UNIVERSITY FOR DEVELOPMENT STUDIES

ASSESSING WATER SECURITY AND ADAPTATION STRATEGIES IN THE SISILI-KULPAWN BASIN OF THE NORTHERN REGION OF GHANA

BY

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DECLARATION

I, Mohammed Jamaldeen Gariba, hereby declare that this thesis does not incorporate, without acknowledgement, any material previously submitted for a degree or diploma in any University; and that to the best of my knowledge and belief, does not contain any material previously published or written by another person, except where due reference has been made in the text.

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SUPERVISOR

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ABSTRACT

This study assessed water security and adaptation strategies in the Sisili-Kulpawn Basin (SKB) of the Northern Region (NR) of Ghana. A sample size of 200 households were considered which comprised of 100 irrigators and 100 non-irrigators. The study used the Water Poverty Index approach to assess the level of water security in the study area. The findings of this model indicated that only Yagaba was water secured but Loagri, Kunkwa and Wiasi were water insecured areas. The findings on adaptation measures revealed that drought resistant varieties and adjusting to planting date were the most practiced strategies among non-irrigators whiles short duration crops and mulching were the most practiced adaptation strategies among irrigators. The recursive model was used to estimate the effects of water security on adaptation strategies and the effects of adaptation strategies on farm income. The Multivariate Probit model was used to estimate the determinants of adaptation strategies and effects of water security on adoption. The results revealed that water security, off-farm, farm size, farm experience, extension services, number crops of grown and sex were the factors that affect the choice of adaptation measure. The study also deployed the Instrumental Variable regression to estimate the effects of adaptation strategies on farm income. The results indicated that predicted value of adaptation strategy, weedicide, labour, farm size, household size, irrigation and number of crops cultivated were affecting farm income. The Kendall's coefficient of Concordance was used to rank the constraints in the study area. Inadequate water for Irrigation and inadequate extension visits were the main problems faced by farmers. The study concluded that Loagri, Kunkwa and Wiasi were the water insecured communities and recommends the need for a capacity building training on adaptation strategies to strengthen their water management abilities.

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DEDICATION

I dedicate this work to the God Almighty for all His love; and to my mother and Issah Jamila for their great support in making this research work a successful one.

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LIST OF ACRONYMS

IWRM	Integrated Water Resources Management
UN	United Nation
WWDR	Worldwide Developer Relations
IWMI	International Water Management Institute
WHO	World Health Organization
ECA	Economic Commission for Africa
IWAD	Integrated Water for Agricultural Development
AWM	Agricultural Water Management
UNCTAD	United Nations Conference on Trade and Development
IFAD	International Fund for Agricultural Development
LDC	Least Development Countries
WEF	World Economic Forum
IISS	Indian Institute of soil Science
UNDP	United Nations Development Programme
NIC	National Intelligence Council
GWP	Global Warming Potential
INBO	International Network of Basin Organization
HDR	Human Development Report
UNESCO	United Nations Education, Science and Cultural Organizations
AfDB	African Development Bank
SSA	Sub-Saharan Africa
ESMAP	Energy Sector Management and Assistance Programme
SWSI	Social Water Stress Index
WPI	Water Poverty Index

WASH	Water Hygiene and Sanitation
UNICEF	United Nations International Children's Emergency Fund
MDG	Millennium Development Goals
TR	Total Revenue
TVC	Total Variable Cost
IPCC	Intergovernmental Panel on Climate Change
SWC	Soil and Water Conservation
FAO	Food and Agriculture Organization
MNL	Multinomial Logit
WFP	World Food Programme
PCI	Problem Confrontation Index
ASI	Adaptation Strategy Index
WRC	Water Resources Commission
MNP	Multinomial Probit model
OLS	Ordinary Least Square
UK	United Kingdom
NGOs	Non-Governmental Organizations
ERSA	European Regional Studies Association
IFPRI	Food Policy Research Institute
SKB	Sisili-Kulpawn Basin
MMD	Mamprugu Moaduri District
PV	Photovoltaic
US	United States
IIA	Independence of Irrelevant Alternatives

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of the study

According to Osei (2004), water which is considered as a key to wealth and prosperity is identified as one of the most important natural resources (Arbués et al., 2003) but due to population growth, urban growth and global industrialization, there have been a lot of pressure on water resource because of the increase in demand. Relevant concerns have therefore been raised about future water scarcity because of the significant role water plays in sustainable development.

Ariyabandu (2001) revealed that household water security is a relatively new concept in water demand management literature for both developed and developing countries. This concept encompasses issues of water availability, accessibility, usage, and water quality. Water accessibility considers water as a commodity and ensures that households have full control of the available water. Access to this commodity therefore depends on its physical location and timely availability. It has traditionally considered availability as the central focus although availability is the main emphasis but water security is affected to a larger extent by environmental factors.

Global water security is gaining a greater prominence as one of the highest priorities on the development agenda. Stated by Arnell (2004), the UN comprehensive Assessment of the Freshwater Resources of the World estimates that about a third of the world's population live in countries suffering from water stress where there is shortage of surface water, and are extracting more than 20% of their available water resources.

The International Water Management Institute (IWMI) estimated 1.4 billion people who live in regions will experience severe water scarcity in the first quarter of the 21st century (Kaluarachchi and Anayah, 2009). It was further projected that by the year 2025, about a billion people living in arid zones will experience absolute water scarcity. Arnell (2004) revealed that by the 2020s, between 53 and 206 million people will fall into water-stressed category whilst between 374 and 1661 million people are projected to experience increases in water stress and that the effect of climate change on water scarcity will largely depend on future water resource management practices.

Globally, the application of water and its use has been an essential factor in increasing agricultural productivity and ensuring greater outputs. By increasing productivity, sustainable water management helps to ensure better production both for direct consumption and for commercial purposes, so enhancing the generation of necessary economic surpluses for uplifting rural economies.

The report of the Human Development Index indicated that water is mainly used for agriculture in developing countries. An estimated 80% of Africans rely on agriculture for employment and water shortage will amount to food scarcity. Some of the arid regions in the continent are experiencing famines because of lack of rainfall to grow crops. The United Nations Economic Commission for Africa and the New Partnership for African Development posit that irrigation is the key to achieving increased agricultural production that is important for economic development and for attaining food security (Awojobi, 2014). According to the World Health Organization (WHO) (2004), about 1.1 billion people in the world rely on lakes, rivers and open wells and majority are from sub-Saharan Africa. About 2 billion people in the rural and urban areas depend on groundwater for water needs but the scarcity of water makes it a major concern to most sub-Saharan African countries.

In Ghana, Water resources play a central role in enhancing living standards, enhancing economic growth, providing food security and livelihood, and eventually alleviating of poverty. Unlike most countries, Ghana is experiencing population growth and associated demand on food production. Therefore, demand on water increases steadily while producing stress on available water resources. Also, climate change impacts on the limited water resources in semi-arid regions can be significant (Herrera and Hiscock, 2008). An accurate assessment of climate change impacts on recharge, temporarily and spatially, is challenging and complex (Jyrkama and Sykes, 2007). Some of these global impacts on water resources will definitely affect security and sustainability of the environment and society in the future (Kaluarachchi and Anayah, 2009).

Inefficient water resource development and conservation systems suitable for small scale farmers are some of the major problems limiting the capacity of agriculture to meet its role in food security and overall development in the country. Improvement of the water use efficiency is therefore important as long as agriculture is concern.

Agriculture in Ghana is largely rain-fed and it is mainly dominated by the rural people who lack the resources to adapt to the consequences of climate change. This makes the agricultural sector in Ghana exposed to more risk. Hence, the irregular nature of rainfall and the uncertainties about climate change will further worsen the concerns of rural people who rely on the agricultural sector.

Rain fed agriculture generally produces much below its potential because rain is irregular and this makes investments very risky. Investing in small scale water technologies could enhance both stability and productivity of smallholder farming even to levels where commercial production becomes possible.

Small multi-purpose reservoirs are usually considered for irrigation purposes. In the rural areas of Ghana where surface water is scarce, reservoirs are used for daily activities to improve the livelihood of the people. In the Northern Regions of Ghana where there are irregular rainfall patterns, small dams have been constructed on small rivers and streams to ensure a year round growing season and also water supply for livestock and domestic purposes (Hagan, 2009).

Climate studies have been conducted in Ghana and the reports have shown distinctive inter-annual and inter-decadal changes in major agriculturally-relevant climate variables such as temperature and rainfall (Challinor, *et al.*, 2007; De Pinto *et al.*, 2012; Amikuzuno and Hathie, 2013). In the Northern Region of Ghana, this phenomenon may have adverse implications on yields and hence livelihood of the rural poor.

The development of dams in the Northern regions of Ghana can be considered as one of the solutions for curtailing the incidence of poverty by improving the standard of living of the people through improved smallholder irrigation techniques and livestock production. They are seen as important tools in achieving some of the goals of vision 2020 of Ghana. There is therefore the need to reduce uncertainty through adapting to strategy tools such as good Agronomic Practices, irrigation, short duration varieties, drought resistant varieties for resilience against climate change hazards. Smallholder agriculture is defined as farmers owning small-based plots of land on which they grow subsistence crops and one or two cash crops relying mostly on family labour.

1.2 Problem statement

The concern about climate change is increasing; several studies (Campbell, 1999; Adejuwon, 2006; Moznyet al.,2009) have considered its potential impacts on agriculture. Ghana, like many other African countries, is in the middle of water crisis. This has fueled significant policy action from governments, each with varying success. With the growth of population which increases water demand, the water insecurity problems in the Northern region are likely to get worse before they get better (Grey and Sadoff, 2007).

In Ghana, the three Northern regions have been widely designated as the poorest regions and the impacts of climate change are expected to be much more severe in these regions. Crop failure due to irregular rainfall patterns has been reported in recent times in the regions (Amikuzuno and Donkoh, 2012).

To identify the empirical gaps of previous studies, this study seeks to quantify the potential economic impacts of water security on agricultural production, adaptation strategies to manage water insecurity, and constraints faced in the SKB of the Northern Region of Ghana. The purpose is to assess how water security, with or without adaptation, will affect livelihood and how farmers respond to these impacts through the implementation of adaptation strategies that promote their resilience. There is a gap between farmers' knowledge and water management technologies in the SKB. This study particularly, seeks to examine how farmers' wellbeing might be affected if future water insecurity issues are curbed.

More specifically, this study seeks to find answers to following questions in the SKB;

- What is the level of farm household water security in the study area?
- What are the adaptation strategies of households to water insecurity in the study area?

- What are the effects of household water security on farm household adaptation strategies?
- What are the effects of household adaptation strategies on farm income?
- What is the profit levels between Irrigators and non-irrigators?
- What are the constraints faced by farmers?

1.3 Objectives of the study

The main objective of the study is to estimate household water security and adaptation strategies in the Sisili-Kulpawn Basin of the Northern Region of Ghana

1.4 The specific objectives are to:

1. estimate farm households water security in the study area;
2. examine the adaptation strategies of households to water insecurity in the study area;
3. estimate the determinants of adaptation strategies and effects of household water security on farm household adaptation strategies;
4. determine the effects of household adaptation strategies on farm income;
5. determine the profitability levels (Gross Margin) between Irrigators and non-irrigators; and
6. identify the major constraints faced by farmers in the Sisili-Kulpawn Basin.

1.5. Justification of the study

The Northern Regions of Ghana have already experienced droughts and floods in the last decade. for instance, farmers were seriously affected in 2013 due to a severe drought in the Region which led to a crop failure.

Extreme rainfall issues related to climate change are expected to be on a rise because of an expected increase in the intensity of anthropogenic activities. The degree of uncertainty associated with climate change is expected to be increased. This is expected to make it difficult for governments, researchers, and other stakeholders to plan effectively and address the impacts of water insecurity in a holistic manner. In this way, the concerns of possible loss of livelihoods, development of adaptation strategies and building long term resilience, and reducing the risk faced by smallholder farmers will not be easy to address. Objective three of the study will help stakeholders in agriculture, NGOs and other Organizations to understanding the adaptation strategies that will help build long term resilience among farmers.

To solve this issue, there is the need to help the multi-stakeholders of climate change appreciate the impacts of water security in a way that will benefit all. This study intends to provide relevant information that will assist in the capacity building of smallholder farmers to adapt to changing climate-related hazards especially droughts and improving long term resilience towards water insecurity.

This study is carried out with the motive of providing empirical evidence on water security on smallholder and farm-level adaptation strategies to manage water insecurity issues. The region is a place of significant climatic occurrences like droughts and thus is more exposed to the forces of nature, compounded by weak institutions and a high incidence of poverty among its population.

1.6. Scope and Limitation of the study

Water resource concept is multidimensional; it is not only limited to its physical measure (hydrological and hydro geological), the ‘flows and stocks’, but presents other more qualitative, environmental and socio-economic dimensions. However, this study focuses on the socio-economic dimensions and quantitative assessment of the water resource.

The study focuses on water security and adaptation strategies in the SKB in the Northern Region of Ghana. However, due to financial and time constraints, the study will be limited only to MMD.

1.7. Organization of the Study

The study will consist of five chapters. The first chapter will be an Introduction and problem setting. The second chapter present the Literature Review, the third chapter discusses the Research Methodology, the fourth chapter deals with Presentation of Results and Discussion of Research findings and the fifth chapter presented the Summary, Conclusion and Recommendations.

CHAPTER TWO

2.0 Literature Review

2.1.1 Background

This section presents a review of studies done by other researchers in fields relating to water security and directly or indirectly relating to the objectives of this study.

