrational use of insecticides. Moreover, insects like bollworm are threatening productivity whereas whitefly induced stickiness is the main bottleneck for quality marketing of cotton. This is coupled with the rank growth phenomenon which is a reflection of how inputs are inefficiently utilized and resources being wasted.

The bulk of pesticide application in irrigated schemes in Sudan is carried out by aerial spraying under the command of the respective scheme administrations (UNEP, n.d). UNEP also mentioned that the Gezira Board has reported that an estimated 125,000 to 205,000 hectares of cotton fields are sprayed annually. Past surveys have also shown that widespread pollution of surface waters and irrigation canals was due to extensive aerial spraying, and this remains a problem today. Aerial spraying of pesticides is a particular challenge in the Managil Extension of the Gezira Scheme, where the irrigation supply canals are also the main source of drinking water.

Pesticides applied in cotton production have been documented as adversely affecting the ecosystems, leading to lower quantities and lessened diversity of water organisms (Hose et al., as cited in Kooistra, Pyburn & Termorshuizen, 2006). Road spectrum pesticides very likely have a negative impact on multiple non-target insects including beneficial insects and other micro-organisms, but to precisely estimate the effects is arduous.

Previous analysis has shown that DDT pesticide and its derivatives were the most widespread contaminants. Moreover, residue testing on food products such as goat milk in the Gezira region has indicated that organochlorine pesticide levels including aldrin and dieldrin as well as endosulfan and HCH significantly exceeded standards set by the FAO/WHO.

One of the challenges that face the cotton industry is to cope with the public demand for clean and safer agricultural practices, reducing the environmental damage of excessive pesticide use while maintaining profitability. Negative public perceptions may lead to unwarranted changes in regulations detrimental to the industry. Further restrictions on the use of certain chemicals, for instance endosulfan, would leave the cotton industry in a vulnerable position and there may be other undesirable outcomes such as loss of profitability and negative environmental impacts from alternative chemicals (Baskaran et. al, 2000).

Agro-ecological Management Practices

The agro-ecological management practices are the practices that contribute to soil quality conservation and improvement (Bulluck et al., as cited in Dantsis, Douma, Giourga, Loumou & Polychronaki, 2010). The practices consist of residue management, application of organic manure, green manure management, crop rotation, growing the genetically modified cotton and multi-cropping. These indicators also reflect the degree of adoption of environmentally friendly techniques.

Some aspects of soil degradation are only slowly reversible (*e.g.* declines in organic matter) or are irreversible (*e.g.* erosion). Essentially, farmers need to balance three key aspects of soil quality: sustaining soil fertility, conserving environmental quality, and protecting plant, animal and human health (OECD, 2001).

Farm Machinery Operation

Mechanized agriculture has been a great bonus for humankind as it frees innumerable labourers from the load of hard work in the fields. However, this freedom has been obtained at the expense of a non-renewable resource: fuels obtained from crude oil which is not sustainable (Mousazadeh, Keyhani, Mobli, Bardi & El Asmar, 2009). Moreover, regarding soil quality, the use of heavy machinery leads to soil compaction, which is considered as one of the most serious environmental problems caused by conventional agriculture

(Hamza & Anderson, 2005). Hamza and Anderson further asserted that the indicator of farm machinery operation takes into account the total number of machinery entrances in the field such as tillage, fertilization, pesticide application, harvest as well as the horsepower of machines used. Conservation tillage reduces the number of operations required to prepare the land before sowing the crop thus reducing field traffic, energy used and cost of required fuel (Schomberg et al., 2003).

Ali (2013) reported that seedbed preparation has an important role in modifying the soil conditions especially with regard to its physical properties. In the Gezira Scheme, tillage for cotton is made by the 3-bottom disc. It has been found that, for many years low productivity of land may be associated with unfavourable physical conditions for plant growth. Root growth is affected by soil physical conditions while optimum crops yield are dependent upon optimum root growth. When the soil is in a good physical condition, the root system can grow extensively into the soil. Undesirable compaction levels may be due to soil forming factors, or to agricultural machines and transportation vehicles used in the seedbed preparation and harvesting of crops. These operations are accompanied by application of pressures to the soil which can be high enough to cause compaction. Another important factor which can cause a compacted layer is the continuous use of ploughs provided the depth of ploughing remains constant for a long time. Furthermore, the effect of the plough itself and the influence of tractor wheels may hasten compaction (Ali, 2013). Extensive compaction is believed to cause, or at least is partially responsible for decreasing the productivity of soils. Naturally occurring soil compaction and ploughing-induced compaction have been shown to restrict root growth and water infiltration, consequently affecting yield.

The Board of the Gezira Scheme has a fleet of agricultural machinery under the supervision of the Department of Agricultural Engineering (DAE) which is in charge of various agricultural operations. These operations include cleaning and maintenance of some of the irrigation canals, land preparation for cotton and wheat, application of pre-emergence herbicides and pesticides, broadcasting of fertilizers. The DAE operates a fleet which currently comprises some 468 wheel-tractors of various sizes, 105 crawlers (for deep ploughing) and over 50 combine harvesters in addition to a large array of agricultural implements (Galal, as cited in Eldaw, 2004).

Availability of Irrigation Water

Cotton cultivation requires large amounts of water. Irrigated cotton cultivation requires 550-950 litres per square meter with an average production of 1600 kilograms of raw cotton per hectare or 550 kilograms of lint cotton per hectare. Otherwise stated, to produce 1kg of cotton lint, 10,000-17,000 litres of water is needed. In areas such as Gezira Scheme where the normal rainfall quantity does not match the irrigation requirements of a cultivated crop irrigation is applied. For this, rivers must be diverted, dams constructed, or soil water pumped up. Irrigation systems differ considerably in terms of efficiency, reliability and price. Irrigation is applied to 53% of the world's cotton fields, generating 73% of the world's cotton production because irrigated cotton on average results in higher yields per unit of area (Hearn, as cited in Kooistra, Pyburn & Termorshuizen, 2006). Cotton irrigation consumes considerable amount of the freshwater and contributes to fresh water deficit. It has been estimated that cotton cultivation accounts for 1-6% of the world's total freshwater withdrawal (Kooistra, Pyburn & Termorshuizen, 2006).

In Sudan, irrigation water concerns are related to availability and equity in water distribution (Faki, 2006). Faki also mentioned that previous studies on head/tail-end difference in water supply in the Gezira scheme have shown that cotton yields along field irrigation canals decrease by a coefficient of 78 kg/ha with the location of fields away from the water outlets. On the other hand, farmers at tail end of the irrigation systems and fields canals were found to incur 50% yield reduction than those at head locations. It was also found that the effect of this phenomenon on farm income was significant amounting to a reduction of 37%.

An estimated area of 8% of the world's total arable land is abandoned due to former use for intensive cultivation (especially cotton cultivation, although the share is not precisely known) with soil Stalinisation being the main reason (FAO, 2011). Irrigation water dissolves calcium carbonate and soluble salts in the soil. Since calcium carbonate is relatively insoluble, it accumulates in the topsoil leading to additional salt deposition (originally from the irrigation water) and water logging.

Adoption of Genetically Modified Cotton (Bt. Cotton)

Cotton was one of the first plants to be modified genetically at a commercial scale, mainly in an effort to reduce the quantity of pesticides used. A gene conferring resistance to glyphosate (an active ingredient in herbicides such as Roundup) was transferred into cotton for the first time in 1987. The Bt-toxin-producing gene of *Bacillus thuringiensis* (Bt) was introduced into the plant's genome resulting in plant resistance against pests, notably the

Bollworm. In 1996, Bt. cotton was first planted in commercial scale in Australia and the USA. Since then, Bt. cotton and glyphosate-resistant cotton varieties have been planted in more than 20% of the area under cotton cultivation (IIED, 2004).

Genetically modified cotton varieties have been introduced in all major cotton producing countries in the world. About 50% of the cotton cropped in Mexico and South Africa has been genetically modified, compared to 80% in the USA and 66% in China. Argentina, Australia, India, and Indonesia have also approved the commercial planting of genetically engineered cotton in recent years (UNCTAD, as cited in Kooistra, Pyburn & Termorshuizen, 2006).

The great benefits for Bt. cotton to producers are reductions in use of pesticides and subsequent economic savings and increased yields due to the plants' resistance to pests and diseases (Zirogiannis, 2008). This argument is consistent with that of Kooistra, Pyburn and Termorshuizen (2006) to be the positive side of genetically modified cotton. Higher revenues have also been noted. However, the explanation of this reduction in pesticide use is unclear. One explanation could be that the Bt. cotton insecticide is in the plant itself. Since the genetically modified plant contains an insecticide, it is obvious that no insecticide needs to be applied to control the insects concerned.

The tangible benefits of improved conservation of natural enemy populations in Bt cotton have been demonstrated in several systems as a result of reduced and selective insecticides, and improvements in other pest management tactics. However, effects of transgenic crops on the natural enemies need to be determined on a regional basis, as the numbers of certain natural enemies in areas planted with transgenic crops may be lower, but their populations may be maintained on the other crops that serve as a host to the target pests (Dhillon, Gujar & Kalia, 2011).

In Sudan, a release of Bt. cotton often pollinated, evaluated in different locations in the irrigated and rain-fed field trails, was commercially made available recently, resulting in average increase of 54% and 87% in seed cotton yield over local varieties Abdin and Hamid respectively (Latif & Babiker, 2012).

Economic Sustainability and Its Indicators

Economic sustainability implies a system of production that satisfies present consumption levels without compromising future needs. The sustainability that economic sustainability seeks is the sustainability of the economic system itself (Basiago, 1999). An economic system designed in light of the theory of economic sustainability is one constrained by the requirements of environmental sustainability. It restrains resource use to ensure the sustainability of natural capital. It does not seek to achieve economic sustainability at the cost of environmental sustainability. Consideration must not only be given to the potential for increasing returns and increasing volatility due to change in productivity but also the environmental benefits of reduced fertilizer and pesticide inputs. The likelihood of producers adopting sustainable management strategies will depend on their expected future change in yield and associated economic volatility (Schomberg et al., 2003). A set of variables have been employed in this study to determine economic sustainability of cotton production in the Gezira Scheme. The variables are explained in the following sections

Farm Financial Resources

The Organisation for Economic Cooperation and Development (OECD) (2001) stated that the availability of financial resources influences farming practices such as the ability to acquire new technologies as well as the type, level and intensity of input use and of production. They also affect the degree of adoption of environmentally benign production methods, including farmers' attitude towards environmental risks; rates of structural adjustment, including farm amalgamation; and the exit and entry of farmers into the sector. The two main sources of farm financial resources include returns from the market of farm outputs and government support (farm household income can also include non-farm sources of income).

In Gezira Scheme, the Gezira Board provides almost all the services and inputs for the production and marketing of cotton. These inputs include seed, sacks, fertilizers and chemicals for plant protection in addition to land preparation, application of fertilizers and spraying of chemicals. All the services and inputs provided are financed by the government (the central bank) and administered by the Gezira Board. The government also determines the interest rates charged on loans to farmers. Up to the early 1990s, the interest rates charged stood at the level of 9 % (Galal as cited in Eldaw, 2004).

The Gezira Board finances cotton and provides cash advances, especially for cotton picking as well as for its cultivation and weeding. However, these cash advances have historically been below the actual costs incurred by tenants for the various farming activities (Eldaw, 2004). Therefore, tenants are confronted with the problem of securing more cash loans to cover the labour costs incurred on various agricultural practices. Four various reasons, many farmers are not in the position to obtain break-even yields. For those tenants, payment of cash advances is deferred in an attempt to avoid build-up of tenant debt.

Recently, there are no formal credit institutions available to Gezira tenants other than the SGB, which provided short-term credit for cotton production and wheat. This is unlikely to change until tenants have the right to transfer tenancy rights to creditors in the event of default on their loans. Informal "sheil" credit provided by private lenders is available but at interest rates that are multiples of the rates charged by formal lending institutions in other parts of the country (Salman, 2010).

Net farm income is calculated as the difference between gross output and all expenses. Agricultural households also obtain a substantial share of their income from non-agricultural activities in many countries and in some countries, the total average income of agricultural households exceeds that of non-agricultural ones (OECD, 2001). Two main subjects under farm financial resources include gross agricultural value and gross agricultural margins.

Gross Agricultural Value

The gross agricultural value measures the current price of cash crop produced per area unit. In order to estimate the contribution of the subsidies to the economic viability of a farm and the result of this policy (Hennessy, as cited in Dantsis, Douma, Giourga, Loumou & Polychronaki, 2010), this indicator is calculated in two ways, including or not including the value of the subsidies.

Cotton is the most profitable crop in the Gezira Scheme, even though it is the most expensive crop to grow. Also, the estimated 10-year average per hectare in real crop profits for the crops of the Gezira Scheme shows that cotton was the most profitable crop (Eldaw, 2004).

Gross Agricultural Margin

The gross margin is expressed as the difference between the gross agricultural value and a variable crop cost (e.g., fertilizers, pesticides and seeds) (Dantsis, Douma, Giourga, Loumou & Polychronaki, 2010). In Sudan, among all crops grown in the Gezira Scheme, the total costs of production are highest for cotton due mainly to higher pesticide and herbicide inputs as well as to higher labour costs. This implies that cotton is by far the most expensive crop to grow (Eldaw, 2004).

Farm Structure

The structure of agriculture refers to the number and size of farms, ownership and control of resources, and the managerial, technological and capital requirements of farming, legal organization (sole proprietorship, partnership or corporation) (Stanton, 1991). Many components of farm structure may contribute to financial viability. Some aspects commonly found in the literature on agricultural structure are highlighted below:

Crop Diversity

The term 'crop diversity' refers to growing more than on crop on a farm. Diversification is the key to resiliency, and it is considered as an important component of sustainable agriculture enterprises (Dooling, 2013). Diversification of agricultural crops on a farm can reduce both economic and ecological risks. Lin (2011) asserted that crop diversification can promote resilience on the farm in multiple ways. It can promote greater protection against pest outbreaks and disease transmission as well as providing a buffer from climate change effects and extreme weather events.

Diversifying crops on the farm increases its productivity and reduces the variability of agricultural income. It is described by the number of different crops cultivated in each farm except that from the target crops (Dantsis, Douma, Giourga, Loumou & Polychronaki, 2010)

Plot Number per Farm

The number of plots may represent the potentials of crop diversity on the farm. Dantsis, Douma, Giourga, Loumou and Polychronaki (2010) reported that the multi-partition of agricultural land results in higher yield variability along with excess of energy and labour required. Plot number per farm can be measured simply by counting how many plots are in the farm.

Agricultural Mechanization

Mechanization of farm practices such as land preparation, sowing, fertilization and spraying of pesticides is essential for increasing farm productivity of agricultural crops and, therefore, it contributes positively to economic sustainability of plant production systems (Vesterby, as cited in Dantsis, Douma, Giourga, Loumou & Polychronaki, 2010). However, mechanized agriculture has been a great bonus for humankind, freeing innumerable labourers from the load of hard work in the fields (Mousazadeh, Keyhani, Mobli, Bardi & El Asmar, 2009). Olaoye and Rotimi (2010) stated that the level, appropriate choice and subsequent proper use of mechanized inputs into agriculture can have direct and significant effect on improving the levels of land productivity, labour productivity, the profitability of farming, the sustainability, the environmental and, on the quality of life of people engaged in agriculture. Mechanization can be viable if it contributes to an increase in the productivity of labour. A family relying totally on hoe technology is severely restricted in the area that can be cropped and cared for. The addition of engine power to agriculture significantly increases the output derived from the human energy (FAO, 2006).

Conceptual Framework of the Study

The literature shows that sustainable production of cotton depends on a number of factors. Within the scope of this research, the factors are grouped under environmental concerns and economic concerns as presented in the conceptual framework of the study (Figure 1).

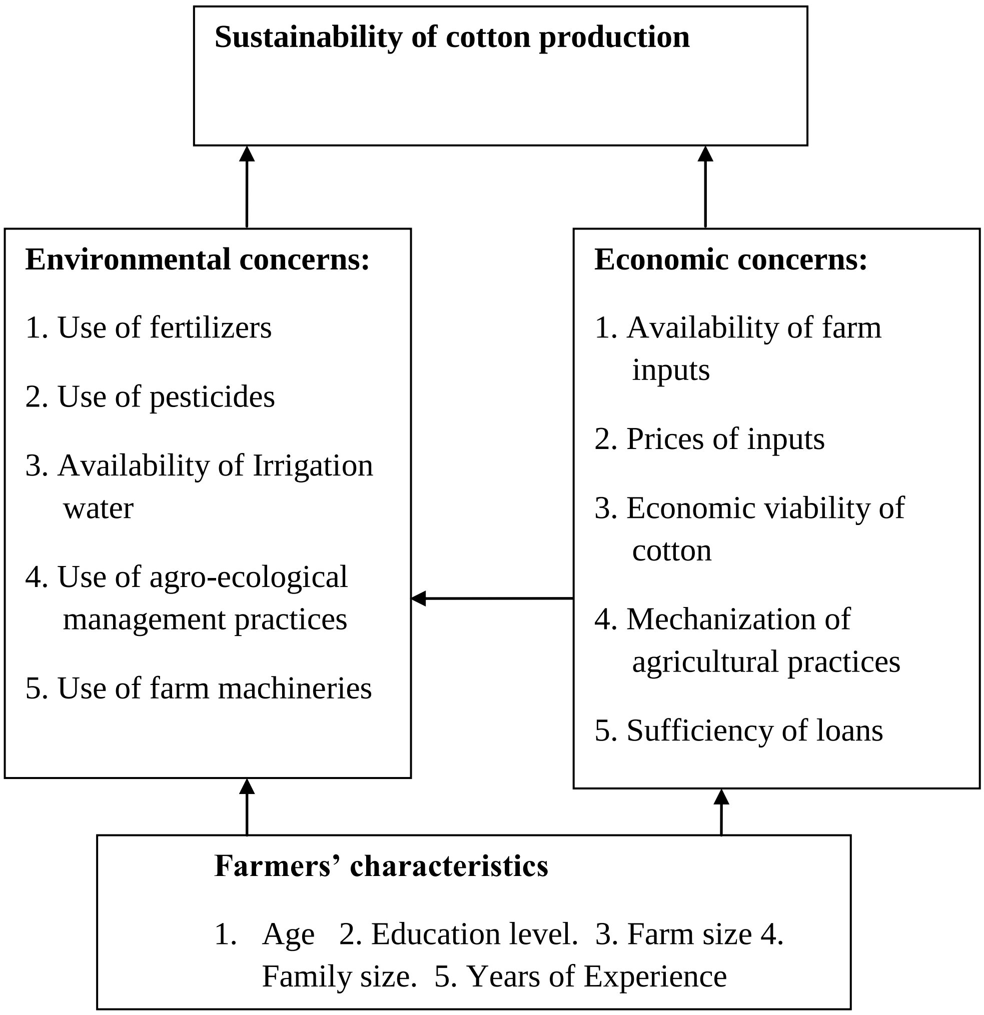

Figure 1: Conceptual Framework for Understanding the Sustainability of Cotton Production in the Gezira Scheme in Sudan.
Source: Authors' construct 2015

The conceptual framework supports the argument that addressing the challenges of environmental and economic sustainability in cotton production systems will lead to maintaining high levels of production with minimal environmental impacts and provide maximum social and economic benefits for the farmers and their communities. This is known as sustainable cotton production system (Ferrigon & Lizarraga, 2009).

The study focused on two main pillars of sustainability which are environmental and economic sustainability. From the literature, the key environmental concerns include use of fertilizer, use of pesticides, availability of adequate irrigation water, use of farm machinery and application of agro-ecological management practices such as incorporating crop residues into the soil, application of organic manures, application of green manures, and following regular and appropriate crop rotation (Dantsis, Douma, Giourga, Loumou & Polychronaki, 2010). Also, the key economic concerns include availability of farm inputs such as seeds, fertilizers, pesticides, sufficiency of loans provided for agricultural practices, input prices, level of economic viability (as measured by yield of cotton, perceived level of cotton price, perceived profit margin and price stability) and level of mechanization of agricultural practices.

From the literature, socio-demographic and farm-related characteristics of the farmers can influence both environmental and economic sustainability of crop production on their farms (OECD, 2001; Dantsis, Douma, Giourga, Loumou & Polychronaki, 2010; Simon, Garba & Bunu, 2013). These characteristics involve age, level of education, farm size, family size, and years of experience in cotton farming. The conceptual framework of this study

(Figure 1) shows that the socio-demographic and farm-related characteristics of the respondents can have influence on sustainability of cotton production systems by influencing the economic and the environmental concerns. In other words, these characteristics can influence farmers' ability to acquire and adopt agricultural practices such as pesticides, fertilizers and machines and thereby having an impact on the sustainability of cotton production (Figure 1).

CHAPTER THREE

METHODOLOGY

This chapter presents methods that were used to determine farmers' perception on sustainability of cotton production in the Gezira Scheme in Sudan. It consists of detailed description of research design, the study area, population of the study, sampling procedure and sample size, instrumentation, data collection and data analysis procedures.

Research Design

There are different paradigms that can be used in scientific research. They include experimental and non-experimental designs, descriptive research, correlation research and factorial design. Descriptive survey design was used to investigate farmers' perceived sustainability of cotton production under the Gezira Scheme in Sudan. This research design allows a researcher to collect data from a large sample drawn from a given population and describes certain features of the sample which are of interest to the researcher without manipulating any independent variable (Nwankwo, 2010). Gravetter and Forzano (2009) stated that survey research allows the researcher to present people with a few carefully constructed questions; it is possible to obtain self-related answers about attitude, perception, options and personal characteristics. Gravetter and Forzano also asserted that the survey provides a "snapshot" of a group of people at a particular time. Moreover, survey can be used to obtain an accurate picture of individuals being studied without the researcher waiting for the behaviour, attitude or responses to occur, by just asking individuals at any time. Survey also provides an opportunity to examine correlations among the participants' responses and to look for possible patterns of cause and effect (Arsenealute et al., as cited in Mc Burney & White, 2010).

Study Area

The study was carried out in Gezira State where the Gezira Scheme is located. Gezira State is one of the 18 states of Sudan. It has an area of 27,549 km^2. As shown in Figure 2, the Gezira Scheme lies between the Blue Nile and the White Nile in the East-Central region of the Sudan. It is located in the arid and semi-arid region south of Khartoum. Based on the 2008 population census, there are 3,575,280 people in Gezira State and most of the workforce of Gezira State is engaged in agriculture and its related activities such as oil, sugar and textile industries. The state is a well populated area suitable for agriculture (UNDP, 2010). The Gezira Scheme is the largest irrigated scheme in Sudan with an area of 900,000 hectares (Salman, 2010).