2.1.2 Climate change and its implication to water security.

According to Wheater (2015), the changing trend of land through urbanization and agricultural intensification is equally reducing the quantity and quality of rivers, wetlands and groundwater due to land management change and water management. Climate is changing globally, due to anthropogenic emissions, but also locally, due to changing land and water use. Milly (2008) conducted a study and it revealed that much less attention has been given to other effects of the Anthropocene on changing land use and land management. Non-stationarity of environmental systems is, however, general and widespread, with major implications for contemporary hydrological practice and water management. Many of the effects are poorly understood and poorly modeled due to lack of knowledge and relevant data. For example, even in densely populated environments, while forestry has been well studied, effects of agricultural intensification remain quite uncertain (Wheater and Evans, 2009). While the effects of urbanization are well known in principle, their hydrological effects are determined by local infrastructure and local management, so that characterization of impacts at the basin scale remains challenging. Similarly, water management systems are often highly complex, and subject to multiple constraints and operational controls. While these may be known at a local level, their representation at regional and global scales remains challenging (Nazemi and Wheater

2015a). The effects of land and water management are therefore complicated and depend very much on the local context. According to Destouni et. al., (2010), attention to these effects has primarily been focused on the aquatic and terrestrial environments; however, the extensive nature of changes is such that increasing evidence of feedbacks to local climate are being reported.

Subtler effects of irrigation and vegetation change on precipitation generation have also been reported; as studies have been conducted in California by Lo and Famiglietti (2013) and Sorooshian *et al.* (2011) to confirm the above information.

Weather (2015) noted that the environment is affecting the quantity and quality of surface and groundwater resources, aquatic ecosystems, and flood hazard, and with potential feedbacks to climate. The study further indicated that to gain understanding of the Anthropocene therefore requires a holistic approach, integrating knowledge across multiple disciplines. This includes the natural sciences and engineering, but given that the Anthropocene is, by definition, a human-natural system, this must also include the social sciences. From a management perspective, while there has been much discussion of the Water–Energy–Food Nexus, this is to simplify the operational realities faced by most water managers. A single reservoir may have conflicting requirements for long-term storage for irrigation supply, short-term management of storage for flood risk reduction, the need to maximize downstream flows for hydropower generation, and various local and downstream constraints for habitat protection and amenity use. According to the Council for Canadian Academies (2013), conflicts concerning environmental flows go beyond allocations for human water use and water for the environment. Concerning flood risk, it is desirable for natural wetlands to experience a diversity of flows and maintain a realistic flood regime, but this may threaten local riparian communities and rural people. And while multiple sectors of the economy depend on water, agriculture has a particularly important role; farmers are managers of land and water, and while agricultural management can affect downstream flows and water quality, land management can also be used to mitigate effects of water quality and flooding. Agriculture can place operation requirements on water quality; increasingly constraints placed on farmers by the supply chain require certification of the quality of water used for irrigation.

There is evidence that water management must address a range of scales, including the largest scale of the systems to be managed that is the whole river basins and groundwater aquifers, and that may involve multiple jurisdictions, with international implications in some cases. Similarly, the needs for underlying science also cross multiple scales. The above effects of land management can be subtle and dependent on the local environmental context. For example, particular agricultural beneficial management practices may be advantageous in one environment and counter-productive in another. The need to understand local effects and their larger-scale implications for management is therefore necessary.

The effects of the Anthropocene are now sufficiently extensive that significant feedbacks can arise from large-scale changes to land and water management. This requires new understanding of feedbacks at the scales of influence for weather systems. Also, with the resolution of weather and climate models rapidly increasing at regional and global levels, there are significant unanswered challenges for hydrologists concerning the appropriate scale of parameterizations for large-scale application (Wood *et al.* 2011, Beven and Cloke 2012).

Nazemi and Wheater (2014) stated that in order to address the societal challenges of Water Security, a new paradigm for interactions between the science and user communities is needed. Hence, translation of scientific understanding into useful information for policy and management is essential. However, it is equally important that the science community addresses the issues of relevance to the management of Water Security, and these are not best defined by the science community. New approaches will be needed to develop appropriate policy and governance in the face of highly uncertain water futures, including vulnerability analysis, adaptive management and no regret solutions. In addition, local stakeholders are an important knowledge base; for example, indigenous and other rural communities have a wealth of traditional knowledge, and farmers will have a depth of understanding of their land that is often multi-generational and will generally exceed that of a research scientist. More generally, engagement with stakeholders, including water managers, local non-governmental organizations and the public in general, is necessary to develop a framework and create awareness to farmers. Essentially the major challenges of Water Security lie with governance and the need to make hard decisions in any democratic governance system, these decisions will reflect public opinion and societal attitudes to water.

2.1.3 The rainfed-irrigation nexus

According to United Nations Conference on Trade and Development (UNCTAD) (2011) agriculture is a mix of rainfed and irrigation farming. Rainfed farming is the world's most common farming system practiced on 80 percent of cultivated land and accounting for 60 percent of the world's food production. In areas of high and reliable rainfall such as in northern Europe, crop yields are good and production is reliable. But in areas of low, erratic, and unreliable rainfall, such as Africa where many of the disadvantaged live, crop yields are low and uncertain, the average yield of grains is only 1 ton/hectare and water consumption is high because of the high evapotranspiration rates between 2,000- 3,000 m/ton of crop. This is roughly twice the global average of 1,000-1,500 m3/ton of crop. The ability of most smallholder farmers to make better use of rainwater is limited. This has been confirmed by Wallace (2000), Rockstrom and Falkenmark (2000) that the fraction of rainfall used for crop transpiration is only 15-30 percent and sometimes it is as low as 5 percent. The remaining portion is lost through surface runoff, drainage, and unproductive evaporation (IWMI, 2009).

Irrigation is only practiced on about 300 million hectares (in 2010), or 20 percent of the cultivated land area (FAO, 2010a) globally. But the bring-out of irrigation is substantial with more than 40 percent of the world's food production. According to IWMI (2004), about 84 percent of the irrigated area is in Africa, Asia, South America. There is still room for expansion, particularly in sub-Saharan Africa in places where there is sufficient water available.

UNCTAD (2011) revealed that Irrigated agriculture offers great opportunities for economic growth and poverty alleviation. It can reduce the risks associated with the unpredictable nature of rainfed agriculture in dry regions and increase crop productivity in humid and tropical zones by extending the wet season and introducing effective means of water control. It can help in the fight against droughts, which are predicted to occur more frequently. Irrigation development can also positively affect crop diversity, yields, employment and lowering food prices (IFAD, 2008). Indirectly it can stimulate input and output markets, stabilize output and economic activities thus providing substantial benefits across economic sectors. But, like rainfed farming, there are concerns about water wastage. In many irrigation schemes in semi-arid areas, particularly among Least Developing Countries (LDCs), less than 20 percent of the water delivered is actually transpired by crops (Wallace, 2000).

Falkenmark (2006) revealed that although rainfed and irrigation farming are often considered to be separate and distinct ways of growing crops, in practice they overlap. Natural rainfall contributes to irrigation farming and irrigation is used to supplement inadequate rainfall. Agriculture exploits both blue water (rivers, wetlands, lakes and ground water) and green water (rain water and soil moisture), often at the same time to meet crop water requirements. This approach to thinking about water is breaking down the traditional divisions between blue and green water and is shifting water resources planning from dealing with runoff (blue water) to a process that values both blue and green water. This is the essence of agricultural water management (AWM).

2.1.4 Water resource development

Agriculture is vital for food security, rural development and poverty alleviation but is one of the most vulnerable sectors to climate change. However, it is also one of the main causes for it; it is responsible for directly emitting 14 % of the Greenhouse gas emissions, deforestation and land-use changes (World Bank, 2013).

Worldwide, the application of water and its managed use has been an essential factor in raising productivity of agriculture and ensuring predictability in outputs. Water is essential to bringing forth the potential of the land and to enable improved varieties of both plants and animals to make full use of other yield-enhancing production factors. By raising productivity, sustainable water management helps to ensure better production both for direct consumption and for commercial disposal, so enhancing the generation of necessary economic surpluses for uplifting rural economies (Betebo, 2014).

According to Kaiyatsa (2014), water is essential for the well-being of mankind and for sustainable development. Increasingly, water is seen as one of the most critically stressed resources, and much attention is now being paid to global water stress and the water needs of the poorest people (Sullivan et al., 2003). It was further stated that water development is key in Malawi due to its direct linkages with agriculture as it is important for irrigation which contributes towards reduction of the over dependence on rain-fed agriculture. Rain fed agriculture produces below its potential because rain is irregular and this makes agricultural investments too risky. Moderate investments in small scale water technologies could enhance both stability and productivity of smallholder farming even to levels where commercial production becomes possible (Betebo, 2014).

Throughout history, the development of water systems has enabled economic growth and productivity, with natural aquatic systems being transformed through changes in land use, urbanization, industrialization, large-scale agriculture, and as a convenient recipient of waste.

Water for food production accounts for about 70% of water withdrawals. Combining increases in overall population, urbanization, and prosperity with changes in dietary demands, the demand for food will further increase considerably. Globally, 80% of water for agriculture comes directly from rain, and about 20% comes from irrigation.

According to Ologunagba et al., (2009), water has become an increasingly important issue in developing nations in last few years. The livelihoods and food security of the small-scale farmers of SSA are particularly threatened by climate change, as it is already having direct impacts on agricultural production and productivity. Climate change could cause serious deterioration of rural livelihoods and increase food insecurity in Sub-Saharan Africa (SSA).

In Nigeria, one prominent factor that has been neglected and has caused much poverty in Africa is Water development. According to the Water Project Organization, the lack of access to quality water makes it difficult for one to grow crops, stay healthy and cook good food (Awojobi, 2014).

2.1.5 Water security at household level

According to Calow and Mason (2012), water's significance in both social and cultural contexts cannot be overlooked, its intersection with the already loaded term 'security' results in some serious responses. Water security as an emerging headline geopolitical issue that may 'tear into various parts of the global economic system' World Economic Forum (WEF, 2011). The concept of water security implies minimizing the effects of water scarcity. Indeed, one widely quoted definition of water security embraces the concept of water risk as one side of the coin, the other being availability.

According to Grey and Sadoff (2007), the availability of an acceptable quantity and quality of water for health, livelihoods, ecosystems and production together with an acceptable level of water-related risks to people, environments and economies.

Hope (2012) stated that water security is a tolerable water-related risk to society. Society means different things to different people, and may leave room for the privileging of some interest over others. While the concept of water security is not new, the term appears to have gained greater importance lately, based on the results from a range of reports and conferences that have considered water security in isolation or in relation to the security of other resources for instance energy and food and land (WEF 2011; NIC 2012; Martin-Nagle et al. 2012; Oxford University Water Security Network 2012).

There have been more limited issues concerning water security, notwithstanding some important interventions (Tarlock and Wouters, 2009; Wouters 2010; Cook and Bakker, 2012) and deliberations about its importance of the term have had less time to evolve and polarize. The definition of water security is centered on availability of the resource but to some degree this underplays issues of access and allocation and aligns more with the concept of physical water scarcity than with other manifestations.

But while the debates on water security have not been extensively discussed, there has been some views around longer established security concepts with which water security is linked to national and human security. This means that the effects of water security are felt.

However, there has been longstanding consideration of water's potential role in conflict, often with reference to water scarcity (CoFR, US Senate, 2011). Clear examples of international conflicts with water as a central causal factor, or as a weapon of war, are in fact rare (Yoffe, Wolf and Giordano 2001: 64). Nonetheless, there are well-documented instances of water playing a part in more localized unrest, terrorism and political oppression into recent history (Pacific Institute, 2011), and commentators reflect that this is likely to be an ongoing and intensifying phenomenon (IISS, 2011). According to De Stefano et al. (2010), the World Bank has attempted to identify potential water conflict hotspots based on physical risk and ability, at least on paper, to manage that risk, matching projected change in hydrological variability against the presence of relevant institutions, for instance treaties and river basin organizations, for different transboundary river basins.

In most cases, water security may increasingly be referred to in articulating water's role in national and international peace and stability due to water's strategic significance as both a fugitive resource that often traverses borders (UNDP 2006: vi) and, in its virtual form, as a globally traded commodity. A report on Global Water Security was commissioned by former US Secretary of State Hillary Clinton from the US National Intelligence Council (NIC). The report considers the implications of water security, understood in terms of national security, for US interests, identifying not only threats but also opportunities, for example in relation to the US's status as a major global food exporter (NIC 2012), picking up on the emerging theme of the nexus between water and food security. The report concludes that in 2022 water insecurity could be a contributing factor to state failure, and increasingly feature as a mechanism for contestation and leverage between states. Beyond 10 years, the report has high confidence that water is more likely to be used as a weapon by states or terrorists.

A study conducted by Tarlock and Wouters (2009) revealed that observing governmental concern with the global water crisis and a narrow interpretation of water security aligned closely with national security. But it can equally be noted that in announcing the NIC commission in 2011, Clinton chose to counterbalance the potential for unrest, conflicts, and instability with the rejoinder that the water crisis can bring people together. The report further stated that improved water management including pricing, allocations and virtual water trade and investments afford the best solutions for water problems (NIC 2012: 6). This goes some way to temper concerns that the defense and foreign policy communities will necessarily accept the concept of water security in support of unilateral military responses.

Brown and Lall (2006) further revealed that beyond transboundary water resources, the national security implications of water extend to how a country manages its own internal water resources for its economic development and stability. The economic importance of water is clear despite the fact that the resource itself is often underpriced or not priced at all. Economic growth is much more closely correlated to an even temporal and spatial distribution of water than it is to high physical availability overall, and that many agricultural low-income countries are particularly vulnerable to intra-annual variability. However, this may underplay the significance of groundwater storage and its potential to provide a buffer against shorter-term variability, especially as groundwater replenishment is unlikely to correlate directly with precipitation. Shah (2007), indicated that growth is unlikely to be so sensitive to irregular rainfall in groundwater-dependent economies, for example in parts of South Asia and the North China Plain where agricultural yields have increased largely on small-scale but based on irrigation from boreholes. A study by Grey and Sadoff (2007) further revealed the issue of rainfall variability is worse where countries lack a minimum platform of hydraulic infrastructure leaving them hostage to hydrology, a difficult situation that applies to the case of groundwater, also in terms of infrastructure to access and store the resource.

There are clearly both politico-military and economic imperatives at the intersection of water security and national security, which may yet influence future paradigms for WRM. IWRM has been extensively promoted at national level, but as a recent report highlights, more work needs to be done to make its goals relevant in a transboundary context where national security discourses tend to play out, and where more heterogeneous legal and institutional regimes and greater disparities of power and interest may be at play (GWP and INBO 2012).

According to Calow and Mason (2012), human security is the second of the existing major security concepts which is likely to influence interpretations of water security. Since its origins, human security has been conceptually opposed to a narrow, conventional analysis of national security. The 1994 Human Development Report (HDR), which brought the term to popular attention, recognized that the scale and nature of many threats to peace and sustainable development cannot be tackled solely through a territorial paradigm of the nation-state backed by force of arms (UNDP, 1994). The 1994 HDR represents a landmark in a narrative which continues through to the water-focused 2006 HDR and beyond, whereby security is conceived in multidimensional terms, rooted in individual rights and perceptions of gradual but with harmful effects in power and resources between individuals and groups. Water security is not mentioned by the 1994 HDR as a category in its own right, but aspects are included within the categories of health and environmental security. Because it places the emphasis on individuals, the concept of human security aligns most naturally with human-centered interpretations of the water crisis, and principle among these is the concept of 'water poverty'.

Water security revolves round issues of water availability, accessibility, usage and quality.

1. Household poverty status

According to Chern et al., (2002), heterogeneity of income across households is important as a socio-economic variable to explain consumption behaviour. Household income also serves as an indicator of household poverty status despite the fact that poverty is sometimes defined in terms of household expenditure (Förster, 1994).

Black and Hall (2003) show that the issue of access to water resources is concerned with far more than just the issue of drinking water, arguing that the "water poor" includes:

- ✓ Those whose livelihood base is persistently threatened by severe drought or flood;
- ✓ Those whose livelihood depends on cultivation of food and natural products and whose water source is not dependable;
- ✓ Those whose livelihood base is subject to erosion, degradation, or confiscation (construction of major infrastructure) without due compensation;
- ✓ Those living far from a water source;

Taken together, issues provide a basis for understanding the links between poverty and water security. Through this, changes to the management of these vital resources can be made to ensure that they contribute more effectively to the reduction of poverty (Narcisse, 2010).

2.1.6 Challenges of water security

Water Security is a phrase that is frequently used to denote the multiple challenges associated with 21st century water management (Cook and Bakker, 2012). It has been defined as the sustainable use and protection of water resources, safeguarding access to water functions and services for humans and the environment, and protection against flood and drought (Wheater and Gober, 2013).

Water Security comprises of a complex, multi-dimensional and interdependent set of issues. There is heightened competition for the use of water at local, regional and international scales, both between sectors of the economy and between upstream and downstream jurisdictions. While resource allocation and competing needs represent one set of Water Security challenges, a second major focus for Water Security is on extreme events. Flooding remains globally one of the most dangerous and damaging natural hazards, and with increasing pressures of population and development, the associated risks are increasing (UNESCO, 2012). Also, drought has many physical and societal dimensions. A lack of precipitation will lead to pressures on water resources and agriculture, and effects can be severe, depending on the resilience of the local society and population. Tensions between competing water uses will be exacerbated, not least between human uses and environmental flows (Grafton, 2011).

2.1.7 Focusing on water technologies

According to UNCTAD (2011), Africa is the region where water and poverty are linked together. A study conducted in SSA revealed that with over 330 million people, 45 percent of the population, live in extreme poverty. Agricultural productivity in the region is among the lowest in the world and output has not kept up with population growth. Over 80 percent of output growth has come from expanding the cropped area since 1980 (AfDB, 2007). This is in complete contrast to other regions where increases in cropped area have been less than 20 percent with changes in technology and innovation. This is clearly not the case in SSA (Svendsen et al., 2009). AfDB, (2007) stated that SSA has little formal irrigation schemes and agriculture is dominated by rainfed farming which is largely subsistence based and concentrated on low value food crops.

Although rainfed farming is what is widely used, rainfall in many of the drier regions of Africa is erratic and unreliable, rainy seasons are short and there are often long gaps between rainfall events but African farmers must make a living in some of the driest regions of the world (NRSP, 2001). Floods have caused more than 40 percent of all declared disasters in the United Republic of Tanzania while droughts have caused only 30 percent over the past century (NRSP, 2002a). Climate change predictions suggest that this may worsen as the extremes of droughts and floods increase. The fragile nature of agricultural production in SSA and its dependency on rainfall Rainfed farming is where the greatest potential exists for improving output and productivity. Even modest low cost technological improvements and modest increases in yield could have significant impacts on production and poverty reduction (UNCTAD, 2011).

Irrigation in North Africa is concentrated in the north along the Mediterranean and, except for Egypt and the Sudan which rely on the Nile River, irrigation is mainly from groundwater. But renewable groundwater resources are overexploited and fossil water reserves are also being mined. This is driven by governments providing substantial subsidies for irrigation equipment, pumps, and energy in order to achieve self-sufficiency in staple foods. However, this situation is just not sustainable (World Bank, 2007).

The share of the cultivated area equipped for irrigation is only a third of the world average and just one-sixth of the value for Asia. Past experiences of investment in irrigation are not good. International donors have shown little interest over the past 30 years following disappointing investments in irrigation in the 1960s and 1970s. National governments too have struggled to keep water for food on the national water agenda in spite of the fact that in most African countries food production is the largest consumer of water (UNCTAD, 2011).

IFAD (2008) stated that the problems range from relatively low population densities to the lack of market access and incentives for agricultural intensification, low quality soils, unfavorable topography, and inadequate policy environments that fail to recognize the predominance of women in agriculture. Together with development costs, which are considerably higher than in Asia, these conditions seriously limit the economic feasibility of irrigation development projects.

Renewable water resources per capita in Africa is substantial and suggest there is a large untapped endowment of water that could be used for irrigated agriculture. In SSA only 4 percent of cultivated land is equipped for irrigation. This area almost doubles when North Africa is included as Egypt accounts for 20 percent of all irrigation in Africa (Svendsen et al., 2009). IWMI (2007) emphasized that these figures represent the more formal irrigation schemes and do not include the many thousands of hectares of informal private, smallholder irrigation across the region in valley bottoms and in peri-urban areas using wastewater, which do not appear in official government statistics. It further revealed that in Nigeria, several hundred thousand hectares of the wetland valleys are estimated to be informally irrigated.

According to Svendsen et al. (2009), Africa produces 38 percent of its crops from only 7 percent of cultivated land on which water is managed, suggesting that additional investment in irrigation would pay dividends. The contribution to agricultural production of Africa’s small irrigated area suggests that returns on additional investment in irrigation would be high, both in terms of greater food security for the continent and greater production of high value crops for export. The different agro-ecological zones across the continent will require different approaches and there is a need to move from a top-down to a bottom-up livelihoods-based paradigm which recognizes the role that women play in agriculture. IFAD (2008), indicated that should a green revolution happen in SSA, it is likely to differ considerably from that in Asia, given the significant differences in resource endowments, demographics, lack of appropriate technologies, public perspectives regarding government support for intensive agriculture, and the completely different economic context at both local and international levels.

2.1.8 Water storage

According to UNCTAD (2011), water storage has perhaps the greatest potential to deliver the improvements in water management. This is an old technology and is one that has been exploited throughout history. Water storage is often associated with dams and environmental and social problems. Over 45,000 large dams have been built for storage across the world and some 40 percent are used for irrigation purposes; but dams are just one means of storage. McCartney and Smakhtin (2010), stated that surface storage includes natural wetlands and reservoirs and subsurface storage consists of groundwater aquifers and soil water storage that can be accessed by plant roots, tanks, and ponds.

Storage makes more water available by capturing water when it is in abundance and making it available for use when there are shortages. Storage can also be used to balance supply and demand over much shorter periods such as storing water from river flows during the night and making it available for farmers to use during the day. This not only makes available water that would have otherwise gone to waste, but it also increases the flexibility of irrigation systems by improving the reliability and timeliness of supplies so that farmers can better schedule their irrigation and reduce water losses. Groundwater storage offers similar benefits and is one of the reasons why ‘water scavenger’ irrigation using groundwater has been widely applied in Asia. Water recharge is the link between surface and groundwater storage. Canals and reservoirs now provide opportunities to recharge groundwater and to act as a buffer between water supply and demand for irrigation (UNCTAD,2011).

In China and India, there are instances of successful water storage used to improve the management of canal irrigation by providing farmers with water as and when they need it. Sudan has a long tradition of night storage canal irrigation. There are instances of storage in reservoirs along canal systems in Nigeria. In Ghana, the storage story is mixed. Some reservoirs have led to more reliable water supplies and have enabled farmers to diversify their crops and have more stable income. But other reservoirs nearby, under similar conditions, have failed to bring about any significant change (McCartney and Smakhtin, 2010).

2.1.9 Canal irrigation

Canal irrigation in Asia is not seriously practiced. Smallholder farmers, who used to depend on the large canal systems for their water, are finding ways around the problem by buying pumps and exploiting local groundwater, often recharged from canal seepage, rather than relying on the uncertainties of canal water. The extensive canal networks cannot easily be abandoned and replaced with small pump schemes. The challenge is to find ways of using existing canal systems by making it as responsive as groundwater irrigation (UNCTAD, 2011).

According to Bhamoriya et al. (2009), Canals are difficult to manage hydraulically, and in many systems tail-enders suffer from a lack of water because those at the head tend to take more water than those at the tail end. Most major canal systems use upstream control technology that not only exacerbates the top-ender, tail-ender problem but is also inflexible to changes in water demand from farmers. This was acceptable in past planned economies when engineers made decisions about how much water was delivered to farmers. But in today’s demand driven economies, farmers want much more control over inputs. There are canal control systems, such as downstream control, that can improve flexibility and provide on-demand irrigation but such systems would require major re-engineering and would be costly. In the Indian state of Maharashtra, a water user association installed pipelines to replace canals in order to distribute water from tertiary canals and to ensure a more equitable share of water. Also stated by Van Bentum (1994), farmers have invested in a storage tank which distributes water through specially designed equal discharge pipelines. Indeed, pipelines, although initially costlier to build than canals, can offer much better control over water supplies, making the system more responsive to farmer demands.

Improving canal irrigation according to Johnson et al. (1998) is not just a technology fix, but also requires institutional changes. China's public canal irrigation schemes are improving because government irrigation agencies are given incentives to align their rewards with those of the farmers who are associated with higher outputs.

2.2 Irrigation methods

According to Dupriez and De Leener (2002), irrigation methods are the system of how to obtain water for irrigation purposes from its sources. The method depends on water resources, topography, plants cultivated and growing seasons.

- ✓ **Basin irrigation**

This is the most common form of surface irrigation, particularly in regions with layouts of small fields. A basin is a piece of land, small or large, surrounded by earth bunds in which water is pounded. The field to be irrigated is divided in two units surrounded by levels or dams. Gated outlets, siphon tubes, spiels, and hydrants conduct water from delivery channels in to each basin. This type of irrigation is suitable for all types of soil and efficient use of water but it needs high initial cost for leveling land (Aregawi, 2014).

- ✓ **Surface irrigation**

This is the oldest method of irrigation, which convey water from the survey to the fields in lined or unlined channels. Surface irrigation is the introduction and distribution of water in a field by the gravity flow of water over the soil surface. According to Widtose (2001), the primary methods of applying water are Basins irrigation, Boarders irrigation, Flood irrigation and Furrows irrigation. The choice of irrigation methods depends on the nature of the soil, the topography of the land, the head of the water stream, the quantity of water available and the type of the crop. Albaji et al. (2007) carried out a land suitability evaluation for surface irrigation in the Shavoor plain, in Iran. The results showed that 41% of the area was suitable for surface irrigation due to soil salinity and drainage problem.

- ✓ **Furrow irrigation**

Furrow irrigation is accomplished by running water in small channels that are constructed with or across the slope of a field. Furrow irrigation avoids flooding the entire field surface by channeling the flow along the primary direction of the field using 'furrows,' 'creases,' or 'corrugations. Water infiltrates through the wetted perimeter and spreads vertically and horizontally to refill the soil reservoir. Water is diverted in to furrows from open ditches or pipes. Irrigation Efficiencies under furrow irrigation are between 50 and 73% (Oster et al., 1986; Battikhi and Abu-hammad, 1994; Chimonides, 1995; Zalidis et al., 1997).

The advantage of this type of irrigation are uniform application of water, less evaporation loses, less intercultural operations but it needs high cost for preparing furrows. Because it requires more and require more labour (Aregawi, 2014).