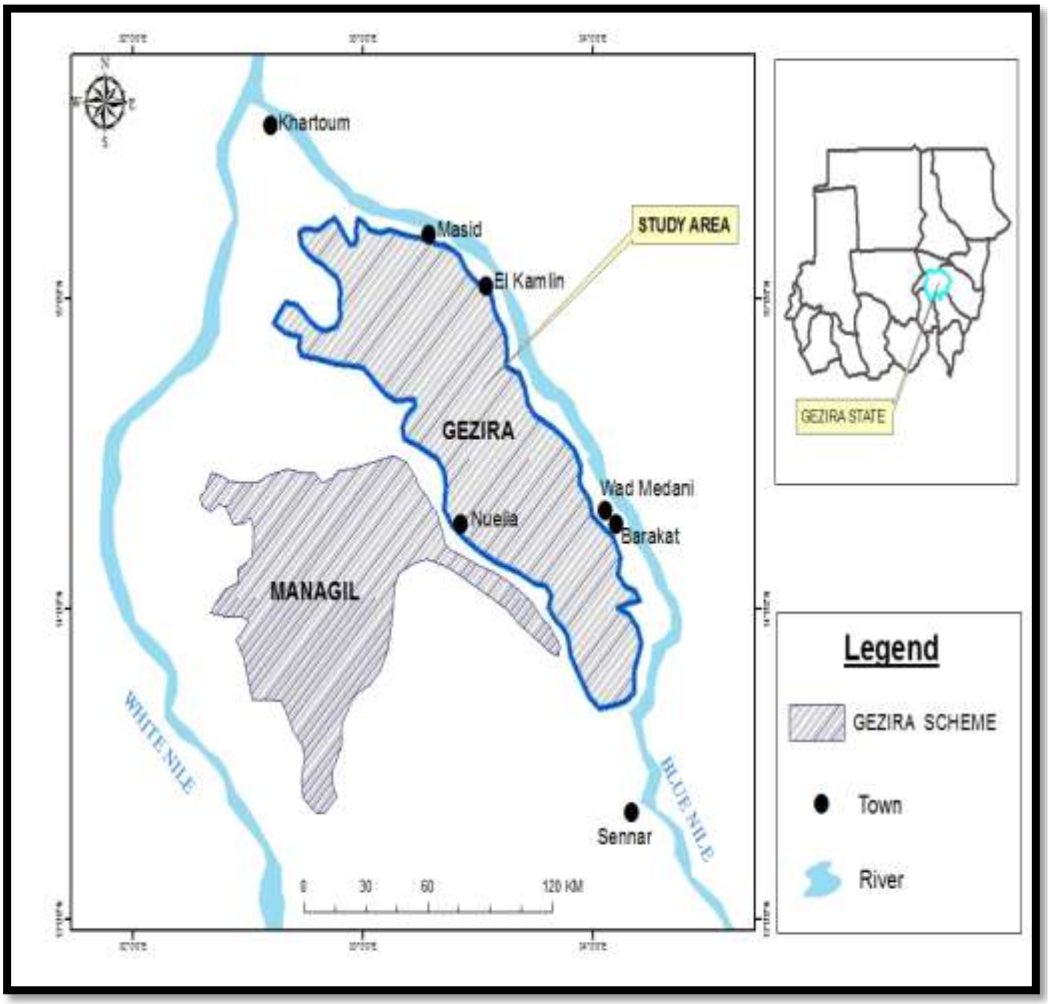

Figure 2: Map of Study Area
Source: Adapted from Elshaikh & Siwar, 2002 and Mahgoub, 2014

The Scheme contributes about 3 % of the Gross Domestic Product (GDP) of Sudan. It provides the opportunity of a basic livelihood to 114,000 tenant families, other job opportunities for 0.5 to 1.0 million casual workers and employs a staff of about 7000 qualified administrators, technicians, scientists, clerks and craftsmen (Eldaw, 2004).

Animal resources in Gezira State reach about 603,700 heads. Educational institutions have been introduced since the period of the Anglo-Egyptian rule and, currently, the state has an estimated number of 1732 basic schools and 437 secondary schools. Water is available in the whole state and is provided by the government. Health services are also available and always provided by government health facilities like teaching hospitals and different health centres with assistance of some health NGOs and other private clinics. The most important towns are Al-Hasahisa, Rofaa, Al-Kamlin and Wad Madani, which is the capital of the State (UNDP, 2010).

About 55 per cent of the Scheme's land is government owned; the remainder is owned by landholders with whom the central government has a long-term rental agreement (Mahgoub, 2014). There have been some major disputes between the owners and the government over rent, with cases pending before the courts (Salman 2013).

The soil of the Gezira scheme is described as black cotton soil, rich in clay content, which when dry results in deep cracks. The rainy season in the study area starts from late July and ends in October. The annual rainfall ranges from 300-800 mm (Dawelbeit, 2008). The area has a hot dry summer from April to June with daily temperature between 32- 42^0C and relative humidity of 20%. The scheme depends on small-farm ownership with an area ranging between 6.3 to 16.8 hectares (Salman, 2010). The main agricultural products in all the divisions of the scheme include cotton, sorghum, wheat, sunflower, groundnuts and vegetables.

Population of the Study

The population of study was all cotton farmers within the Gezira Scheme. According to the information given by the Gezira Scheme Management, the estimated number of cotton farmers in the scheme is about 7500 farmer. Previous studies showed that the majority of farmers in the

Gezira Scheme are literate and farmers' average farm size is estimated at 8.4 hectares (Salman, 2010; Abdel Rahman & Hamid, 2013).

Sampling Procedure and Sample Size

The multistage sampling procedure was adopted for the study. Eleven irrigation divisions under cotton cultivation were purposively selected in stage one. The second stage involved random selection of seven irrigation divisions out of the eleven. Using the lottery method, the names of all the eleven irrigation divisions that grow cotton were written on pieces of papers and shaken to mix, and seven divisions were selected. They were Elbasatna, Eltorabi, Elshargi, Elhaj Abdalla, Qurashi, Abd Elmajid and Tabat. The seven divisions represent 63.7 % of the total number of irrigation divisions engaged in cotton cultivation and comprise an estimate number of 4,898 cotton farmers constituting about 65.3% of the population.

The third stage involved the selection of respondents. Due to the lack of sampling frame, snowball sampling was used to select respondents from each of the selected divisions (Table 1). In the snowball sampling the first respondent in each division was selected by the extension agents then, the following respondents were determined by the previous ones, until the possible required sample size in each division was interviewed. Based on Krejcie and Morgan (1970) a sample size of 355 was selected for the study. According to Nwankwo (2010), the equation Population of subgroup/Total population*Sample size needed was used to constitute a proportional allocation of the sample size (Table 1).

Table 1: Population and Sample Size in Each of the Selected Divisions

Irrigation division	Population	Sample Size
Elshargi	1139	83
Elhajabdalla	1025	75
Elturabi	1025	75
Tabat	797	58
Elbasatna	342	24
Qurashi	342	24
Abdelmajed	228	16
Total	4898	355

Source: Author's construct, 2015.

Instrumentation

A structured and validated interview schedule was used for data collection. The instrument (Appendix A) was developed based on the objectives of the study and relevant related literature. This type of instrument facilitated understanding and made provision for face-to-face contact between the researcher and the respondents.

The instrument comprised three sections. Section One was designed to collect data on selected socio-demographic and farm-related characteristics of the farmers. The characteristics included were family size, level of education, number of years in formal education, years of experience in cotton farming, off-farm activity, farm size under cotton cultivation and total farm size.

Questions included in the section were open-ended and close-ended with ordered and unordered choice questions. Sections Two and Three were designed as five points Likert-type scale (Table 2) ranging from very high= (5), high= (4), moderate= (3), low= (2) to very low= (1) (Chang, 1994). The two sections were used to measure farmers' perceived environmental and economic sustainability of cotton production taking into account selected environmental and economic indicators. The interpretation of Likert-type scale is explained in Table 2.

Table 2: Interpretation of Likert-Type Scales

Ratings	Interval	Level of use
5	4.5-5.0	Very High (VH)
4	3.5-4.4	High (H)
3	2.5-3.4	Moderate (M)
2	1.5-2.4	Low (L)
1	1.0-1.4	Very Low (VL)

Source: Author's construct, 2014

Face validity was done by the researcher to ensure face value and appropriate superficial appearance of the measurement procedure. To validate the instrument in terms of construct and content validity, it was given to the researcher's supervisors at the Department of Agricultural Economics and Extension in the University of Cape Coast to ensure that the domains of the study had been captured.

Pre-Test

To ensure reliability of the research instrument and to rule out any ambiguity, a pre-test was conducted by collecting data from 19 cotton farmers in Rahad Irrigation Scheme. The Statistical Product and Service Solutions (SPSS) Version 20.0 software was used to generate Cronbach's Alpha coefficient to determine the internal consistency of all Likert type scale items. Alpha value of 0.70 or more was considered reliable (Lacobucci & Duhachek, 2003). According to the results of the reliability test presented in Table 3 all the sub-scales of the instrument were reliable except that of section one, which was designed with four items to measure farmers' perception on level of use of four types of fertilizers. However, two items about use of phosphorus and potassium fertilizers were not responded to by farmers because they do not apply these types of fertilizers, therefore, farmers could not tell about their level of use. As a result, the farmers responded to only two items. This section therefore remained with very few items. According to Cortina (1993), the number of items can affect the reliability of measurement. In this regard, the low reliability was due to the few items included, rather than the measurement not been consistent. Therefore, the data was considered for analysis.

Table 3: Alpha Coefficient of the Research Instrument

Subscales	Number of Items	Cronbach's Alpha
Use of fertilizers	2	0.458
Use of pesticides	3	0.977
Agro-ecological management practices	5	0.833
Use of farm machinery	5	0.925
Availability of farm resources	5	0.735
Prices of farm resources	5	0.966
Economic viability of cotton	4	0.829
Agricultural mechanization	5	0.934

Source: Author's construct, 2014

Data Collection

The study employed primary and secondary data. Primary data was collected from the respondents using the structured and validated interview schedule. Secondary data was collected from the Gezira Scheme Management, books and other scholarly publications. Five assistants were trained in a group discussion and they assisted in data collection. The researcher and his assistants collected the data from farmers by interviewing them in their houses. Three hundred and fifteen out of 355 respondents were interviewed within six weeks between September and October 2014. 40 respondents could not be interviewed because of the time limitations and difficulty in mobility since the field survey was conducted during the rainy season.

Data Analysis

Data collected was entered into Statistical Product and Service Solution (SPSS) Version 20 and Microsoft Excel 2007. To describe selected socio-demographic and farm-related characteristics of the respondents, descriptive statistics such as frequency, mean and standard deviation were used. Objective Two of this study was to determine the perceived level of environmental and economic sustainability of cotton production in the study area. The objective was analysed with descriptive statistics including frequency, percentages, means and standard deviations. For objective Three which was to examine the relationship between farmers characteristics (socio-demographic and farm-related) and their perceived level of sustainability, the non-parametric test **S**pearman rank correlation coefficient was used. An alpha level of 0.05 was used to determine the significant relationship. The Spearman rank correlation was employed in the study because the data did not meet the assumption of parametric statistics.

CHAPTER FOUR

RESULTS AND DISCUSSION

This chapter presents the results and discussion of the study. It consists of four sections. The first section describes selected socio-demographic and farm-related characteristics of the respondents. The second section deals with the factors determining perceived level of environmental sustainability of cotton production. The third section analyzes perceived level of economic sustainability of cotton production while the fourth explains the relationship between the perceived level of sustainability and selected socio-demographic and farm-related characteristics of cotton farmers in the study area.

Socio-demographic and Farm-related Characteristics of the Respondents

This section describes selected socio-demographic and farm-related characteristics of the respondents. It consists of description of farmers' age, sex, level of education, family size, farm size and other characteristics.

Age Distribution of Respondents

The ages of the cotton farmers range between 18 and 90 years. Based on the definition given by UN (2013), 36.6% of farmers were in their productive age (18-45), 7.3% of them were youth between the age of 18 and 32 years and 29.3% of them were between 33 and 45 years old (Table 4).

Table 4: Frequency Distribution of Age of Respondents

Age Range (year)	Frequency	Percentages
<33	23	7.3
33-45	92	29.3
46-58	93	29.6
>58	106	33.8
Total	314	100.0

$\overline{X}$ = 51.9, S.D =13.9, Minimum= 18, Maximum= 90

Source: Field Data, 2014

As Table 4 reveals, 63.4% of farmers were above the productive age, which is 45 years. About 29.6% of the farmers were between 46 and 58 years and 33.8% were above 58 years. The mean age of cotton farmers was 52 years and the standard deviation was 13.9. The result is different from that was found by Abdel Rahman and Hamid, (2013) where the mean age was 42 years. Since the majority of farmers were aging, Van Passel, Mathijs and Van Huylenbroeck, (2006) argued that age has a significant negative effect on the farm sustainability and the best sustainability scoring farms have younger farm managers. Also, a younger workforce is more likely to be able to respond rapidly to changing economic and environmental conditions leading to the sustainability of agriculture (OECD, 2001). Table 4 shows that the percentage of young farmers is extremely lower than that of aging farmers, which may imply lower sustainability efficiency.

Sex of the Respondents

The result of the study shows that most of the cotton farmers (96.8%) in the study area were male (Figure 3). Only few (3.2%) were female. As the case in most African countries, male farmers have more access to land and production inputs. This accounts for the differences in the involvement of more male in cotton production compared to female.