- ✓ **Border irrigation**

According to Aregawi (2014), an open-field method viewed as an extension of basin irrigation to sloping, long rectangular or contoured field shapes, with free draining conditions at the lower end. Here a field is divided into sloping borders**.** Water is applied to individual borders from small hand-dug checks from the field head ditch. Soils can be efficiently irrigated which have moderately low to moderately high intake rates but, as with basins, should not form dense crusts unless provisions are made to furrow or construct raised borders for the crops.

A study into the irrigation of maize was conducted and showed that 210 mm of irrigation applied by border irrigation under a mulch of wheat straw gave a good grain yield, total evapotranspiration and water use efficiency of 8000 kg/ha, 390 mm and 2.2 kg m3, respectively (Zhang et al., 2002). Increasing the amount of irrigation by 270 mm increased the yield to 8834 kg ha. So the use of Border has a positive influence on crop yields just that its water requirement is very high. The benefits of this type of irrigation are uniform application of water, uniform application of water, efficient use of water but it requires repairing of ridges and supervision during irrigation and land needs to be graded uniformly.

- ✓ **Flood irrigation**

Flood irrigation is an ancient method of irrigating crops. It is the first form of irrigation used by humans as they began cultivating crops and is still one of the most commonly used methods of irrigation used today. Water is delivered to the field by ditch and simply flows over the ground through the crop. This type of irrigation is least cost method and does not require any skill but it is inefficient method, result in uniform stand of crops and low yield, and more wastage water due to run off, deep seepage and evaporation.

- ✓ **Drip irrigation**

This method is one of the more advanced irrigation techniques being used today because for certain crops, it is much more efficient than flood irrigation. Water runs through pipes with holes in them either buried or lying slightly above the ground next to the crops. Water slowly drips onto the crop roots and stems. Drip irrigation has the potential to increase Irrigation Efficiency because the farmer can apply light and frequent amounts of water to meet crops needs. The Irrigation Efficiency ranged from 80 to 91% when the crop was grown in fields using a surface drip system (Battikhi and Abu-hammad, 1994; Chimonides, 1995). Liu et al. (2006) evaluated the land suitability for drip irrigation in the Sichuan province, China, using a Sys's parametric evaluation system. Drip irrigation was more suitable due to the minor environmental problems that it caused.

- ✓ **Sprinkler irrigation**

water is sprayed into the air and allowed to fall on the ground surface somewhat resembling rainfall. This is the type of irrigation used by IWAD. According to Dupriez and De Leener (2002), Sprinkler irrigation imitates rainfall. It is also called overhead irrigation. The spray is developed by the flow of water under pressure through small orifices or nozzles. In the northern part of China, Liu et al. (2003) reported that the yield and Water Use Efficiency of winter wheat under sprinkler irrigation conditions increased from 28 - 48% and 636 m^3/ha water was saved compared with other irrigation conditions.

Albaji et al. (2010) investigated different irrigation methods based upon a parametric evaluation system in an area of 29,300 ha in the Abbas plain located in the West of Iran.

The results demonstrated that by applying sprinkler irrigation, the capacity of the land to support crop production increases by 21,250 ha (72.53%).

This type of irrigation is beneficial for uniform distribution of water and highly efficient use of water. But it needs high initial costs and more maintenance, and there is high evaporation lose.

- ✓ **Motorized pump**

According to world Bank (2011), motorized irrigation is less physically demanding than human powered pumps. At an average cost of CFAF 250,000 (US$500), motorized pumping can irrigate larger areas of land, which can raise producers' incomes. The profitability of motorized pumps depends on the area irrigated, the yield obtained, the market for the produce, and the subsidies available for energy which can account for 40% of the annual cost for the initial investment. Motorized pumps have been widely used since the 1980s in Nigeria, where highly subsidized fuel and the support of several agricultural development projects have encouraged the installation of more than 100,000 motorized pumps. Cultural proximity and informal trade has spread the distribution of motorized pumps across the border from Nigeria to Niger. Motorized pumps have also been promoted by projects in Mali and Burkina Faso.

In Burkina Faso, the maximum area irrigated by one pump varies between 0.24 hectares and 0.38 hectares with an average of 0.26 hectares (Enterprise Works 2004b). These figures are similar to those reported in other West African countries (Senegal, Benin) and to those observed in East Africa. Enterprise Works (2004a) found that, with the acquisition of a pump, the irrigated area of a plot formerly watered with a bucket or calabash could be more than doubled. The average net income can also be doubled: this amounts to about CFAF

350,000 over the cropping season in Burkina Faso, CFAF 182,000 in Niger, CFAF 196,000 in Mali, and CFAF 410,000 in Benin and Senegal. Operating costs are limited to maintenance and repair costs which amount to about CFAF 4,800 per year. The use-life of a pump is estimated at 3 to 5 years. Motorized pumps are widely used irrigation systems in the study area. Most of the farmers bought them as part of a group. Other households gain access to the pumps through renting from the owners.

2.2.1 Micro-irrigation technologies

According to UNCTAD (2011), modern irrigation technologies, such as sprinklers and micro-irrigation are often seen in LDCs as one of the keys to increasing food production on smallholder farms which make up a large proportion of the land farmed. Sprinklers and micro-irrigation are not suited to the major rice growing areas in South and Southeast Asia, nor are they suited to growing staple grains. But modern methods do offer considerable potential for making best use of available water in Africa which includes 13 out of the 18 nations in the world having less than 1,000 m/capita/day. Cornish (1998) micro-irrigation can be targeted at selected environments where water costs are high; soil, topography and water quality make surface irrigation impracticable; high value cash crops can be grown and marketed; and where the farmer desires to increase his/her income.

Micro-irrigation technologies are commonly used in water scarce areas in developed countries and are an intervention that has potential to use water with minimal wastage. They generally fall into two categories: low-cost technologies which are used for small plots and gardens; and the state-of-the-art micro-irrigation systems which are used by large commercial agri-businesses mainly for high value fruit and vegetable crops. These technologies can improve productivity, raise income through improved yields and outputs thereby enhancing household food security. The challenge with this irrigation technology is that they are not suitable for staple crops

Although micro-systems provide the potential for water saving by reducing the water wastage that often occurs with other methods such as surface flooding, these benefits are not always realized in practice. Indeed, the amount of water used by the crop is the same whether the water is supplied from a micro-system, sprinkler, or a surface flooding method. Much depends on how the systems are managed rather than the systems (UNCTAD, 2011)

In India, Micro-systems have been extensively marketed among smallholder farmers and commercial farmers for over three decades in line with government policy but with unfulfilled results. The systems were heavily subsidized, at times up to 90 percent of the cost, but the farmers responded moderately. Although the government provided subsidies, other factors were lacking including: groundwater access, crop-specific micro-irrigation technologies, know-how, and access to financing. Additionally, micro-systems did not effectively reach the smallholder farmer target group. Rather, the technology was mainly adopted by wealthy commercial farmers. Thus greater efforts are needed to promote the technologies to small holder farmers (IWMI, 2006).

According to Pandit et al, (2010), an international NGO named KickStart, developed a low-cost micro-irrigation pump which is purchased by local entrepreneurs and used to establish new, small agricultural businesses. These pumps allow users to irrigate their crops year-round and to not depend solely on seasonal rainfall.

Irrigating crops during the dry season allows pump owners to take advantage of the higher crop prices in the marketplace. Successful models of micro-irrigation in India and Nepal have increased crop yields and reduced water consumption in addition to increasing income and household food security

2.2.2 Human powered pumps

According to UNCTAD (2011), many smallholder farmers still rely on lifting water by hand, using buckets and other similar containers to transport water from source to field. These simple tools, though appropriate for many, are limiting, inefficient, and time consuming. They prevent the poor, particularly women, from taking up alternative opportunities for income generating tasks.

Kay (2000) stated that most hand-operated mechanical pumps are designed for domestic water supply purposes and are not well suited to the high water volume requirements of irrigation. Treadle pumps changed such views on the use of human power by transferring the driving force from the arms to the legs. They were first developed in Bangladesh in the 1980s for lifting relatively large volumes of water through small lifts of up to 1 m for rice irrigation. Their acceptance among farmers has been described as extraordinary as over 500,000 pumps are now used daily in the country. Treadle pumps are seen as a strong foundation between hand lifting and motorized pumping. The initial capital cost is low, between US$50-120, thus investment is modest.

This type of technology was introduced into Africa from Bangladesh in the 1990s and are now widely used across the continent. Although the current number of pumps installed is not known, it is estimated that there are many thousands used in Niger, Kenya, Zambia, Zimbabwe, and Malawi. In some countries, notably Kenya, a commercial market has been established with supply chains so that spares and pump maintenance services are available.

Kay in 2000 revealed that farmers in northern Nigeria lost their traditional use of the wetlands along the rivers following the construction of dams to control the river floods for urban water supply and irrigation. As an alternative they turned to small-scale irrigation using shallow groundwater recharged by the river and lifting it with hand lifting devices in the dry season to grow vegetables for local and city markets. This has been one of the most successful irrigation developments in Nigeria, with many thousands of pumps being used by private farmers. Maintenance is well established and farmers have confidence in the technology.

2.2.3 Electric and fossil fuel pumps

Snell (2001) indicated in a study that a rapid growth in motorized pumping across the world in the past few decades has resulted to the development of cheap well drilling technology, rural electrification, and subsidized energy. Pumps provide a level of freedom that smallholder farmers did not have on the larger state-owned schemes. They can irrigate as and when crops need water and when it is convenient to irrigate usually during the day rather than at night.

In places where there is electricity access near farmlands, electric pumps can be an attractive option. However, electric pumps are not a feasible option in areas with an intermittent electricity supply. Motorized pump costs also tend to benefit large-scale farmers due to economies of scale but tend to be uneconomical for certain smallholder farmers with limited land and revenues (Adeoti, 2009). For instance, IWMI (2005) stated that in Ghana, the cost of the motorized pump was 5.6 times higher than a treadle pump, a high capital investment for small scale vegetable plots owners. Also, the operational costs of motorized pumps were high compared to the returns. Often users would have to travel long distances for repair support and spare parts. Capabilities in maintenance and repair are important considerations in the adoption of motorized pumps (UNCTAD, 2011).

2.2.4 Renewable energy powered pumps

Snell (2001) and Fraenkel (2006) in their studies argued that renewable energy sources do not have the long term and loss-free energy storage inherent in fossil fuels. The energy supply is therefore usually unreliable, while the equipment needed to capture and apply a useful amount of power to a pump for irrigation purposes is expensive. However, other studies have found that some renewable sources are more cost competitive than traditional sources of energy in rural areas and for small scale applications, such as micro-irrigation (ESMAP, 2007; Burney et al. 2010).

UNCTAD (2011) indicated that solar power is used for applications requiring relatively small power inputs in remote locations telecommunications and small isolated potable water supplies are typical examples. Despite many years of intensive research attempting to develop cheap and robust solar energy gathering devices, they remain expensive relative to their power output. Both the solar energy devices and the associated equipment for bringing the energy to a pump are quite delicate and sensitive. A study regarding solar-powered agricultural irrigation by Kelley (2010), found that photovoltaic (PV) pumping irrigation systems are technically and economically feasible, but the main constraint is land availability for the solar array. At present, solar-powered devices are only cost-effective in low-powered and specialized applications. Nevertheless, they should be considered on the list of potential technologies, and future improvements in cost and robustness should improve their competitiveness.

A study conducted by Al Suleimani and Rao (2000), noted that wind power has been used extensively for lifting water, usually for draining low-lying land where there are persistent strong winds. Relative to their water-lifting output, both ancient and modern wind-powered devices are large and expensive in comparison with other technologies now available but they tend not to be very reliable. An additional factor is the regional and seasonal availability of strong winds. Over most of the cultivable lands of SSA, wind speeds are not high for much of the year. Nevertheless, some experiences have shown that wind energy resources can be successfully used for abstracting groundwater and irrigating crops. In India, wind power pumps hold great potential for smallholder irrigation provided that certain conditions like farmer's income, wind resources among others are met (UNCTAD, 2011).

The decision to use renewable energy technologies rather than conventional energy sources depends on several factors such as; availability of renewable resources on the site, the power needed and type of utilization, among others. Similar technologies that have been adopted the in rural areas of South Africa and Namibia are wind pumps for irrigation. Other applications include small biomass plants for water pumps, micro-hydroelectric plants and solar energy for micro-irrigation (UNCTAD, 2010).

2.2.5 Measuring water security and identifying appropriate index for study

During the past two decades, different approaches have been concerned with the capturing of relevant aspects of pressures on water resources and with the characterization and measurement of water security. The concept of water security (and its reverse water scarcity) is complex to define because it means different dimensions or facets. First, security needs to be understood as a relative concept, i.e., an imbalance between "supply" and “demand” that varies according to local conditions. Second, water security and water scarcity are fundamentally dynamic. The description of water security by using more or less complex indicators involves difficulties and uncertainties, thus there is no consensus on a standardized measurement.

A particular weakness of current indicators is the focus on water withdrawal instead of actual water consumption. Thus, they do not represent a comprehensive tool for the assessment of water scarcity situations, but, however, support the indication of disequilibrium of water abstraction and water availability.

The most common approaches widely used are the Falkenmark Indicator, the Social Water Stress Index (SWSI), the Water Resources Vulnerability Index also known as the Criticality Ratio, the Physical and Economical Scarcity Indicators and the Water Poverty Index (WPI).

2.2.6 Falkenmark Indicator

According to Falkenmark (1989), this indicator is widely used to measure water security or water stress. The best-known indicator of national water scarcity is per capita renewable water, where threshold values of 500, 1 000 and 1700m^3 are used to distinguish between different levels of water stress (Falkenmark and Widstrand, 1992; UN-Water, 2006b). Based on this indicator, water conditions can be categorized as no stress, stress, scarcity and absolute scarcity. The index thresholds 1700m^3 and 1000m^3 per individual in a year are used.

The table below shows the thresholds within which each water condition falls;

Table 2.1 Falkenmark water stress index

Index	Condition
>1700	No stress
1000 - 1700	Stress
500 - 1000	Scarcity
<500	Absolute scarcity

So according to this indicator, water security will be measured based on the quantity of water available for usage. Based on this, the Falkenmark Indicator will be considered for the study as a measure of water security. When there is water scarcity it means a water security problem because it will mean less water will be available and accessible by households for a period of time. This measures the amount of water available for agricultural production hence the appropriate water security index to work with.

2.2.7 Water poverty

As stated by Kropp and Tekken (2012), water poverty is a state where a nation or region cannot afford the cost of sustainable clean water to all people at all times. Water poverty serves as a link between availability and access to water and the socioeconomic status of an individual or group of individuals. People can be water poor in the sense of not having sufficient water for their basic needs because it is not available. They may have to walk a long way to get it or even if they have access to water, supplies may be limited for various reasons. People can be 'water poor' as they are income poor, although water is available; they cannot afford to pay for it especially the improved water sources.

2.2.8 Water poverty index

According to the Centre for Ecology and Hydrology (2016), the Water Poverty Index is a new holistic water management tool that is mainly relevant both at the household and community level. It can be used to determine priorities for action and to monitor progress towards targets.

Water poverty tends to be a concept most often deployed in relation to drinking water hygiene and sanitation (WASH). UNICEF (2010) indicated that the association of water security with national security agendas may make water poverty a more palatable option for rights oriented organizations, though UNICEF refers to ‘household water security’ as a synonym for water supply. A WASH-focused interpretation of water poverty or human water security directs attention to some of the most pressing water challenges. Despite the achievement of the Millennium Development Goals MDG target for water at a global level in 2012, huge geographical and social disparities remain, especially when the many non-functional water points are discounted as many as 40% of the total in rural Liberia, for example (Hirn 2011). But an exclusive emphasis on WASH may risk overlooking the other ways in which water interlinks with people’s livelihoods. In fact, earlier definitions of water poverty do not necessarily restrict themselves to WASH. Black and Hall (2004) categorization of the water poor puts the headline emphasis on broader relations between water and the livelihood base (Black and Hall 2004: 24), including water for cultivation though water for other productive purposes, such as small scale manufacturing and industry, is not mentioned directly. IFAD (2007) indicated that gender dimensions of wider water use and management should also be considered, for instance the tendency for water access for irrigation and livestock to be dependent on land rights which are limited for many rural poor people, but especially women. While Black and Hall propose a number of quantitative and qualitative thresholds in their definition, it should be noted that applying these collectively would result in double counting in many contexts. The thresholds would therefore need some attention if they were to be applied as part of a water-related target (Calow and Mason, 2012).

The concept of water poverty will be largely considered in this study because, the people we are considering are the rural households. According to Molden et al., (2007) cited in Namara et al., (2010), Crop and livestock production, agro-processing, fishing, ecosystems among others are all influenced by the quality and quantity of available water. In many cases, poor people do not have access to enough water for production, simply because the resource is physically scarce. As a result, it is therefore necessary to consider this index for the study since majority of the respondents along the volta basin are the rural poor.

The water poverty index is a new holistic water management tool that is mainly useful at the community or household level. It can be used to determine priorities for action and to monitor progress towards targets. The water poverty index (WPI) provides such a simple and easy-to- use indicator for the water sector. It can be used for planning the water sector by water managers and planners. But, at the community level or household level, it is also possible for people to apply it to their own situations to understand how water can best be managed to meet their own needs. The idea of a water poverty index (WPI) is to combine measures of water availability and access with measures of people's ability to access water (Kropp and Tekken, 2012).

According to a study conducted by Kaiyatsa (2014) in Malawi centered on two communities revealed that both communities were water insecure as they had their WPIs lower than 50%. Despite the level of water insecurity in the two communities, their capacity to manage water resource was high. Each component was applied with a standard weight of 0.2 which confirms the standard of Sullivan (2002). So multiplying each component by 0.2, the WPI for each community can be achieved. The table below gives an illustration of the above information;

Table 2.2 Water security in Mitundu and Chitsime

Community	Access	Availability	capacity	Environment	Use	WPI
Mitundu	43.35	14.75	59.43	29.85	25.47	34.57
Chitsime	56.10	14.75	33.09	28.28	18.38	30.12

Source: Kaiyatsa (2014)

From the table above water poverty level is lower in Mitundu than in Chitsime communities. According Sullivan et al. (2003) the highest value 100, is taken as the best while 0 as the worst situation. Since water poverty index scores for both communities were below 50, the level of water poverty in both communities is high hence deemed water insecure.

2.2.9 Estimating water poverty index

There are many approaches that are used in estimating water poverty index. Among them are the simple-time analysis approach, matrix approach, Holistic approach and the conventional composite index approach according to some researchers.

2.3 The Conventional composite index approach

Using the composite index approach, the WPI could comprise various elements, such as:

- Water availability,
- Sanitation,
- Access to safe water and
- Time taken to collect domestic water.

This would result in the WPI formula as follows

$$\mathrm{WPI} = \mathrm{WaA} + \mathrm{WsS} + \mathrm{Wt}(100 - \mathrm{T}) \qquad 2.0$$

Where,

Adjusted water availability (A) assessment as %. It is calculated on the basis of ground and surface water availability related to all other domestic demands, as well as the demand from agriculture.

Since A, S and T are all defined to be between 1 and 100, and Wa, Ws, and Wt are between 0 and 1 to produce a WPI value of between 0 and 100, the formula needs to be modified as follows:

$$\mathrm{WPI} = \frac{1}{3}(\mathrm{WaA} + \mathrm{WsS} + \mathrm{Wt}(100 - \mathrm{T})) \qquad 2.1$$

In this method, the higher the value of WPI, the lower the degree of water stress. Water access and time spent to collect water can be used as a proxy for socioeconomic well-being as stated by Sullivan (2002).

2.3.1 The Holistic approach

This approach is based on constructing an index consisting of five major components, each with several sub-components which are discussed below;

Resources: the physical availability of surface and ground water, taking account of the variability and quality of the resource as well as the total amount of water.

Access: Access to water for human use, accounting for not only the distance to a save source, but the time needed for domestic water collection, and other significant factors. Access means not simply safe water for drinking and cooking, but water for irrigating crops.

Capacity: the effectiveness of people's ability to manage water. Capacity is interpreted in the sense of income to allow purchase of improved water, and education and health which interact with income.

Use: the ways in which water is used for agricultural purposes is the taking into account.

Environment; people's use of natural resources, reports of crop loss during last 5 years and the percentage households reporting erosion on their land can be used as proxy

Mathematical structure of WPI

The WPI is calculated using a composite index approach. The five key components are combined using the general expression:

$$WPI = (\sum wiXi)/(\sum wi) \qquad 2.2$$

Where WPI is the Water Poverty Index value for a particular location,

Xi refers to component i of the WPI structure for that location, and wi is the weight applied to that component. Each component is made up of a number of sub-components, and these are first combined using the same technique in order to obtain the components. For the components listed above, the equation can be re- written:

$$WPI = (wrR + waA + wcC + wuU + weE)/(wr + wa + wc + wu + we) \qquad 2.3$$

Which is the weighted average of the five components Resources (R), Access (A), Capacity (C), Use (U) and the environment (E) Each of the components is first standardized so that it falls in the range 0 to 100; thus the resulting WPI value is also between 0 and 100. This approach is will be considered for the study.

2.3.2 A simple time-analysis approach

According to Sullivan (2002), another possible way of addressing the methodology of constructing a WPI is to use a time analysis approach, where time is used as a numeraire for the purpose of assessing water poverty. In this method, the WPI is determined by the time required (per capita) to gain access of a particular quantity of water. As such, the WPI would be as follows:

$$\mathrm{WPI} = \frac{\mathrm{T}}{1000}\,\mathrm{m3} \qquad 2.4$$

Here T is the time required per person to collect a quantity of water.

2.3.3 The Social Water Stress Index

Building on the Falkenmark indicator, the “adaptive capacity” of a society to consider how economic, technological, or other means affect the overall freshwater availability status of a region (Ohlsson, 2000). Ohlsson argued that the capacity of a society to adapt to difficult scenario is a function of the distribution of wealth, education opportunities, and political participation. The UNDP Human Development Index (HDI) is a widely accepted indicator used to assess these societal variables. The HDI functions as a weighted measure of the Falkenmark indicator in order to account for the ability to adapt to water stress and is termed the Social Water Stress Index.

2.3.4 Water Resources Vulnerability Indices

The water scarcity indices have measured water resource status based on fixed human water requirements and water availability, mostly on a national scale but have not incorporated renewable water supply and national, annual demand for water (Rijsberman 2006). In 1987 Shiklomanov and Markova from the State Hydrological Institute in St. Petersburg published estimated current and predicted water-resources use by region and sector (Shiklomanov 1993). Water use was separated into industrial, agricultural, and domestic sectors, as well as incorporated water lost from reservoir evaporation. Population and economic factors were used as the major variables. Raskin et al. (1997) used

Shiklomanov's water resource availability data and modified the approach by substituting water withdrawals in place of water demand. Since water demand varies between societies, cultures, and regions, the term is subjective (Rijsberman 2006) and using it as a variable can lead to inaccurate assessments. The Water Resources Vulnerability Index, sometimes referred to as the Willingness To Accept (WTA) ratio, was then developed as the ratio of total annual withdrawals to available water resources. A country is then considered water scarce if annual withdrawals are between 20 and 40% of annual supply, and severely water scarce if withdrawals exceed 40% (Raskin, et al., 1997). This method and 40% threshold is commonly used in water resources analyses and has been termed the criticality ratio which is the ratio of water withdrawals for human use to total renewable water resources (Alcamo, Henrichs and Rosch 2000).

2.3.5 Physical and Economical Water Scarcity

The International Water Management Institute (IWMI) used a similar water scarcity assessment though on a slightly larger scale across the entire globe. They conducted an analysis that considered the portion of renewable freshwater resources available for human requirements, with respect to the main water supply. The analysis labeled countries as "physically water scarce" when more than 75% of river flows are withdrawn for agriculture, industry, and domestic purposes. This implies that dry areas are not necessarily water scarce. Indicators of physical water scarcity include: acute environmental degradation, diminishing groundwater, and water allocations that support some sectors over others (Molden 2007). Countries having adequate renewable resources with less than 25% of water from rivers withdrawn for human purposes, but needing to make significant improvements in existing water infrastructure to make such resources available for use, are considered as economically water scarce (Seckler et al., 1998).

Table 2.3 Water security indicators

Index	Strengths	Limitations
Falkenmark indicator (1989)	Total annual renewable water resources available to the population per cap/year freshwater availability. Determines thresholds for minimum per capita water requirements. Data most often available as well on regional or smaller scales. Easy to apply and intuitively understandable	Focus on blue water stress only, omits green water. Excludes main drivers for water scarcity, e.g., demand, efficiency, management and lifestyles. Societal adaptive capacity is not included. Assumes that all countries globally use or need the same amount of water for development
Social water stress index (2000)	Builds on the Falkenmark indicator and applies the UNDP's Human Development Index (HDI) to depict the social dimension of water scarcity. Contextualizes water stress with a low social adaptive capacity.	The HDI does not include ecological factors and focuses mainly on economic criteria. The HDI does not depict intra-national differences, as the data applied is country-based only.
Water Resource Vulnerability index (criticality ratio) (2000)	Withdrawal-Ratio of human water use to total renewable water resources. Comparison of country-specific water demand and availability. Scarcity: proportion of total withdrawals relative to total available resources.	Role of non-natural resources recycled or re-used water is not considered. Omits behavioral change as a reaction towards reducing water capacities, example is the implementation of new technologies
Physical and economical scarcity indicator (2007)	Accounts for all renewable water resources available for	Measuring of indicator is very complex and time-consuming.

	primary supply under future scenarios of improved water management policies. Physical scarcity: countries being unable to meet future demands despite future adaptive capacity (e.g., investments in water infrastructures). Economical scarcity: countries unable to meet future water demand without investments in water infrastructures despite sufficient renewable resources	Data requirements difficult to meet, thus it's mainly based on expert judgments. Omits ability to adapt by virtual water imports (food) or water saving devices. Partly green and blue water are summed up, providing too high potential availability values. Country-based aggregated analysis
Water poverty index (2003)	Determines water security at household and community level based on income and wealth. Measures and aggregates five dimensions: level of access to water; water quantity, quality and variability; water used for domestic, food, and productive purposes; capacity for water management; environmental aspects	Focuses on limitations of the Falkenmark Index. Comprehensive amounts of data required. Approach of high complexity. Lacks intuitive understanding. Suited for smaller rather than national scales

Source; Kropp and Tekken (2012)

2.3.6 Assessing household water security

Another restricting factor to agriculture and water availability is climatic changes in the region, such as prolonged droughts and decreased rainfall quantity (Dobrici, 2013). According to Betebo (2014), improved agricultural water use in irrigated and rainfed agriculture will play a key-role in coping with the expected water scarcity stress. Improving water use or water productivity is often understood in terms of obtaining as much crop as possible per volume of water.