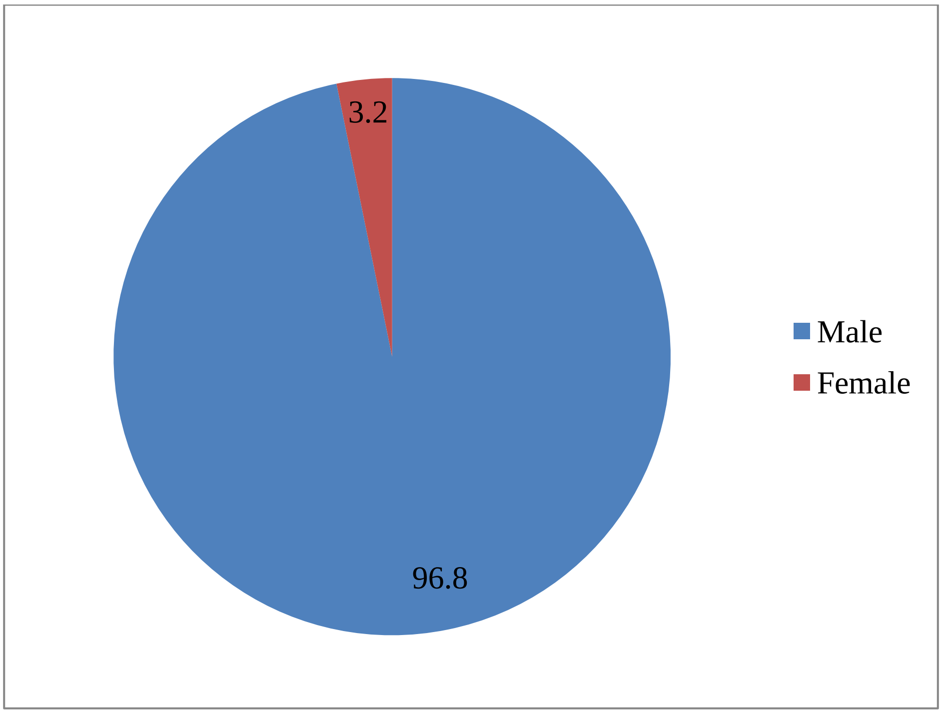

Figure 3: Distribution of Sex of the Respondents
Source: Field Data, 2014

Education Level of the Farmers

Farmer's educational level influences effective farm management practices and farmers' decision to adopt environmentally friendly management practices (OECD; 1999). The results revealed that 83.3% of cotton farmers have had access to formal education and are more probable to effectively manage their cotton farms and adopt timely environmentally benign practices. Specifically, 37.8%, 27.9% and 11.9% of the farmers have had secondary, primary and bachelors degree level of education respectively. Only 16.7% of cotton farmers have no formal education (Figure 4).

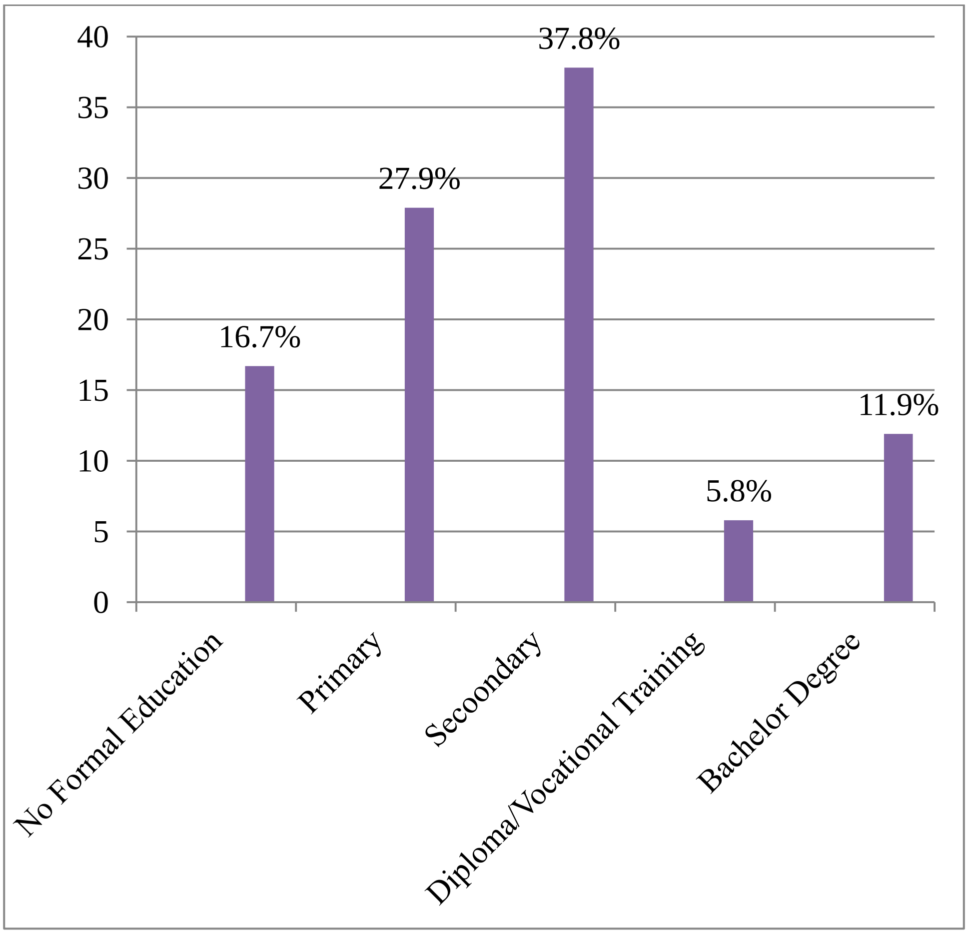

Figure 4: Level of Education of the Farmers
Source: Field Data, 2014

In a study on farmers in the study area, similar results were reported by Abdel Rahman and Hamid (2013), where 34.44% of farmers had secondary education and only 11% of the farmers were illiterate.

Family Size of Cotton farmers

The study reveals that the family size of majority (87.9%) of cotton farmers ranges between 1 to 10 persons. About 12.1% of the farmers have family size of more than 10 persons (Table 5). The average family size was 7 persons. The result of the average family size is almost consistent with the finding of Sudan Central Bureau of Statistics (2010) that the average household size is 6 persons.

Table 5: Frequency Distribution of Family Size of Cotton Farmers

Family size (person)	Frequency	Percentages
<6	99	31.5
6-10	177	56.4
11-15	32	10.2
>15	6	1.9
Total	314	100.0

$\bar{X}$ =7, SD =3, Maximum =30 Minimum =1

Source: Field Data, 2014

With reference to the classification of household size given by Anyanwu (2013) under the African Development Bank, the average family size of 7 indicates that the cotton farmers in the Gezira Scheme have large family size. Household size determines the availability of cheap family labour compared to hired labour. When household size is small, there is great opportunity and need for hired labour to meet up with challenges of use of sustainable agricultural management practices, which may lead to increase in crop production variable cost (Simon, Garba & Bunu, 2013).

Farm Size of the Respondents

The results in Table 6 indicate that about 67% of cotton farmers in the study area have more than 6.5 hectares of farm size whilst 33% of the farmers have farm size of less than 6.51 hectares.

Table 6: Frequency Distribution of Farm Size of the Respondents

Size Range (ha)	Frequency	Percentages
<2.5	6	1.9
2.5-6.5	98	31.1
6.51-10.51	178	56.5
>10.51`	33	10.5
Total	315	100.0

$\bar{X}$ =8.24, SD =4.15, Maximum =37.80 Minimum =0.84

Source: Field Data, 2014

The study found that cotton farmers have average farm size of 8.24 hectares. The average farm size agrees with the findings of Salman (2010) who found 8.4 hectares to be the average farm size of farmers in the Gezira Scheme. The literature supports that a larger size of agricultural land increases yield and may represent potentially higher sustainability efficiency (Van Passel et al., as cited in Dantsis, Douma, Giourga, Loumou & Polychronaki, 2010). Of the 8.24 hectares average farm size, the results (see Appendix C) show that only 1.84 hectares (22.33 %) is under cotton cultivation. Since the size of the cotton farm is less than 2 hectares, the Gezira Scheme cotton production system can be considered as small-scale pattern of production (Murphy, 2012).

Existence of Off-farm Activity within the Household of Cotton Farmers

The study found that there was off-farm economic activity(ies) within the household of majority (56.2%) of the respondents (Table 7).

Table 7: Frequency Distribution of Existence of Off-farm Activity within the Household of Cotton Farmers

Existence of the Off-farm Activity	Frequency	Percentages
Exists	176	56.2
Does not Exist	137	43.8
Total	313	100.0

Source: Field Data, 2014

A study conducted by Elshaikh and Sewar (2002) concluded that the existence of off-farm activities within the farmers' household in the Gezira Scheme was a major predictor for the farmers to be put under or above the poverty line. This existence of some off-farm economic activities within the farmers' household supports the economic sustainability requirements of agricultural crop production system. Farmers who farming is not the main source of their livelihood can have different attitudes towards farming and risk, and consequently may be more likely to take environmental quality into account in their farm management decisions. Also, part-time farmers may substitute farm chemicals for labour, which can have adverse environmental effects (OECD, 2001).

Years of Experience of the Cotton Farmers

The years of experience in farming influence farmers' decision to adopt or reject new technologies. Therefore, years of experience play an important role in the sustainability of crop production. The results of this study revealed that 64% of cotton farmers in the study area have more than 10 years of experience in cotton farming, whilst 36% of the farmers have at most 10 years of experience in cotton farming (Table 8).

Table 8: Frequency Distribution of Years of Experience of Cotton Farmers

Years of experience	Frequency	Percentages
1-10	107	36.0
11-20	94	31.6
21-30	42	14.1
30<	54	18.2
Total	297	100.0

$\bar{X}$ =19, Maximum =60, Minimum =1, SD =13

Source: Field Data, 2014

Due to the early establishment of the Gezira Scheme in 1925 and the engagement of elderly farmers, most of the cotton farmers have more than 10 years of experience. This may indicate higher sustainability efficiency in the sense that experienced farmers are likely to manage their farms in an effective ways.

Distribution of Adoption of Genetically Modified Cotton (Bt. Cotton)

The study shows that the genetically modified cotton (Bt. cotton) is adopted by the majority (97.5%) of cotton farmers in the study area. Only 2.5% of the farmers were growing the local varieties (Figure 5).

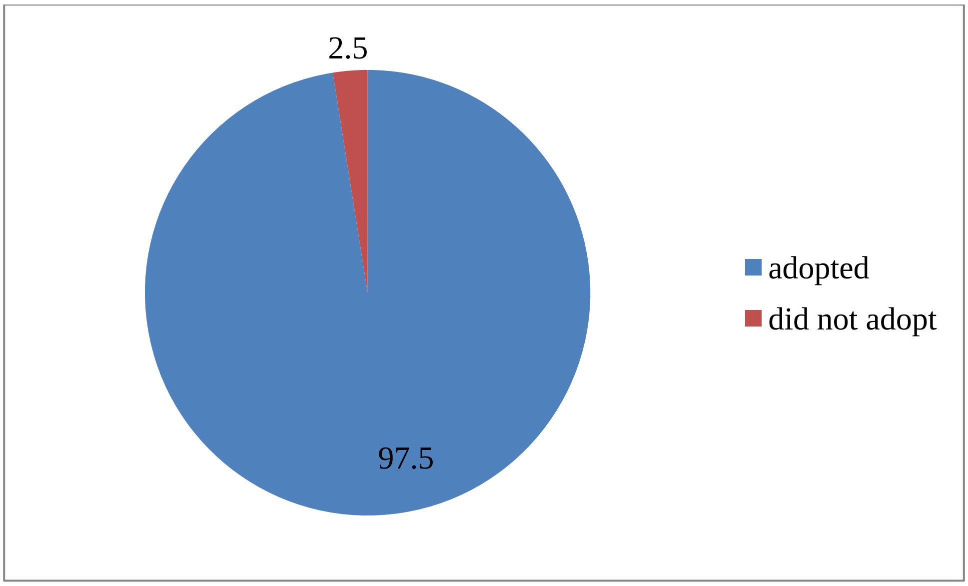

Figure 5: Distribution of the Adoption of the Bt. Cotton

Source: Field Data, 2014

The wide adoption Bt. cotton is not surprising after its average increase of 54% and 87% in seed cotton yield over local varieties Abdin and Hamid respectively (Latif & Babiker, 2012).