There are empirical studies that have been conducted on water resource development contribution to household income, food security and poverty in Ethiopia. For example, the study conducted in Bale Ethiopia on socio-economic and institutional determinants of small-scale irrigation schemes utilization revealed that irrigation schemes are poorly operated and managed. However, irrigation water use increased farmers yield per unit area and it is beneficial as compared to without irrigation but the result was not as expected. The significant determinants of households' irrigation water use decision were education, market distance, access to extension age of the household head, off/non-farm income, household participation in post scheme implementation, insect and pest infestation of plots and total family labour in man equivalent. On the other hand, access to improved technology for irrigation, market distance, distance from the main road, total labour in man equivalent, insect and pest and post irrigation implementation participation were found to significantly affect intensity irrigation water use of households (Tafese, 2007).

Betebo (2014), conducted a study in the Ambo district in western Ethiopia on poverty reduction impacts of small-scale irrigation development used the Indris irrigation system as a case study. Results indicate that the incidence, depth, and severity of poverty are significantly lower among those farm households with access to irrigation. Also, variables such as farm size, livestock holding size, land productivity, and family size significantly influence the level of household consumption expenditure. However, the portion of poor people in the overall sample, notwithstanding access to irrigation, is alarmingly high, indicating the deep rooted and critical situation of poverty in rural Ethiopia (Dereje et al., 2006).

Research conducted by Degefa and Tesfaye, (2008), stated that almost all respondents, both beneficiaries and non-beneficiaries of water schemes, are of the conviction that lack of access to sufficient water adversely affects their household food security: 92% of non-beneficiary households believe that the absence of water makes them vulnerable to drought; 93% believe water problems are a factor in their low agricultural production and productivity.

2.3.7 Profitability Analysis of Irrigators and Non-irrigators

A gross margin for an enterprise is its financial output minus its variable costs. The use of gross margins became widespread in the UK from about 1960, when it was first popularized amongst farm management advisers for analysis and planning purposes (Barnard and Nix, 1973). Gross margin is defined as the difference between total revenue and total variable cost

Mathematically

$$GM = TR - TVC \qquad 2.5$$

$$TR = PQ \qquad 2.6$$

Where, TR= Total Revenue

P=Price

Q= Quantity

TVC= Total Variable Cost

Total Revenue (TR) is the product of output while the Total Variable Cost (TVC) is the aggregation of the costs of land preparation, planting materials, yam seeds, planting, weeding, mulching and harvesting.

According to Olumese and Izekor (2010), the variable cost incurred included cost of labour, planting materials such as yam setts and chemicals. The analysis shows that labour accounted for the highest portion of the total variable cost. The total variable cost per hectare was N78,500 while the total revenue per hectare was N 136,900 to arrive at a gross margin of N 58, 400.00.

A study conducted by Nhundu et al., (2010) used Gross margin to conduct farm income analysis based on irrigators and non-irrigators. The findings revealed that higher costs were incurred in rainy season than dry season production, which were $10,955.29 in dry season against $58,217.16 for rainy season. However, the Gross margin for maize was $31,500 for non-irrigators which is quite higher than $20,250 for irrigation.

2.3.8 Adaptation strategies

UNDP (2000), has revealed that Climate change poses a great threat to human security through irregular rainfall patterns by means of decreasing crop yields which leads increased hunger. New studies confirm that Africa is one of the most vulnerable continents to climate variability and change because of multiple stresses and low adaptive capacity. Some adaptation to current climate variability is taking place but maybe insufficient for future changes in climate (IPCC, 2007). Given the climate changes and the importance of other external factors such as technological development and changes in demand for food, farmers have been used to adapting to changing conditions. It is frequently assumed that if climate change is gradual, it may be a small factor that will not be noticed by most farmers as they adjust to other change.

One of the policy options for reducing the negative impact of climate change is adaptation (Adger et al., 2003; Kurukulasuriya and Mendelsohn, 2006). The way farmers think and behave in relation to climate changes as well as their values and aspirations, have a significant role to play in addressing climate change (Doss and Morris, 2001). Nevertheless, indigenous and other traditional farmers are only rarely considered in academic policy and public discourses on climate change, despite the fact that they are greatly impacted by impending changes of climate (Berkes and Jolly, 2001).

In some instances, farmers can draw on already existing mechanism for coping with short-term adverse climatic condition. Some of these responses may be traditionally included in their normal subsistence activities, while others may be acute responses, used only in case of critical weather conditions (Scott and Kettleborough, 2002). According to IPCC (2007), adaptation to climate change is the adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities. It also refers to all adjustments in behaviour or economic structure that reduce the vulnerability of society to changes in the climate system including its current variability and extreme events as well as longer-term climate change (Smit et al., 2000). Obayelu et. al., (2014) distribution of farmers by their choices of adaptation methods revealed that a larger proportion of the farmers preferred soil and water conservation adaptation methods to climate change; followed by adjustment of planting period. However, mixed farming and diversification to non-farm activities were the least preferred adaptation measures by the farmers. The soil and water conservation measures mainly adopted by the farmers shown in mulching while the least adopted conservation measures were sole planting of legumes and a combination of planting of legumes and mulching

Significant investments have been made in the Volta basin since 1970s to develop and promote a range of agricultural water management (AWM) technologies in order to enhance food productivity, food security and farmers' income in the face of extreme rainfall variability and severe droughts (Douxchamps et al. 2012, 2014). Given these challenges, small-scale farmers and pastoralists must adapt, in particular by adopting technologies to increase the productivity, the stability and the resilience of their production systems.

2.3.9 Empirical studies on coping and Adaptation strategies to climate change

Entsminger et. al., (2014) findings using a Binary regression model revealed that age is negative and significantly (at 10% level) related to farmers' adaptive strategies to climate change effects. This implies that the probability of adaptation significantly decreases the older a respondent farmer. It can be predicted that such farmers have less interest or less incentives in taking climate change adaptation measures.

Perhaps older farmers do not see the necessity to adapt to climate change effects. Moreover, these older farmers may be more set in their ways, interested in following traditional methods familiar to them rather than adopting modern farming techniques. Entsminger et. al., further revealed that education is positive and significantly (at 5% level) related to adaptation strategies to climate change effects. According to Deressa et al. (2008, 2009), family size is positive and significantly related to farmers' adaptation strategies to climate change effects. large family size makes available more labour which can actively engage in work, better facilitating the adoption of adaptive measures against climate change effects, ceteris paribus, this finding is in line with the large body of literature on technology adoption such as Mignouna et al., (2011) and Tiamiyu et al. (2009). Other studies, such as that of Quayum and Ali (2012), have shown that family size was negative and significantly related to adoption of technologies which contradicts the findings of Entsminger et. al., (2014) and Derressa et. al., (2008,2009).

Kim et al., (2012) found that household income is positive and significantly influences the adaption to climate change while Gbeibouo (2009) explained that wealthier farmers are more interested to adapt by changing planting practices, using irrigation, and altering the amount of land farmed. The scope of AWM interventions adapted by Douxchamps et al. (2012) after Johnston and McCartney and Smakhtin (2010) and other previous work that identified high potential for adoption and adaptation of three main streams of AWM technology (Barron et al. 2011; Evans et al. 2012). They are; small reservoirs, small electric/diesel pumps for smallholder irrigation and soil and water conservation (SWC). Small reservoirs are used for multiple purposes, including irrigation, fishing and livestock watering (Sally et al. 2011). Also, Soil and water conservation (SWC) interventions incorporate a range of technologies for reducing soil erosion and improving soil moisture infiltration for crop and plant growth. Findings from the national agricultural surveys in Sahel revealed a percentage rise from 1993 to 2006 in the proportion of surveyed farmers' fields having at least one SWC measure in place. It is important to note that often farmers use a combination of measures, which has a greater impact than using one in isolation (Magombeyi et al. 2014; Zougmoré et al. 2003, 2005).

Lack of efficient water resource development and conservation systems suitable for small scale farmers are one of the major problems limiting the capacity of agriculture to meet its role in food security and overall development in the country. A study conducted in Kenya revealed that some of the long-term measures include sensitizing communities about efficient and effective use of water, supporting and encouraging the use of rainwater harvesting techniques, de-silting or dams, and adopting energy-saving technologies will help communities in water insecurity situations (FAO, 2014).

According to Betebo (2014), the following were considered to address water insecurity problems;

- ✓ **Run off and Flood Farming.** The technique involves diversion of runoff from the farm, run off from roadsides, foot trails and farm boundary grass waterways
- ✓ **Ponds:** These are used to harvest rainwater for both human and livestock watering, particularly in the arid and semi-arid rural areas.
- ✓ **Dug Wells:** Dug wells (3 to 15 meters) are major sources of water both for domestic water supply and agricultural uses and they are widely used in wetland areas, sand river beds and valley bottom lands.
- ✓ **Soil Moisture Conservation:** In -situ water harvesting using open and tied ridges in moisture stress areas improved land and crop productivity by 100% and farmers are increasingly using them in drought prone areas.
- ✓ **Roof Water Harvesting:** People collect water from their individual house roofs, churches, schools, etc. They use tanks, drums and other huge containers to collect water

2.4 Factors affecting the choice of adaptation measures

A study conducted by Nhemachena and Hassan (2008) using the multinomial Logit (MNL) on adoption revealed that household size has both positive and negative impacts on farmers' adoption of agricultural technologies. Larger family size is expected to enable farmers to take up labour intensive adaptation measures (Nyangena, 2007; Dolisca et al., 2006; Anley, 2007; Birungi, 2007). Tizale (2007) also confirmed the above studies that large family might be forced to divert part of its labour force into non-farm activities to generate more income and reduce consumption demands. However, the opportunity cost of labour might be low inmost smallholder farming systems as off-farm opportunities are rare. It is therefore expected that farm households with more labour are able to take up adaptations in response to changes in climate better. The findings of Apata et al., (2008) in South Western Nigeria confirmed the studies of Nhemachena and Hassan (2008) that household size had a negative influence on adaptation to climate change among arable food crop farmers.

The influence of age on these choices has been mixed in the literature. Some studies found that age had no influence on a farmer's decision to participate in forest and soil and water management activities (Thacher et al., 1997; Anim, 1999; Zhang & Flick, 2001; Bekele &Drake, 2003). Others, however, found that age is significantly and negatively related to farmers' decisions to adopt (Gould et al., 1989; Featherstone & Goodwin, 1993; Lapar & Pandely, 1999; Burton et al., 1999; Dolisca et al., 2006; Nyangena, 2007; Anley et al., 2007). On the other hand, Okoye (1998) and Bayard et al. (2007) found that age is positively related to the adoption of conservation measures. The age of the farmers is also identified as a factor in adaptation by Obayelu et. al., (2014) as the study indicated that age was negatively related to diversification to non-farm activities, use of improved varieties mixed farming and adjustment of planting period. Thus, increase in age of the farmers decreased the use of improved varieties, mixed farming, diversification to non-farm activities and adjustment of planting period relative to soil and water conservation techniques as adaptation measures to climate change. It was further confirmed that the years of farming experience of the farmers had a negative influence on diversification to non-farm. This is contrary to the findings of Kebede et al., (1990) which posited that a positive relationship exists between the number of years of experience in agriculture and the adoption of improved agricultural technologies in Ethiopia.

Many studies have shown that gender is an important variable affecting adoption decision at the farm level. Female farmers have been found to be more likely to adopt natural resource management and conservation practices (Newmark et al., 1993; Burton et al., 1999; Dolisca et al., 2006; Bayard et al., 2007). However, researchers found that household gender was not a significant factor influencing farmers' decisions to adopt conservation measures (Bekele &Drake, 2003). Obayelu et al., (2014) used the multinomial logit regression model to analyze farmers' adaptation measures and it was significant at one percent level indicating that all the independent variables jointly influenced the dependent variables. The study also revealed that gender of the household heads had a positive influence on the likelihood of diversifying to non-farm activities and adjustment of planting period implying that a male farmer had higher probability of diversifying to nonfarm activities and adjusting their planting period relative to adopting soil and water conservation method. The male farmers were also more likely to adapt to climate change by adjusting their planting period than using soil and water conservation method. This was consistent with the findings of Tenge De Graffe and Heller (2004) in which being a female head of a household had negative effects on the adoption of soil and water conservation measures, because women have limited access to information, land and other resources due many social barriers.

Several studies have shown that improving education and disseminating knowledge are an important policy measure for stimulating local participation in various development and natural resource management initiatives (Bultena & Hoiberg, 1983; Anderson & Thampallai, 1990; Shields et al., 1993; Heinen, 1996; Traoré et al., 1998; Higman et al., 1999; Anim, 1999; Lapar & Pandely, 1999; Glendinning et al., 2001; Dolisca et al., 2006;

Anley et al., 2007; Tizale 2007). Better education and more farming experience improve awareness of potential benefits and willingness to participate in local natural resource management and conservation activities.

However, Clay et al. (1998) found that education was an insignificant determinant of adoption decisions, while Okeye (1998) and Gould et al. (1989) found that education was negatively correlated with such decisions. Maddison (2006) also stated that evidence from various sources indicate that there is a positive relationship between the education level of the household head and adaptation to climate change. This implies that farmers with higher levels of education are more likely to adapt better to climate change. The years of formal education of the farmers was positively related to both diversifications to non-farm activities and adjustment of planting period relative to soil and water conservation adaptation techniques.