Distribution of Types of Funding

The study found that most of the cotton farmers in the study area (80.6%) were receiving funding from government whilst 15.9% were privately funding their farming activities. The remaining minority (3.5 %) were combining both governmental and private funding (Figure 6).

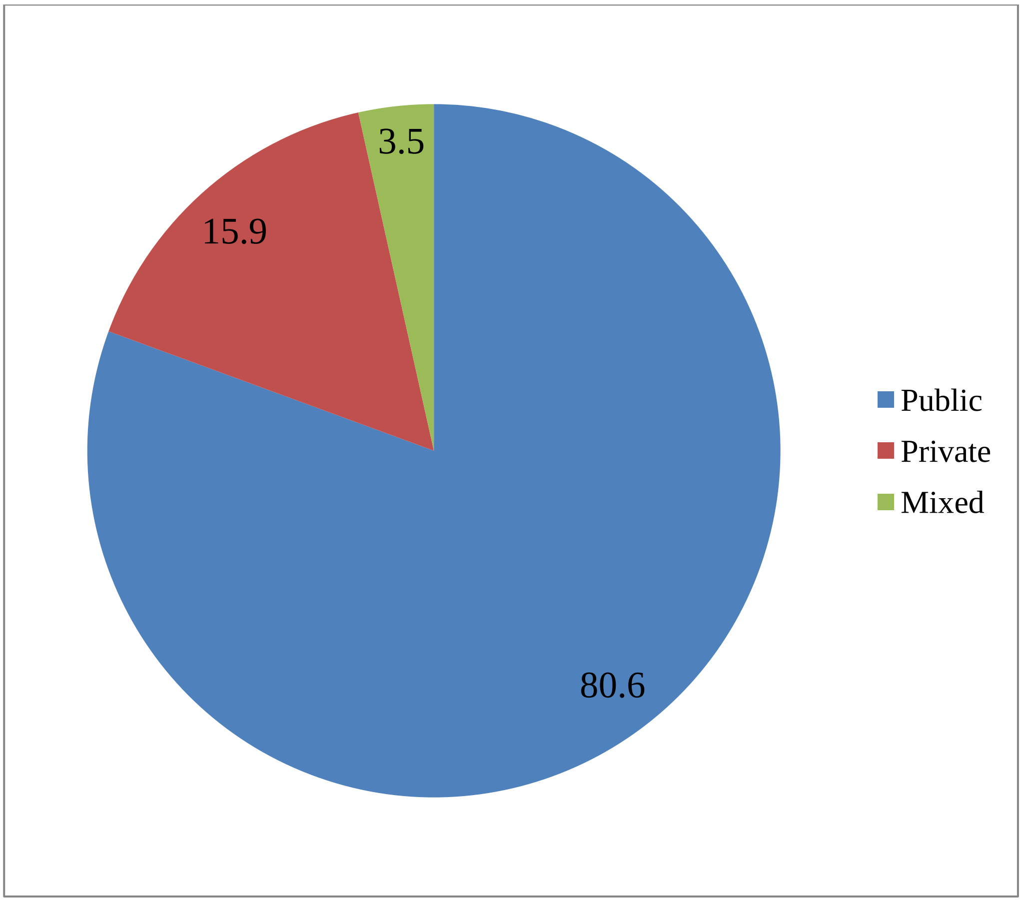

Figure 6: Types of Funding for Cotton Production in the Study Area

Source: Field Data, 2014

The results imply that the public sector is highly engaged in the cotton industry, providing inputs and loans for the farmers. The results are consistent with the findings of Eldaw (2004) that the Gezira Board provides almost all the services and inputs such as seeds, land preparation, fertilizers and pesticides for the production and marketing of cotton.

Perceived Environmental Sustainability of Cotton Production

This subsection determines the level of perceived environmental sustainability of cotton production in the Gezira Scheme. The variables employed were use of fertilizer, use of pesticides, use of agro-ecological management practices, availability of irrigation water and use of farm machinery.

Percentage of Farmers Who Use Fertilizers

The use of chemical fertilizer puts the production system under serious challenge to cope with the global issues of sustainability and sustainable development. This study found that nitrogen fertilizer (Urea) and NPK fertilizer were commonly used in cotton production in the study area. Almost all cotton farmers (100%) in the study area were using nitrogen fertilizer (Urea) and 94.6% of them were using NPK fertilizer (Table 9).

Table 9: Frequency Distribution of Use of Fertilizers by Cotton Farmers

Type of Fertilizer	Frequency	Percentage
Nitrogen (Urea)	315	100.0
NPK	298	94.6

Source: Field Data, 2014

Note: Multiple responses analysis

The results corroborate with the findings of Kooistra, Pyburn and Termorshuizen (2006) in that common inorganic fertilisers used for cotton are typically combinations of nitrogen (N – usually in the form of ammonium or nitrate), Phosphorus (P), and Potassium (K).

Level of Use of Fertilizers

Cotton farmers in the study area use Urea and NPK fertilizers. The farmers used Urea and NPK fertilizers almost four times in the last five years as indicated by their respective mean values of 3.6 and 3.5 (Table 10).

Table 10: Perceived Level of Use of Fertilizer

Type of Fertilizer	Frequency and Percentages of Perceived Level of Use of Fertilizer F (%)					Mean $\bar{X}$	SD
	VH	H	M	L	VL		
Nitrogen (Urea)	57 (18.6)	101 (32.9)	133 (43.3)	13 (4.2)	3 (1.0)	3.6	.86
NPK	50 (17.2)	76 (26.2)	146 (50.3)	15 (5.2)	3 (1.0)	3.5	.87

Source: Field Data, 2014;

Means were calculated from a scale of 1 to 5, where using the fertilizer five times in the last five years is very high (VH= 5), four times in the last five years is high (H= 4), three times in the last five years is moderate (M= 3), two times in the last five years is low (L= 2), once in the last five years is very low (VL= 1).

Since the means of levels of use of fertilizers were 3.5 and above, the results imply high level of use of fertilizer. The high level of use of fertilizers represents potential threat to environmental sustainability of cotton production in the study area. The literature shows that, use of chemical compounds in agriculture contributes to soil deterioration and increase global warming in the universe (Higgins, as cited in Kooistra, Pyburn & Termorshuizen, 2006).

Percentages of Cotton Farmers Who Use Pesticides

The results show that the pre-emergence herbicides were used by majority of cotton farmers (95.5%) in the study area. This followed by fungicides and insecticides whilst post emergence herbicides were used by only 9.5% of the farmers (Table 11).

Table 11: Frequency Distribution of Cotton Farmers Who Use Pesticides

Type of Pesticides	Frequency	Percentages
Pre-emergence Herbicides	301	95.6
Fungicides	290	92.1
Insecticides	175	55.6
Post-emergence Herbicides	30	9.5

Source: Field Data, 2014

Note: Multiple responses analysis

The most interesting result in Table 11 is the decrease by 44.4% in the percentage of cotton farmers who use insecticides. In the past, the whole area under cotton cultivation which was estimated between 125,000 and 205,000 hectares of cotton was sprayed annually (Eldaw, 2004). This decrease in the use of insecticides could be explained by the adoption of Bt-cotton. The great benefit of Bt. cotton is that it is resistant to pests and diseases. This can reduce pesticides use, increase yield and subsequent improvement in economic savings (Zirogiannis, 2008). This is believed to be helping the cotton industry in the study area to cope with the public demand for clean and safer agricultural practices, reducing the environmental damage of excessive pesticide use while maintaining profitability.

Level of Use of Pesticides

Pesticides contribute to agricultural productivity but also pose potential risks to human health and the environment. The risk variations depend on pesticide's inherent toxicity and exposure. Irrational use of pesticides leads to pesticide residues affecting the environment and contribute to soil deterioration.

The results show that cotton farmers in the study area used pesticides almost three times in the last five years as represented by means of 3.2, 3.4, 3.4 and 2.7 for insecticides, fungicides, pre-emergence herbicides and post-emergence herbicides respectively (Table 12).

Table 12: Perceived Level of Use of Pesticides

Type of Pesticide	Frequency and percentages of perceived level of use of pesticides F (%)					Mean $\overline{X}$	SD
	VH	H	M	L	VL		
Insecticides	13	17	79	36	23	3.2	1.0
	(7.7)	(10.1)	(47.0)	(21.4)	(13.7)		
Fungicides	12	26	125	61	45	3.4	1.0
	(4.3)	(9.4)	(54)	(21.9)	(19.4)		
Pre-emergence	20	26	112	78	58	3.4	1.1
Herbicides	(6.8)	(8.8)	(38.1)	(26.5)	(19.7)		
Post-emergence	9	5	8	1	7	2.7	1.5
Herbicides	(30.0)	(16.7)	(26.7)	(3.3)	(23.3)		

Source: Field Data, 2014;

Means were calculated from a scale of 1 to 5, where using the pesticide five times in the last five years is very high (VH= 5), four times in the last five years is high (H= 4), three times in the last five years is moderate (M= 3), two times in the last five years is low (L= 2), used once in the last five years is very low (VL= 1).

Since the means of levels of use of the different pesticides are more than 2.5 and less than 3.5, the results imply that the pesticides were used three times in the last five years. The study found remarkable reduction in cotton area that is sprayed annually. This result contradicts findings of UNEP (2010) that an estimated area between 125,000 and 205,000 hectares of cotton fields are sprayed annually representing the whole area under cotton cultivation in the Gezira Scheme. However, irrational use of pesticides is considered as threat to environmental sustainability. Pesticides applied in cotton production have been documented as adversely affecting the ecosystems, leading to lower quantities and lessened diversity of water organisms (Hose et al., as cited in Kooistra, Pyburn & Termorshuizen, 2006).

Frequency of Farmers Who Use Agro-ecological Management Practices

Agro-ecological management practices are considered to contribute to soil quality and soil conservation. They also reflect the level of adoption of environmentally benign technologies (Dantsis, Douma, Giourga, Loumou & Polychronaki, 2010).

The study found that, about 98.4% of cotton farmers in the study area follow a regular crop rotation, 95.9% grow genetically modified cotton, 68.3% were practicing multi-cropping, about 43.2% of the farmers were mixing crop residues with soil. Only few farmers were applying organic manure and green manure (Table 13).

Table 13: Frequency Distribution of Farmers Who Use Agro-ecological Management Practices

Type of practice	Frequency	Percentage
Following Crop Rotation	310	98.4
Growing Genetically Modified Cotton (Bt.)	302	95.9
Multi-cropping	215	68.3
Mixing Crop Residues With Soil	136	43.2
Applying Organic Manure	38	12.1
Applying Green Manure	5	1.6
Growing Cover Crops	1	.3

Source: Field Data, 2014

Note: Multiple responses analysis

Level of Use of Agro-ecological Management Practices

The key agro-ecological management practices followed by farmers in the Gezira Scheme were the use of genetically modified cotton, crop rotation, multi-cropping, applying organic manure, mixing crop residues with soil and applying green manure. The study reveals that farmers in the study area tend to grow the genetically modified cotton, follow crop rotation and multi-cropping almost four times in the last five years. Therefore, the three practices are the most contributing practices to soil conservation with mean of 3.8, 3.6 and 3.5 respectively (Table 14).

Table 14: Perceived Level of Practicing Agro-ecological Management Practices

Type of Practice	Frequency and Percentages of Perceived level of Practicing some Agro-ecological Management Practices F (%)					Mean $\bar{X}$	S.D
	VH	H	M	L	VL		
Growing the Bt. cotton	85	113	80	19	2	3.8	0.9
	(28.4)	(37.8)	(26.8)	(6.4)	(0.7)		
Crop Rotation	87	85	80	28	23	3.6	1.2
	(28.7)	(28.1)	(26.4)	(9.2)	(7.6)		
Multi-cropping	34	87	78	17	2	3.5	0.8
	(16.3)	(37.3)	(37.3)	(8.1)	(1)		
Applying Organic Manure	3	9	15	6	2	3.1	1.0
	(8.6)	(25.7)	(42.9)	(17.1)	(5.7)		
Mixing Crop Residues with Soil	12	26	58	32	8	3.0	1.0
	(8.8)	(19.1)	(42.6)	(23.5)	(5.9)		
Applying Green Manure	1	0	1	1	1	2.7	1.7
	(25)	(0)	(25)	(25)	(25)		

Source: Field Data, 2014

Means were calculated from a scale of 1 to 5, where using the practice five times in the last five years is very high (VH= 5), four times in the last five years is high (H= 4), three times in the last five years is moderate (M= 3), two times in the last five years is low (L= 2), used once in the last five years is very low (VL= 1).

The study also reveals that mixing crop residues into the soil, applying green manure and organic manure were practiced almost three times in the last five years. All the six management practices are known to contribute to soil quality and soil conservation.

Frequency of Cotton Farmers Who Use Farm Machinery

The study found that all cotton farmers use ploughing machine as essential farm machine to prepare the seedbed. In the study area, tillage for cotton is made by the 3-bottom disc. Ali (2013) reported that seedbed preparation has an important role in modifying the soil conditions especially with regard to its physical properties. Also, it is found that the continuous use of the 3-bottom disc which gives tillage depth of less than 15 cm and rough soil surface together with using ridging alone had contributed greatly to deterioration of cotton yield in the Gezira Scheme (Ali, 2013).

Table 15: Frequency of Farmers Who Use Farm Machinery in Cotton Farming

Type of Machine	Frequency	Percentage
Ploughing Machine	314	100
Pesticide Application	242	76.8
Fertilizer Application	230	73.0
Sowing Machine	159	50.5
Weeding Machine	130	41.3

Source: Field Data, 2014

Note: multiple responses analysis

The other most commonly used machines in cotton farming in the study area were pesticide application machine (76.8%) fertilizer application machines (73%), sowing machine (50.5%) and weeding machine used by 41.3% of the cotton farmers. Research shows that the excessive use of heavy machinery leads to soil compaction, which is regarded as one of the most serious environmental problems caused by conventional agriculture (Hamza &

Anderson, 2005). In the following section the level of use of farm machinery is presented and discussed.

Level of Use of Farm Machinery

The means of level of use of farm machinery in cotton farming were all more than 3.5, reflecting high level of use of farm machinery (Table 16). This means that cotton farmers in the study area tended to use all the machines mentioned in Table 16 almost four times in the last five years.

Table 16: Perceived Level of Use of Farm Machinery

Type of Machine	Frequency and Percentages of Perceived Level of Use of Farm Machinery F (%)					Mean $\overline{X}$	SD
	VH	H	M	L	VL		
Ploughing Machine	121 (39.5)	123 (40.2)	50 (16.3)	11 (3.6)	1 (0.3)	4.1	0.8
Sowing Machine	42 (27.1)	41 (26.5)	62 (40.0)	10 (6.5)	0.0 (0.0)	3.7	0.9
Pesticide Application	62 (26.6)	85 (36.5)	60 (25.8)	18 (7.7)	8 (3.4)	3.7	1.0
Fertilizer Application	64 (28.2)	76 (33.5)	60 (26.4)	22 (9.7)	2.2 (%)	3.7	1.0
Weeding	27 (20.9)	50 (38.8)	38 (29.5)	11 (8.5)	3 (2.3)	3.6	0.9

Source: Field Data, 2014

Means were calculated from a scale of 1 to 5, where using the machine five times in the last five years is very high (VH= 5), four times in the last five years is high (H= 4), three times in the last five years is moderate (M= 3), two times in the last five years is low (L= 2), used once in the last five years is very low (VL= 1).

Even though, the mechanization of agricultural practices leads to increase in yield and production efficiency, it is found to harm the environment by increasing fuel consumption which may contribute to global warming.

Moreover, the use of heavy machines puts more pressure on soil and causes soil compaction. However, the results show that the number of each of the machines entering the field is almost four times in the last five years and this is described as high level of use.

Adequacy of Irrigation Water

Adequate water supply is essential for growth and development of cotton cultivation. In Sudan, irrigation water concerns are related to availability and equity in water distribution (Faki, 2006). This study sought to find out cotton farmers' perception on the level of adequacy of supply of irrigation water. Results of the study revealed that cotton farmers perceived the supply of irrigation water to be available and adequate (Table 17).

Table 17: Perceived Level of Adequacy of Irrigation Water

Item	Frequency and Percentages of Perceived Level of Adequacy of Irrigation Water F (%)					Mean $\bar{X}$	S.D
	VH	H	M	L	VL		
Adequacy of Irrigation Water	98 (31.5)	97 (31.2)	65 (20.9)	46 (14.8)	5 (1.6)	3.7	1.0

Source: Field Data, 2014

Mean was computed from a scale of 1 to 5, where water is very much available and adequate is very high (VH= 5), available and adequate is high (H= 4), fairly available and adequate is moderate (M= 3), scarce is low (L= 2), very scarce is very low (VL= 1).

Irrigated cotton cultivation requires 550 to 950 litres of water per square meter to give an average production of 1600 kilograms raw cotton per hectare or 550 kilograms lint cotton per hectare (Kooistra, Pyburn & Termorshuizen, 2006). The field survey of this study showed that the supply of irrigation water for cotton production in the study area is almost sustainable where the irrigation water was perceived to be available and adequate (Table 17).

Perceived Environmental Sustainability of Cotton Production

The results show that the weighted mean of all environmental indicators was 2.8 constituting moderate level of environmental sustainability of cotton production in the study area (Table 18).

Table 18: Perceived Level of Environmental Sustainability of Cotton Production

Variables	Mean $\bar{X}$	Level of Sustainability	SD
Adequacy of Irrigation Water	3.7	High	1.0
Agro-ecological Management Practices	3.2	Moderate	0.9
Use of Pesticides	2.7	Moderate	1.1
Use of Fertilizer	2.3	Low	0.8
Use of Farm Machinery in Cotton	2.1	Low	0.9
Weighted Mean ($\bar{X}$w)	2.8	Moderate	0.94

Source: Field Data, 2014

The study reveals that the use of fertilizers and use of farm machinery were the main threats to environmental sustainability represented by means of 2.3 and 2.1 respectively, which constitute low level of sustainability. Irrational use of fertilizer in agriculture contributes to deterioration of the environment in several ways. For example in the production of nitrate and ammonium much energy is needed, and this is said to contribute to global warming (Kooistra, Pyburn & Termorshuizen, 2006).

Availability and adequacy of irrigation water, use of agro-ecological management practices and use of pesticides are the most contributing factors to environmental sustainability of cotton production in the study area with means of 3.7, 3.2 and 2.7 level of sustainability respectively. In the past the use of pesticides was the greatest challenge to environmental sustainability within the Gezira Scheme when the whole area under cotton cultivation was sprayed annually (Eldaw, 2004). Now the widely adopted Bt. cotton has contributed to reduction in the use of pesticides on cotton in the study area.

Perceived Economic Sustainability of Cotton Production

This subsection determines the perceived economic sustainability of cotton production in the study area. It includes analysis of variables such as availability of farm inputs, perceived level of prices of inputs, perceived level of economic viability of cotton farming, sufficiency of loans and perceived level of mechanization of agricultural practices.

Frequency of Cotton Farmers Who Receive Inputs

The study found that nitrogen fertilizer and seeds were received by almost all cotton farmers in the study area. A large proportion of the cotton farmers (94.6%) receive NPK fertilizer. Herbicides and insecticides were received by 94.2% and 55% of cotton farmers respectively (Table 19).

Table 19: Frequency Distribution of Cotton Farmers Who Receive Inputs

Type of Input	Frequency	Percentages
Nitrogen Fertilizer	315	100.0
Seeds	311	99.4
NPK Fertilizer	296	94.6
Herbicides	295	94.2
Insecticides	172	55.7

Source: Field Data, 2014

Note: Multiple responses analysis

The result implies that farm inputs were easily accessed by farmers. Since availability of inputs is essential for crop growth and increasing yield, the results indicate high sustainability efficiency.

Perceived Level of Availability of Farm Inputs

Availability of farm resources plays an important role in farmers' ability to acquire new technologies including environmentally friendly production methods and the exit and entry of farmers into the sector (OECD, 2001). The study reveals that, all the inputs indicated in Table 20 were perceived to be high or supplied with enough in the amount and easily accessed except insecticide supply and this is represented by mean 3.4 or moderate level. This indicates that the pesticides supply was not enough but easily accessed. Moreover, the standard deviation of the levels of availability of all farm inputs (Table 20) ranges between 0.9 and 1 on a scale of 1-5 meaning that, farmers tend to agree on the same level of availability of farm resources for cotton in the study area (Table 20).

Table 20: Perceived Level of Availability of Farm Inputs

Type of Input	Frequency and percentages of perceived level of availability of farm resources F (%)					Mean $\overline{X}$	S.D
	VH	H	M	L	VL		
Nitrogen fertilizer	72 (23.5)	130 (42.3)	84 (27.4)	14 (4.6)	7 (2.3)	3.8	0.9
Seeds	77 (254.)	112 (37)	91 (30)	17 (6.5)	6 (2)	3.7	0.9
NPK fertilizer mixture	71 (24.4)	111 (38.1)	88 (30.2)	13 (4.5)	8 (2.7)	3.7	0.9
Herbicides	57 (19.9)	113 (39.4)	88 (30.7)	15 (5.2)	14 (4.9)	3.6	1.0
Insecticides	31 (18.1)	52 (30.4)	67 (39.2)	10 (5.8)	11 (6.4)	3.4	1.0

Source: Field Data, 2014

Means were calculated from a scale of 1 to 5, where the input is more enough in the amount and easily accessed is very high (VH= 5), enough in the amount and easily accessed is high (H= 4), not enough and accessed is moderate (M= 3), not enough and to some extent easily accessed is low (L= 2), not enough and hardly accessed is very low (VH= 1).

The results are not surprising because of the governmental support to the cotton sector. The results are consistent with the finding of Eldaw (2004) who stated that the Gezira Board provides almost all the services and inputs for the production and marketing of cotton. These inputs include seed, sacks, fertilizers and chemicals pesticides for plant protection, in addition to land preparation, application of fertilizers and spraying of chemicals.

Perceived Level of Input Prices

The results show that all the means of farmers' perception on input prices were above 3.5 and ranged from 4.2 to 4.4 (Table 21). The result implies high level of prices and consequently represents low level of sustainability as the prices were all perceived to be hardly affordable.

Table 21: Perceived Level of Inputs Prices

Type of Input	Frequency and percentages of perceived level of price of farm inputs F (%)					Mean $\overline{X}$	S.D
	VH	H	M	L	VL		
Seeds	160	91	46	11	0.0	4.2	0.8
	(51.9)	(29.5)	(14.9)	(3.6)	(0.0)		
Insecticides	102	38	25	4	0.0	4.4	0.8
	(60.4)	(26.5)	(14.8)	(2.4)	(0.0)		
Herbicides	157	76	51	8	0.0	4.3	0.8
	(53.8)	(26.0)	(17.5)	(2.7)	(0.0)		
Nitrogen fertilizer	165	92	43	8	0.0	4.3	0.8
	(53.6)	(29.9)	(14.0)	(2.6)	(0.0)		
NPK fertilizer mixture	160	82	47	3	1	4.3	0.8
	(54.6)	(28.0)	(16.0)	(1.0)	(0.3)		

Source: Field Data, 2014

Means were calculated from a scale of 1 to 5, where if the price is not at all affordable is very high (VH= 5), hardly affordable is high (H= 4), affordable is moderate (M= 3), easily affordable is low (L= 2), and very easy to afford is very low (VL= 1).

The farmers tend to agree on the high level of prices (SD= 0.8). The results indicate that the prices of farm inputs constitute a major constraint towards economic sustainability of cotton production in the study area.

Perceived Level of Loan Sufficiency

Providing loans is an important part of ensuring that farmers follow good agricultural practices in cotton production. The results show that cotton farmers perceive the quantum of loans to be low (Mean= 2.1) and not sufficient to cover the cost of most of the agricultural practices (Table 22).