Awareness of the problem and potential benefits of taking action is another important determinant of adoption of agricultural technologies. Maddison (2007) found that farmers' awareness of changes in climate attributes is important for adaptation decision making. Several studies have found that farmers' awareness and perceptions of soil erosion problems positively and significantly affected their decisions to adopt soil conservation measures (Gould et al., 1989; Traoré et al., 1998; Anim, 1999; Araya & Adjaye, 2001). We expect that farmers who notice and are aware of changes in climate would take up adaptation measures that help them reduce losses or take advantage of the opportunities associated with these changes. Studies have revealed that farmers that had more information on climate change, increased their use of improved varieties, diversified to non-farm activities and adjusted their planting period relative to the use of soil and water conservation measures. This is consistent with other findings that access to information through extension services increases the likelihood of adapting to climate change (Maddison, 2006; Nhemachena and Hassan, 2007).

Empirical adoption studies have found mixed effects of farm size on adoption. For example, a study on soil conservation measures in South Africa showed that farm size was not a significant adoption factor (Anim, 1999). Other studies, however, found that farmers with larger farms were found to have more land to allocate for constructing soil bunds (embankments) and improved cut-off drains in Haiti (Anley et al., 2007) and Nigeria (Okoye, 1998). On the other hand, Nyangena (2007) found that farmers with a small area of land were more likely to invest in soil conservation than those with a large area. This study hypothesizes that farmers with large farms would adopt measures that require a large area of land such as livestock systems, while farmers with small farms are expected to diversify their options.

Various studies of determinants of soil and water conservation technologies have shown that farm assets (e.g. machinery) significantly affect adoption decisions (e.g. Barbier, 1998, Pender &Kerr, 1998; Lapar & Pandely, 1999). Kurukulasuriya & Mendelsohn (2006a) found that ownership of heavy machinery significantly and positively increased net farm revenue on African cropland. This study expects that ownership of more farm assets improves farmers’ ability to adapt.

Extension services are an important source of information on agronomic practices as well as on climate. Extension education was found to be an important factor motivating increased intensity of use of specific soil and water conservation practices (Anderson & Thampallai, 1990; Traoré et al., 1998; De Harrera & Sain, 1999; Baidu-Forson, 1999;

Bekele & Drake, 2003; Tizale, 2007). Other studies have revealed that Farmers with better access to extension services were more likely to adopt improved technologies (Anley et al., 2007). Also, increased extension contact with extension agent increased the likelihood of adjustment to planting period and decreased the probability of the use of soil and water conservation measures (Obayelu et. al., 2014). Other adoption studies, however, have found that extension was not a significant factor affecting the adoption of soil conservation measures (Pender et al., 2004; Nkonya et al., 2005; Birungi, 2007). This study postulates that the availability of better climate and agricultural information helps farmers make comparative decisions among alternative crop management practices and hence choose the ones that enable them to cope better with changes in climate (Kandlinkar & Risbey, 2000; Baethgen et al., 2003; Jones, 2003).

Several studies have shown that credit access is an important factor enhancing the adoption of various technologies (Anderson & Thampallai, 1990; Yirga et al., 1996; Hassan et al., 1998; Kandlinkar & Risbey, 2000; Tizale, 2007). With more financial and other resources at their disposal, farmers are able to make use of all their available information to change their management practices in response to changing climatic and other conditions. For instance, with financial resources and access to markets farmers are able to buy new crop varieties, new irrigation technologies and other important inputs they may need to change their practices to suit the forecasted climate changes. The findings of Caviglia-Harris (2000) is in conformity with previous studies that access to credit is an important variable which has a positive effect on adaptation behaviour.

Market access is another important factor affecting adoption of agricultural technologies (Feder et al., 1985). Input markets allow farmers to acquire the inputs they need such as different seed varieties, fertilizers and irrigation technologies. At the other end, access to output markets provides farmers with positive incentives to produce cash crops that can help improve their resource base and hence their ability to respond to changes in climate (Mano et al., 2003).

Madison observed that long distances to markets decreased the probability of farm adaptation in Africa and that markets provide an important platform for farmers to gather and share information. Lapar & Pandely (1999) found that in the Philippines access to markets significantly affected farmers' use of conservation technologies (Nhemachena and Hassan, 2008)

Households with higher income and greater assets are in a better position to adopt new farming technologies (Shiferaw and Holden 1998). Results from Obayelu showed that increase in farm income improved the use of water and soil conservation measures while non-farm income increased the likelihood of mixed farming.

Also, increase in number of livestock increased the farmers' preferences for the use of soil and water conservation measures but decreased their likelihood of diversification to non-farm activities.

Dhaka et al. (2010) also found in their study that the majority of the farmers were using various adaptation strategies in response to climate change. Increased use of irrigation was ranked first and thus most important, among farmers' adaptive strategies to climate change. Irrigation increases the yield of production, improving nutrient availability to the plants but also leading to increased soil salinity. Practicing crop diversification was identified as the second-ranked adaption strategy. Continuous mono-cropping has different adverse effects which include pest resurgence, and soil quality deterioration, in addition to the issues of loss risk associated with monocultures. In response to these effects, farmers adopt diversified cropping practices, reducing overall farm risk and expanding opportunities for farm profit, which generally act to boost the farmers' average incomes (Entsminger et. al., 2014).

2.4.1 Economics of water security, coping and adaptation strategies

There is enough information and scientific evidence that indicates an increase in average temperature and in climate variability in the semi-arid tropics, with rapid increase in the occurrence of droughts and floods that affect people, their crops and their livestock (IPCC, 2001 and 2007).

According to Aklilu (2013), In the last few decades ensuring food security has been one of the main issues in developing countries, where a significant proportion of the population lives in poverty. FAO (2012), report that 870 million people are chronically undernourished worldwide in 2010-12. The largest share lives in developing countries, where about 15% percent of the population is food insecure. Ensuring food security is challenged by drought and famine augmented by lack of proper water management. Pressured water resources ultimately resulted in a significant decline in water availability. This has had a destructive impact on the agricultural sector.

According to Molle and Mollinga (2003) water is essential for food security, this category of water use corresponds to individuals who need additional water to grow the food they consume The commonest example is that of smallholders and peasant farmers who irrigate their fields and depend on agricultural production for their food and subsistence. 80% of Africans are said to rely on agriculture for employment and water shortage will amount to food insecurity. Some of the arid regions in the continent are experiencing famines because of lack of rainfall to grow crops. The United Nations Economic Commission for Africa and the New Partnership for African Development posit that irrigation is the key to achieving increased agricultural production that is important for economic development and for attaining food security (Awojobi, 2014).

water management in crop production tends to be concentrated on food crops where the timing and reliability of supply is critical. Water management (irrigation, drainage and water conservation and control) achieves stability of crop production by maintaining soil conditions close to optimum for crop growth. Irrigation allows the cultivation of crops when rainfall is erratic or insufficient, insures high-value, high-risk horticulture from failure and has played a major role in achieving national and regional food security in Asia, as well as improving individual livelihoods (Hussain, 2005). Irrigation can benefit the poor through improving yields and production, reducing the risk of crop failure, and generating higher and year-round farm and nonfarm employment. It can ensure smallholders to adopt to more diversified cropping patterns and to shift from low-value subsistence production to high value market-oriented production, which increase income of household (Betebo, 2014).

Extreme drought and flood have been challenging fragile economies of developing nations. The study of Davies (2010) on the impact of shocks on consumption in rural Malawi shows that drought and flood has prominent short-term negative impact on the level of consumption. But in the long run flooding has been found to have positive impact because households benefit from the increased rainfall. Furthermore, Dercon et al. (2005) analyzes the impact of drought, flood and other shocks on socio-economic aspects of rural Ethiopia. It shows that Ethiopia is a shock-prone country, the most important shocks being drought. It was further stated that maize production in 2011 in Eastern Province dropped by 8% due to a poor harvest caused by early cessation of the 2011 short rains, attributed to changing climatic conditions.

2.4.2 Constraints to the adaptation measures

Constraints to Adopting Coping Strategies Faced by Farmers were studied by Entsminger et. al., (2014) using the Problem Confrontation Index (PCI). The study revealed that lack of available water was ranked first and seems to be the most severe problem of the farmers in the region studied in terms of adoption of climate change adaptation strategies. Shortage of cultivable land was ranked as the second most severe problem.

According to Aregawi (2014), the major problems associated with small-scale irrigation in the study area are problems related to cost, lack of sufficient irrigation water, lack of effective marketing system, lack of input supply and irrigation facilities, and presence of pests and diseases. Anang et al., (2013) used the Kendall's coefficient of concordance to rank the constraints faced by farmers in Ghana. The constraints that were ranked were Insufficient supply of chemicals, inadequate spraying personnel and Favoritism by the spraying personnel. The results indicated that the coefficient of concordance (W) was 0.72 meaning that 72% of the respondents were in agreement with the rankings of the constraints. Insufficient supply of chemicals was identified as the most critical constraint, followed by inadequate spraying personnel. Favoritism by the spraying personnel was the least constraint. The results are consistent with the findings of Abankwah et al (2010) who identified setbacks to the cocoa mass spraying program to include insufficient supply of chemicals, stealing of pesticides by sprayers and inadequate fuels for spraying machines.

The use of these rankings (Problem Confrontation Index and Kendall's coefficient of Concordance) indicates which constraint need serious attention. Using these models in this study will help identify constraints farmers face in Mamprugu Moaduri District and also help in identifying which of these constraints needs immediate intervention by ways of ranking them.

CHAPTER THREE

Research Methodology

3.0 Introduction

This chapter describes the study area; sampling procedures and sample size; data collection and analysis methods and the theoretical framework.

3.1. Study Area.

The Sisili-kulpawn Basin is a catchment area located in the Mamprugo-Moaduri District. In 2012, the district with its capital as Yagaba was carved out from West Mamprusi District. The district is within longitudes 0°35'W and 1°45'W and Latitude 9°55'N and 10°35'N. It is bounded by Builsa South district in the Upper East region and Sisala East district in the Upper West region, West Mamprusi district to the west, North Gonja district and Kumbungu district both to the south; in the Northern Region. The district geology is made up of Middle Voltain rocks normally suitable for rural water supply. The district is largely covered by flat and undulating terrain. The major drainage feature of the district is the White Volta Basin and its main tributaries such as the Sisili and the Kulpawn rivers. Along the valleys of these rivers are large arable land that is suitable for the cultivation of rice and other cereals.

According to Owusu (2015), the district however has an average temperature ranging from 30°C to 40°C per annum which is distributed from November to April and an average rainfall ranging from 1,000mm to 1,200mm per annum, which is also distributed from May to October with August and September as the months with highest rainfall. The area has an abundant arable land (average no. of ha/capita or household) and sunshine to allow the cultivation of a wide variety of crops given sufficient water availability.

MMD lies within the savannah agro-ecological zone with single maximal rainfall regime, averaging between 1000mm and 1400mm. The rainfall season occurs between May and October, with July to September being normally the peak period in terms of incidence and level of rainfall. Floods occur during the peak period, after which there is a prolonged dry season from November to April. Temperatures are generally high all year round with the hottest month being March. While in the rainy season there is high level of humidity, sunshine with heavy thunder storms, the dry season is characterized by dry Harmattan winds from November-February and high sunshine from March-May.

The SKB is characterized by difficult agro-ecological conditions, such as annual flooding, drought periods, poor soils, erratic rainfall, exacerbated by the adverse effects of climate change. Recent investigations into the scenarios for development of water management and irrigation and drainage practices have demonstrated that there is a great potential for large scale irrigation in the North (IWAD, 2013).

Subsistence agriculture is the dominant economic activity in the S-K basin. The river valleys consist of large stretches of arable land, good for cultivation of rice and cereals on a commercial scale. This also presents opportunities to do dry season farming. A wide range of rain-fed crops such as millet, cowpea, maize, rice, sorghum, groundnuts and vegetables can be cultivated throughout the district. The agricultural strategies adopted by local villages are largely in response to the short wet and extended dry season. In fact, these sharp seasonal factors largely drive the subsistence livelihoods adopted by local villages. Rain-fed cropping is undertaken at elevated areas where flood risks are negligible, but where water functions as a major constraint, particularly during the dry season (Wit and Norfolk, 2014).

3.2 Sampling technique and sample size

The sampling procedure that was considered in this study was a multi-stage purposive sampling procedure. Firstly, SKB is selected as it is identified as one of project intervention areas as in the IWAD project. Four communities were purposively selected namely; Loagri, Gbima, Kunkwa and Wiasi representing two irrigation and non-irrigation communities respectively. The stratum of irrigation user consists of households who have access to irrigated land for direct utilization. The second stratum referred to hereafter as non-users composed of households who do not have access to irrigated land. In the second stage, farm households consisting of 100 irrigation users and 100 non-users were selected using simple random sampling technique.

A household in this study was defined as a group of people who live together in the same dwelling and share meals together.

3.3 Method of data collection

Both primary and secondary data collection methods were employed. The primary data required for this study were collected from respondents using a structured interview schedule, personal observations of physical features, and informal discussions with the water resource beneficiaries.

The enumerators for the data collection were selected on the basis of their educational back ground and their ability to speak the local languages (Mampruli and Buli) and training was conducted for the enumerators. The data collection started after pretesting and modifications. The field/farm specific questions were collected based on the conditions that prevailed during 2015/2016 cropping year.