Table 22: Perceived Level of Loan Sufficiency

Item	Frequency and Percentages of Perceived Level of Loan Sufficiency F (%)					Mean $\overline{X}$	S.D
	VH	H	M	L	VL		
Loan sufficiency	4 (1.6)	25 (10.2)	29 (11.8)	140 (56.9)	48 (19.5)	2.1	0.9

Source: Field data, 2014

Mean was calculated from a scale of 1 to 5, where if quantum of loan is very sufficient to cover the cost of all agricultural practices is very high (VH= 5), sufficient to cover the cost of most of the agricultural practices is high (H= 4), sufficient to cover the cost of majority of the practices is moderate (M= 3), not sufficient to cover the cost of most of the practices is low (L= 2), and not sufficient to cover the cost of few of the agricultural practices is very low (VH= 1).

The results are consistent with the findings of Eldaw (2004) that the loans and cash advances provided for cotton cultivation have historically been below the actual costs incurred by farmers for the various farming activities. Consequently, farmers perceive the loan to be low and many of them are confronted with the problem of securing more cash to cover the labour costs.

Economic Viability of Cotton Farming

Farmers' perceived level of economic viability of cotton production was determined using four variables: yield of cotton, price of cotton product, price stability and profit margin. The results show that profit margin and price stability were perceived to be far less than the expected levels (Mean is less than 2.5). The yield of cotton (Mean =3.6) was perceived to be high and meets the expectation of the farmers, but the price of cotton in the market was perceived to be moderate (Mean =2.5) and slightly less than what the farmers were expecting (Table 23).

Table 23: Perceived Economic Viability of Cotton Farming

Item	Frequency and percentages of perceived level of economic viability of cotton farming F (%)					Mean $\bar{X}$	S.D
	VH	H	M	L	VL		
Yield of cotton	75	88	116	23	10	3.6	1.0
	(24.0)	(28.2)	(37.2)	(7.4)	(3.2)		
Price of cotton	4	29	136	92	50	2.5	0.9
	(1.3)	(9.3)	(43.7)	(29.6)	(16.1)		
Profit margin	15	27	90	91	87	2.3	1.1
	(4.8)	(8.7)	(29.0)	(29.4)	(28.1)		
Stability of cotton	2	5	103	121	79	2.1	0.8
prices	(0.6)	(1.6)	(33.2)	(39.0)	(25.5)		

Source: Field Data, 2014

The means were computed from a scale of 1 to 5, where more than the expected is very high (VH =5), expected is high (H =4), slightly less than expected is moderate (M =3), far less than the expected is low (L =2), and disappointing is very low (VL =1).

The high yield could be explained by the adoption of genetically modified cotton which led to remarkable increase in cotton yield in the study area as also reported by Latif and Babiker (2012) who noticed that the Bt. cotton contributed to increase in yield compared to local varieties. Even though, the yield of cotton was perceived to be high, the profit margin gained from marketing the cotton product was perceived to be low. This phenomenon could be explained by the high prices of production inputs as explained earlier in Table 21.

Perceived Level of Mechanization of Agricultural Practices

In the field of sustainability of plant production systems, many scholars agree that mechanization of farm practices is essential to increasing farm productivity of agricultural crops and it therefore contributes positively to economic sustainability of plant production systems (Dantsis, Douma, Giourga, Loumou & Polychronaki, 2010). The study reveals that all the means of the variables that were used to assess the perceived level of mechanization of agricultural practices in cotton were more than 3.5 (Table 24), meaning that agricultural machines were used almost four times in the last five years.

Table 24: Perceived Level of Agricultural Mechanization in Cotton

Type of Machine	Frequency and percentages of perceived level of mechanization of agricultural practices in cotton F (%)					Mean $\bar{X}$	S.D
	VH	H	M	L	VL		
Ploughing Machine	118 (38.2)	135 (43.7)	48 (15.5)	4 (1.3)	4 (1.3)	4.1	0.8
Sowing Machine	43 (27.2)	41 (25.9)	66 (41.8)	8 (5.1)	0.0 (0.0)	3.7	0.9
Fertilizer Application Machine	69 (28.8)	75 (31.3)	70 (29.2)	19 (7.9)	7 (2.9)	3.7	1.0
Weeding Machine	26 (20.3)	47 (36.7)	43 (33.6)	9 (7.0)	3 (2.3)	3.6	0.9
Pesticide Application Machine	56 (24.2)	83 (35.9)	66 (28.6)	16 (6.9)	10 (4.3)	3.6	1.0

Source: Field Data, 2014

Means were calculated from a scale of 1 to 5, where using the machine five times in the last five years is very high (VH= 5), four times in the last five years is high (H= 4), three times in the last five years is moderate) M= (3); two times in the last five years (low) L= (2); used once in the last five years (very low) VL= (1); Mean ≥3.5 is high.

The most frequently used agricultural machine was the ploughing machine followed by sowing and fertilization machines. The results imply high level of mechanization. This high level of mechanization helps in ensuring economically sustainable cotton production system by increasing the yield, making cotton production a profitable business.

Perceived Level of Economic Sustainability of Cotton Production

Five indicators were used to assess the level of perceived economic sustainability of cotton production in the study area. These indicators are mechanization of agricultural practices, availability of farm inputs, economic viability of cotton farming, sufficiency of loans and price of farm inputs. The results reveal that the weighted mean of all economic indicators was 2.7, constituting moderate level of economic sustainability of cotton production in the study area (Table 25).

Table 25: Perceived Level of Economic Sustainability of Cotton Production

Variables	Mean $\bar{X}$	Level of sustainability	SD
Level of Mechanization of Agricultural Practices	3.7	High	0.9
Availability of Farm Inputs	3.6	High	0.9
Economic Viability of Cotton Farming	2.6	Moderate	0.9
Sufficiency of Loans	2.1	low	0.9
Prices of Farm Inputs	1.9	Low	0.8
Weighted Mean	2.7	Moderate	0.88

Source: Field Data, 2014

Level of mechanization of agricultural practices and availability of production inputs were found to have means of 3.6 and 3.7 respectively. These two variables represent the most contributory variables to economic sustainability. In contrast, farmers perceived the prices of the inputs to be high or hardly affordable. This perception constitutes a threat to economic sustainability and therefore the sustainability of cotton production.

Overall Sustainability of Cotton Production

The study found that farmers' perception of environmental and economic sustainability concerns in the cotton production industry in the study area were about equal and both were perceived to be moderate (Table, 26). However, environmental sustainability (mean=2.8) was slightly better than economic sustainability (Mean=2.7).

Table 26: Perceived Level of Sustainability of Cotton Production

Sustainability dimension	Mean $\overline{X}$	Level of sustainability	SD
Environmental sustainability	2.8	Moderate	0.94
Economic sustainability	2.7	Moderate	0.88
Weighted Mean	2.75	Moderate	0.90

Source: Field Data, 2014

The two means gave a weighted mean of 2.75 for the overall perceived sustainability. Since the weighted mean is more than 2.4, the result simply implies moderate level of sustainability.

Relationship between Farmers' Characteristics and Sustainability

Based on Davis Convention (1971) (see Appendix B) for describing correlation coefficient, the results of the Spearman correlation show a low positive relationship between farm size and the level of farm sustainability as represented by r= .123 correlation coefficient (Table 27). The result implies that, as farm size increases, the farm sustainability increases. The findings agree with that of Van Passel, Mathijs and Van Huylenbroeck (2006) who reported that the more sustainable farms were found to be bigger in size and, larger agricultural land increases farm production and may represent potentially higher sustainability efficiency.

Table 27: Spearman Correlation Matrix of Relationship between Farmers' Characteristics and their Perceived Level of Sustainability

Variable	Y
X_1	.123*
X_2	-.134*
X_3	.091
X_4	-.011
X_5	-.097

Source: Field Data, 2014

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

Key: Y= Overall sustainability

X_1= Farm Size

X_2= Age

X_3= Education Level

X_4= Family Size

X_5= Experience.

The results also show negative low relationship between farmers' age and their perceived level of sustainability as represented by r= -.134 correlation coefficient (Table 27). It means that increase in farmers' age reduces the level of sustainability of their farms. The result is consistent with Van Passel, Mathijs and Van Huylenbroeck (2006) who noted that age has a significant negative effect on the farm sustainability, and the best sustainability scoring farms have younger farm managers. Furthermore, Dantsis, Douma, Giourga, Loumou and Polychronaki (2010), argued that age is associated with farmer's education level, attitudes, managerial features, commitment to farming, size of farming operation and all contribute to farm sustainability.

The relationship between farmers' education level and their perceived level of sustainability is positive and negligible r= .091 (Table 27). The result is consistent with the findings of the OECD (1999) that a farmer's educational level and effective farm management as well as timely adoption of environmentally friendly management practices are positively correlated. However, in the case of the Gezira Scheme, type and amount of input used on the farm are influenced by the funding organisation that supplies the inputs and, therefore, farmers have no choice other than to apply these inputs. The implication is that acquisition and application of technologies may have little to do with farmers' education level and as such, may explain the negligible correlation between farmers' education level and sustainability of cotton production on their farms. This argument is supported by Eldaw (2004) who reported that, in Gezira Scheme, the Gezira Board provides seed, sacks, fertilizers and chemicals for plant protection in addition to land preparation, application of fertilizers and spraying of chemicals.

There is negative negligible relationship between farmers' number of years of farming experience and their perceived level of sustainability, r= -.011 (Table 27). The result contradicts with the findings of Simon, Garba and Bunu (2013) who concluded that the experience of farmers play an important role in sustainability of agricultural plant production systems. It influences farmer's decision as to whether to use or to discontinue use, or to reject farm innovations. Most of the experienced farmers that participated in this study were elderly farmers and therefore, the contradiction could be explained by age of the farmers and its negative relationship with sustainability as aforementioned.

There is negative negligible relationship between farmers' perceived level of sustainability and their family size, correlation coefficient r= -.097. The result contradicts with the findings of Simon, Garba and Bunu (2013) who noted that a larger household size indicates higher sustainability potential and it determines the availability of cheap family labour compared to hired labour. According to the results of this study, most of the agricultural practices in cotton were mechanized starting from land preparation, sowing, weeding, fertilization and pesticide application. As a result, the need for family labour or hired labour did not really affect the level of farm sustainability.

Hypotheses Testing

The result in Table 27 shows that testing the significant values of the relationship between farmers' farm size and the perceived level of sustainability, it is observed that, the relationship was significant at 95% confidence level. As a result, the study rejects the null hypotheses about farm size and age.

As Table 27 shows, testing the significant values of the relationship between farmers' age and the perceived level of sustainability, it is observed that, the relationship was significant at 95% confidence level. As a result, the study rejects the null hypotheses that there is no significant relationship between farmers' age and the perceived level of sustainability.

On the other hand, the Study failed to reject the null hypotheses in the case of education level, family size and experience. It means that the there was no statistical evidence to say that the relationships between education level, family size and experience and, perceived sustainability were significant at 95% confidence level.

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

This chapter summarises the study, provides conclusions of the study and recommends some theoretical, practical and policy strategies for improving the sustainability of cotton production in the Gezira Scheme. The chapter also provides suggestions for future studies for understanding and improving sustainability of cotton production in Sudan.

Summary

The study involved environmental and economic concerns to measure farmers' perceived sustainability of cotton production under the Gezira Scheme in Sudan. After describing selected socio-demographic and farm-related characteristics of the respondents, the study determined the level of environmental sustainability based on perceived level of use of fertilizers, pesticides, agro-ecological management practices, farm machinery and level of adequacy of irrigation water. The study also determined the level of economic sustainability by taking into account the level of agricultural input supply, perceived level of input prices, level of economic viability, mechanization of agricultural practices and sufficiency of loans provided for the various agricultural practices in cotton. The descriptive survey research design was used to collect data related to the objectives of the study. Interview schedule was used to obtain information from 315 cotton farmers in the Gezira Scheme. The interview schedule was administered by the student researcher and four research assistants who were trained in a group discussion. Some personnel of the Gezira Scheme also helped to establish linkages with the respondents.

Descriptive statistics such as means, standard deviation and percentages were used to describe selected socio-demographic and farm-related characteristics of the respondents as well as to determine the perceived level of sustainability. Spearman rank correlation was employed to examine the relationship between selected socio-demographic and farm-related characteristics of the respondents and their perceived level of sustainability. The study used frequency tables, graphs and correlation matrix to display the results.

The results revealed that majority of farmers were aging with the mean age being 51.9 years. A great proportion of the farmers were male. Also, most farmers were literate (83.3%) and had large family size ranging from 6-10 people. Farmers operate on average of farm size of 8.24 hectares farm size with about 1.84 hectares (22.33%) of it under cotton cultivation. Off-farm activities were found to exist within majority of the farmers' household. The government remains the main source of funding for cotton production, providing inputs and marketing services to majority (80.6) of the producers.

The results generally showed that, the overall sustainability of cotton production in the Gezira Scheme is moderate.

Cotton production in the Gezira Scheme is environmentally sustainable. The highly available and adequate irrigation water in conjunction with moderate level of agro-ecological management practices and pesticides were the major contributing factors to environmental sustainability. The use of fertilizer and farm machinery were found to decrease the level of environmental sustainability of cotton production.

In terms of economic sustainability, cotton production in the Gezira Scheme is moderately sustainable. While mechanization of agricultural practices and availability of farm inputs were highly sustainable, the business of cotton production was found to be economically viable but, moderately sustainable. The moderate economic viability was mainly due to the high yield. The quantum of loans received was perceived to be low. However, prices of inputs were perceived to be high.

Significant positive relationship was found to exist between farm size and the perceived level of sustainability. The relationship between farmers' age and sustainability was found to be negative and low. Education level of the farmers was found to have positive negligible relationship with their perceived level of sustainability. Farming experience and family size had negative negligible relationship with sustainability.

Conclusions

From the findings of the study, the following conclusions are drawn:

The Gezira Scheme cotton production is dominated by small-scale male farmers with some formal education, but who are aging. The farmers have large family size and depend mostly on government for financing their cotton production.

Environmental sustainability of cotton production system in the Gezira Scheme was generally perceived to be moderate. The availability of adequate irrigation water and the appropriate use of pesticides coupled with effective soil conservation practices such as incorporating crop residues into the soil, application of organic manures and following crop rotation were perceived to be the major contributors to the moderate environmental sustainability of cotton production in the Gezira Scheme. The application of inorganic fertilizer and high level of use of farm machinery were however, perceived to be the major threats to environmental sustainability of cotton production in the Gezira Scheme.

Economic sustainability of the Gezira Scheme's cotton production can be considered as moderate. The major contributors to the moderate economic sustainability being the perceived high level of mechanization of agricultural practices and availability of production inputs. The major threats to economic sustainability in the Gezira Scheme can be considered as high price of inputs and insufficient loans to producers.

Farm size and education level of the farmers have positive relationship with the level of sustainability of cotton production in the Gezira Scheme. Family size and years of experience of the farmers have negative relationship with the sustainability of cotton production in the Gezira Scheme.

Recommendations

Based on the findings of the study, the following recommendations are made to improve the sustainability of cotton production in the study area:

1. The government of Sudan and NGOs should develop policies and strategies that will attract the youth into the cotton production industry in the study area to deal with the problem of aging farmers in cotton production in the Gezira Scheme.

2. The Ministry of Agriculture and the Management of the Gezira Scheme should promote the use of organic fertilizer to minimise the use of chemical fertilizer in the scheme.
3. Farmers should be sensitised by extension agents to increase their level of use of some soil conservation practices such as application of organic manure, green manure, and be consistent in following appropriate crop rotation so as to conserve soil and improve its fertility.
4. The Ministry of Agriculture and the Gezira Scheme Management should seek for strategies to educate the farmers on the need to reduce the frequency at which heavy machines enter the cotton field to avoid soil compaction and deterioration.
5. The Gezira Scheme Management should negotiate with input suppliers and cotton market actors to reduce price of production inputs to affordable levels and increase the price of the cotton.

Suggestions for Further Studies

The following are suggestions for further studies:

1. The study should be extended to other cotton producing schemes in Sudan such as Rahad and Halfa irrigated schemes.
2. Other sustainability domains such as social sustainability should be included in future studies.
3. There are different methodological approaches to assess and analyse sustainability of plant production systems. For more insight, analysis techniques like Multi-Criteria Decision Analysis and Web-HIPRE should be used to assess sustainability of cotton production.

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APPENDICES

Appendix A: Interview Schedule

UNIVERSITY OF CAPE COAST

DEPARTMENT OF AGRICULTURAL ECONOMICS AND EXTENSION

Interview Schedule for Cotton Farmers

Introduction:

The information obtained by this instrument will be used only for academic purposes. Therefore, the respondents are asked to be scientific and objective in their answers. The confidentiality of the information is assured.

Title: Farmers' Perceived Sustainability of Cotton Production under the Gezira Scheme in Sudan

Section One: Socio-demographic and Farm-related Characteristics of the Farmers

1. Age at last birthday-----------------------------years
2. Sex: Male [ ] female [ ]
3. Respondent's highest Level of education:
   No formal education [ ] Primary [ ] secondary [ ]
   diploma/vocational training [ ] BSc [ ]
4. Number of years in formal education----------------------years
5. Number of persons dependent on the cotton farmer------------------persons
6. Total size of the farm---feddanes
7. Size of farm under cotton cultivation--------------------fedanes
8. Off- farm activity within the farmer's household.
   Existing [ ] Specify---------------------------------. Not existing [ ]
9. Number of years of experience in cotton production-------------years
10. Type of the funding agency: public [ ] private [ ]

Section Two: Environmental Sustainability of Cotton

1) Use of Fertilizers

Please indicate the type and the level of use of the fertilizer that you use, where using the fertilizer five times in the last five years is very high (VH= 5), four times in the last five years is high (H= 4), three times in the last five years is moderate (M= 3), two times in the last five years is low (L= 2), once in the last five years is very low (VL= 1).

	Type of fertilizer	**Yes/ No**	**Level of Use**				
			Very Low	**Low**	**Moderate**	**High**	**Very High**
1	Nitrogen Fertilizer(Urea)						
2	Potassium (k)						
3	Phosphorus (p)						
	NPK						

2) Use of Pesticides

Please indicate the type and the level of use of pesticides, where using the pesticide five times in the last five years is very high (VH= 5), four times in the last five years is high (H= 4), three times in the last five years is moderate (M= 3), two times in the last five years is low (L= 2), used once in the last five years is very low (VL= 1).

	Type of Pesticides	**Yes/ No**	**Perceived Level of Use**				
			Very Low	**Low**	**Moderate**	**High**	**Very High**
1	Insecticides						
2	Fungicides						
3	Pre-emergence herbicides						
4	Post-emergence Herbicides						

3) Adequacy of Irrigation Water

Please indicate the level of adequacy of irrigation water, where water is very much available and adequate is very high (VH= 5), available and adequate is high (H= 4), fairly available and adequate is moderate (M= 3), scarce is low (L= 2), very scarce is very low (VL= 1).

a) very high [ ] high [ ] moderate [ ] low [ ] very low [ ]

4) Agro-ecological Management Practices

Please indicate the type of practice and the perceived level of the practice, where using the practice five times in the last five years is very high (VH= 5), four times in the last five years is high (H= 4), three times in the last five years is moderate (M= 3), two times in the last five years is low (L= 2), used once in the last five years is very low (VL= 1).

	Type of Practice	**Yes /No**	**Perceived Level of Practice**				
			Very Low	**Low**	**Moderate**	**High**	**Very High**
1	Mixing crop residues and ploughing it with soil						
2	Green manure						
3	Organic manure/livestock manure						
4	Crop rotation						
5	Double crop/multi-cropping						
6	Cover crops						
	Genetically modified cotton						

5) Farm Machinery Operation

Please indicate the type and the perceived level of use of the machines, where using the machine five times in the last five years is very high (VH= 5), four times in the last five years is high (H= 4), three times in the last five years is moderate (M= 3), two times in the last five years is low (L= 2), used once in the last five years is very low (VL= 1).

	Type of Machine	**Yes /No**	**Perceived Level of Use**				
			Very Low	**Low**	**Moderate**	**High**	**Very High**
1	Ploughing machine						
2	Sowing machine						

3	Weeding machine						
4	Pesticide application machine						
5	Fertilizer application machine						
6	Harvesting machine						

Section Three: Economic Sustainability of Cotton Production.

1. Do you receive loans from any funding agency? Yes [ ] No [ ]
2. If 'Yes' how much do you receive during the growing season------- SD POUND
3. Please indicate your perception about sufficiency of the loan, where if quantum of loan is very sufficient to cover the cost of all agricultural practices is very high (VH= 5), sufficient to cover the cost of most of the agricultural practices is high (H= 4), sufficient to cover the cost of majority of the practices is moderate (M= 3), not sufficient to cover the cost of most of the practices is low (L= 2), and not sufficient to cover the cost of few of the agricultural practices is very low (VH= 1).

   Very high [ ] high [ ] moderate [ ] Low [ ] Very low [ ]

1) Farmers' Perception on Availability of Farm Inputs

Please indicate the type and the level of availability of inputs, where the input is more enough in the amount and easily accessed is very high (VH= 5), enough in the amount and easily accessed is high (H= 4), not enough and accessed is moderate (M= 3), not enough and to some extent easily accessed is low (L= 2), not enough and hardly accessed is very low (VH= 1). The level of availability of input ranges from very high to very low.

	Type of Inputs	Yes/ No	Perceived Level of Inputs Supply				
			Very Low	Low	Moderate	High	Very High
1	Seeds						
2	Herbicides						
3	Insecticides						
4	Nitrogen fertilizer						
5	Potassium fertilizer						
6	Phosphorus fertilizer						
	NPK mixture						

2) Farmers' Perception of Prices of Farm Inputs

Please indicate the level of input price, where if the price is not at all affordable is very high (VH= 5), hardly affordable is high (H= 4), affordable is moderate (M= 3), easily affordable is low (L= 2), and very easy to afford is very low (VL= 1).

	Type of Inputs	Perceived Level of Cost				
		Very Low	Low	Moderate	High	Very High
1	Seeds					
2	Herbicides					
3	Insecticides					
4	Nitrogen fertilizer					
5	Potassium fertilizer					
6	Phosphorus fertilizer					
7	NPK mixture					

3) Farmers' Perception of Economic Viability of Cotton

Please indicate the level of price, where more than the expected is very high (VH =5), expected is high (H =4), slightly less than expected is moderate (M =3), far less than the expected is low (L =2), and disappointing is very low (VL =1).

	Item	Very Low	Low	Moderate	High	Very High
1	Yield of Cotton					
2	Price of Cotton					
3	Price Stability					
4	Profit Margins					

4) Agricultural Mechanization

Please indicate the type and the level of use of machines, where using the machine five times in the last five years is very high (VH= 5), four times in the last five years is high (H= 4), three times in the last five years is moderate) M= (3); two times in the last five years (low) L= (2); used once in the last five years (very low) VL= (1)

	Type of Machine	Yes/No	Perceived level of use				
			Very Low	Low	Moderate	High	Very High
1	Ploughing Machine						
2	Sowing Machine						
3	Weeding Machine						
4	Pesticide Application Machine						
5	Fertilizer Application Machine						

Appendix B: Interpretation of Correlation Coefficient Based on Davis Convention

Spearman Correlation Coefficient (r)	Interpretation
$0.01 \geq r \geq 0.09$	Negligible
$10 \geq r \geq 0.29$	Low
$30 \geq r \geq 0.49$	Moderate
$50 \geq r \geq 0.69$	Substantial
$r \geq 0.70$	Very Strong

Source: Lamm & Israel, 2013

Appendix C: Frequency Distribution of Size of Farm under Cotton Cultivation

Farm size (ha)	Frequency	Percentages	Cumulative percentage
0.5-2	257	81.8	81.8
2.01-3.60	46	14.6	96.5
3.61-5.01	2	0.6	97.1
>5.01	9	2.9	100.0
Total	314	100.0	

$\bar{X}$ =1.84, S.D =1.60, Maximum =18.90, Minimum =0.74

Source: Field data, 2014