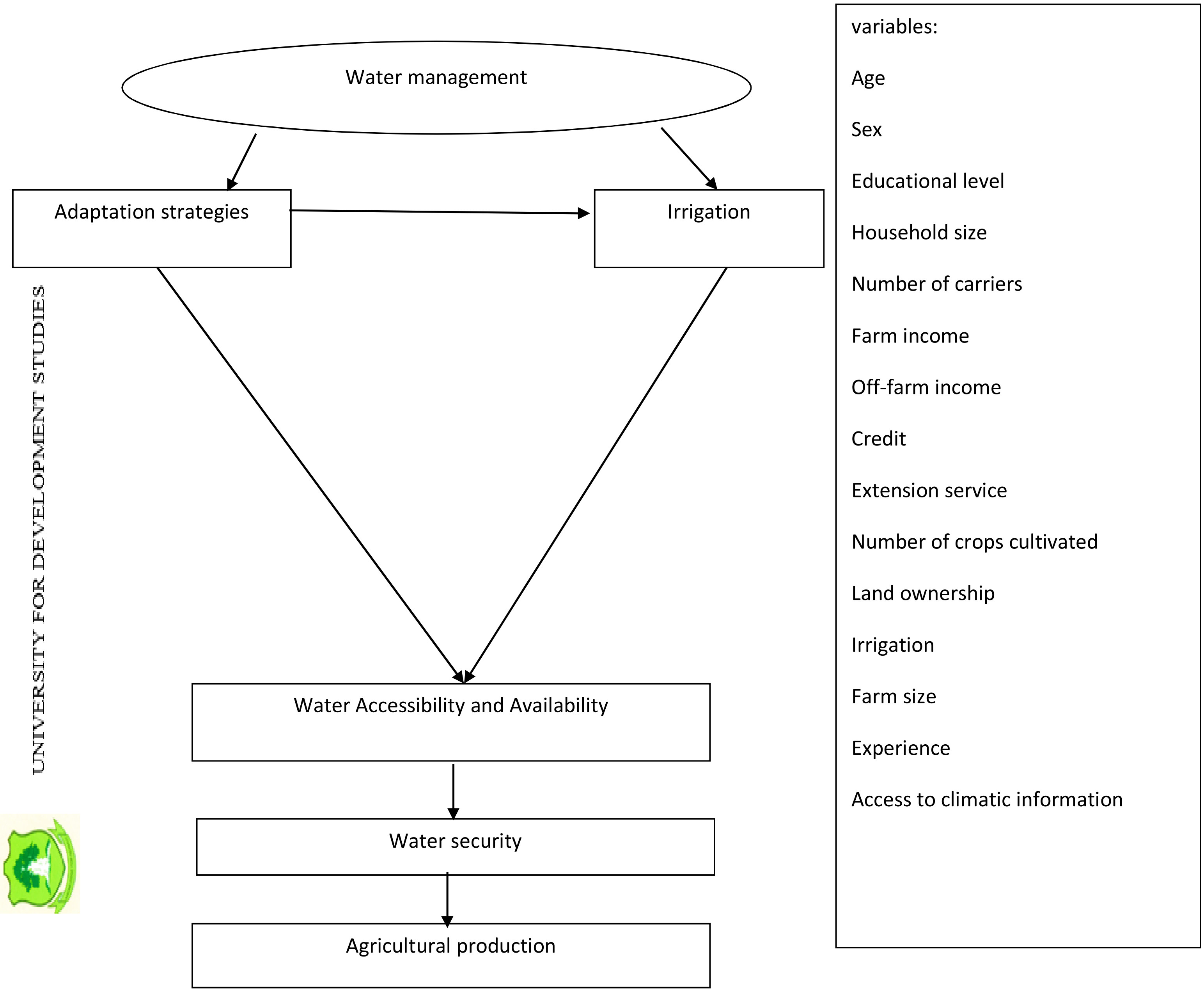

Fig 1: conceptual framework adapted from Betebo (2014)

Cullis (2005) and Sullivan et al. (2002) call for a comprehensive framework for water management especially in developing countries. It is with this that the Water Poverty Index was developed by Caroline Sullivan to examine poverty in relation to water resources accessibility. According to Garrga and Perez-Foguuet, the WPI is an integrated assessment of water stress and scarcity, linking physical estimates of water availability and the socio-economic factors which impact on access and use of this resource.

3.4 The analytical framework

This study addresses the impact of adaptation strategies on farm income, first through changes in household water security. Higher levels of water security lower adoption of adaptation strategies.

Let *Xi* (*i = 1, 2, …..*) define subsets from the vector of relevant household, farm, and other characteristics that influence adoption and farm income. Household socio-economic characteristics include education, farm income, family size, age and sex of the household head. Among other characteristics are farm size, access to extension services, number of crops cultivated, access to sufficient water among others. The following system of recursive equations captures the direct and indirect impacts of water security:

Adaptation equation:

$$A = f(w, x_i) \qquad 3.0$$

Where A= adaptation strategies

w = water security

x = exogenous variables

Farm income equation:

$$y = f(A, X_i) \qquad 3.1$$

Where y = farm income

In the above system of equations, *Xi* defines the relevant subset of exogenous variables such that the equations are fully identified. Eq. (3.0) states that, the adoption of adaptation strategies, A, depends on water security and a set of variables represented in X. In equation

(3.1), y is Farm income which also depends on a set of explanatory variables, X and the predicted value of A. The problem of simultaneity bias arises when equation (3.1) is estimated by OLS. This is because the random error terms are likely to be correlated, since unobserved household variables affect both A and y. Because of the likelihood of the simultaneity of some of the right-hand variables and the dependent variable, the instrumental variable approach was used. A two-stage procedure was used to produce unbiased and consistent estimates. In the first stage, an estimate A* of A is obtained by using a multivariate probit method for equation (3.0). In the second step of the recursive model, the effect of adoption of adaptation strategy on farm income is estimated, using the predicted value of adaptation strategies and other explanatory variables in the farm income equation.

3.5 Method of data analysis

3.5.1 Objective one (estimate farm household water security)

The WPI is calculated using a composite index approach. The five key components are combined using the general expression:

$$WPI = \frac{\sum \text{wixi}}{(\sum wi)} \qquad 3.2$$

Where WPI is the Water Poverty Index value for a particular location,

Xi refers to component i of the WPI structure for that location, and wi is the weight applied to that component. Each component is made up of a number of sub-components, and these are first combined using the same technique in order to obtain the components. For the components listed above, the equation can be re- written:

$$WPI = \frac{(wrR + waA + wcC + wuU + weE)}{(wr + wa + wc + wu + we)} \qquad 3.3$$

Which is the weighted average of the five components Resources (R), Access (A), Capacity (C), Use (U) and the environment (E) Each of the components is first standardized so that it falls in the range 0 to 100; thus the resulting WPI value is also between 0 and 100. Values of 50% approaching 100% indicates higher water poverty index whiles values below 50% are indicating lower water poverty index hence water insecurity.

3.5.2 Water Poverty Index pentagram (WPI pentagram)

WPI pentagram is an instrument that shows how information can be displayed in an accessible way to stakeholders and policy-makers. This makes it easier to understand which specific attributes of the water sector most need immediate attention, helping in making decisions. The WPI pentagram was used to display the five components of Water Poverty based on each community.

Table. 3.2 Measurement of water poverty components

WPI components	Sub-components used
Resource (R)	% of household members that reports physical availability of water
Access	% of households members having access to sufficient water
Use	% of household members who use water for irrigation purposes
Capacity	% of respondents who are Educated
	% of households members engaged in Economic activities
Environment	% of households members who reported crop loses in the last 5 years

These measurements are in line with the Center for Ecology and Hydrology (2016) and Matshe et. al., (2016). Similar measurements were adopted in this study.

3.5.3 Objective two (To examine farmer's adaptation strategies to water security)

Farmers were asked to list their own adaptation strategies to water insecurity. The adaptation index was used to identify the adaptation strategies according to its relative importance and results were displayed in tables.

Adaptation Strategy Index

To identify those adaption strategies which held relative importance over others, an adaptation index procedure was used, as measured by the formula presented below. Farmers were asked to assess different adaptation strategies by using four-point rating scale; high, medium, low and not at all which represent rates of 3,2,1 and 0 respectively to rate the importance of each strategy based on their experience. The relative importance of adaptation strategies to water scarcity was calculated based on the following index formula and constraints was ranked according to the Index:

$$A = An \times 0 + Al \times 1 + Am \times 2 + Ah \times 3 \qquad 3.4$$

where,

A = Adaptation Strategy Index

An = Frequency of farmers rating adaptation strategy as having no importance

Al = Frequency of farmers rating adaptation strategy as having low importance

Am = Frequency of farmers rating adaptation strategy as having moderate importance

Ah = Frequency of farmers rating adaptation strategy as having high importance

The adaptation strategy with the highest index was reported as the most used adaptation strategy.

3.5.4 Objective three (estimate the determinants of adaptation strategies and the effects of household water security on household adaptation strategies)

The study considered the multivariate probit model to estimate the determinants of adaptation measures and effects of household water security on adaptation strategies. The multivariate probit model considered in this study is characterized by a set of n binary dependent variables y_i with observation subscripts suppressed such that:

$$y_i = 1 \; if \; x^1\beta_i + \varepsilon_i > 0 \qquad 3.5$$

$$y_i = 0 \; if \; x^1\beta_i + \varepsilon_i \leq 0, i = 1,2..n \qquad 3.6$$

Where x is the vector of explanatory variables, $\beta_1, \beta_2, \ldots \beta_n$ are the conformable parameter vectors and random error terms and are distributed as multivariate normal distribution with zero means, unitary variance and an n×n contemporaneous correlation matrix $R = [\rho_{ij}]$, with density $\varphi(\varepsilon_1, \varepsilon_2 \ldots \varepsilon_n)$. The likelihood contribution for an observation is the n-variate standard normal probability

$$P_r(\, y_i \ldots y_n \,|x = \int_{-\infty}^{(2yi-1)x^1\beta_1} \int_{-\infty}^{(2y2-1)x^1\beta_2} \ldots\ldots x \int^{(2yn-1)x^1\beta_n} \varphi(\varepsilon_1, \varepsilon_2 \ldots \varepsilon_n, Z^1RZ)d\varepsilon_n..d\varepsilon_1 \qquad 3.7$$

Where Z= dias [$2y_1 - 1 \ldots 2y_n - 1$]. The maximum likelihood estimation increases the sample likelihood function, which is a product of probabilities across sample observation. The marginal Effects of explanatory variables on the propensity to adopt each of the adaptation strategy is calculated as follow;

$$\partial Pi \,|\partial xi = \varphi(x^1\beta)\beta_i, i = 1,2 \ldots \ldots . . n \qquad 3.8$$

Where Pi is the probability of an event (that is increased used of each adaptation strategy), $\varphi(.)$ is the standard univariate normal cumulative density distribution function, x and β are vectors of regressors and model variables respectively (Hassan,1996). The five (5) dependent variables are drought tolerant varieties, short duration crops, improved farming methods (creating of bunds), Adjusting planting date and Mulching. Each adaptation strategy has a binary response.

The choice of explanatory variables was derived by empirical literature and data availability. Water Poverty Index (WPI) is used as an explanatory variable in the multivariate probit model to estimate how water security influence adaptation strategies. According to Kandlinkar and Risbev (2000), resource limitations coupled with household characteristics limits the ability of most farmers to take up adaptation measures in response to changes in climate.

Demographic and Socio-Economic Variables

Sex: This is a dummy variable based on gender. Male household head = 1 and female household head = 0.

Age: The age of the respondent will be measured on a continuous scale.

Farming experience: This variable refers to the total number of years that the sampled household has spent in farming. A farmer with longer experience in farming, a wider knowledge and experiences are gained on the operation and conduct of the agricultural activities and methods of production. Thus, this variable was hypothesized to have a positive relationship with participation in irrigation scheme. That is more likely that farmers with longer farming experience are ready to accept changes and adopt new ideas and techniques. Experienced farmers are expected to have more knowledge and information about climate change and agronomic practices that they can use in response (Maddison, 2006). We expect that improved knowledge and farming experience will positively influence farmers’ decisions to take up adaptation measures

Household size: This continuous variable measures the total number of the household members living under the same roof adjusted to adult equivalent. Previous studies found a two-way relationship between family size and decision to participate in irrigation and other agricultural technologies. Therefore, this variable was hypothesized to have a positive effect on household heads decision to irrigation participation. A household with large labour force can participate in small-scale irrigation more than a household with a low level of labour force (Shimelis, 2009).

Off-farm Income: This continuous variable measures the amount of money in Ghana cedis that household head acquired from other sources

Farm Size: This continuous variable measures in acres and it refers to the total cultivated land size of the household heads. In many previous studies, it has been noted that enough size of land holding is the basic requirement for adoption of agricultural technologies. It is thus hypothesized that the larger the farm size the farmer has, the higher the probability to adopt irrigation technology. Total cultivated land should have a positive relationship with income of a household (Kamara et al., 2001).

Number of crops cultivated: This is a continuous variable and it refers to the total number of crops that were cultivated in the 2015/2016 production year.

Access to sufficient water: This is a dummy variable based on access = 1 and No access = 0. This indicates whether the household head gets access to sufficient water.

Access to extension service: This is a dummy variable based on access = 1 and No access = 0. This indicates whether the household head gets extension service from extension agents or not. Extension service provides the necessary information to acquire new skills and knowledge to farmers to improve agricultural production. According to Bacha et al., (2011), there is a significant difference between irrigators and non-irrigators in access to extension. The higher is the probability for the farmers to access and use irrigated agriculture. Thus, this variable was hypothesized to positively influence participation in irrigation.

Table 3.3 list of all variables and measurement

Variable	**Measurement**	**A Prior Expectation**
Sex	1= male, 0= otherwise	+
Age	Number of years	+
Number of crops grown	Number of crops	+
Farm size	Number of acres	+
Farm exp.	Number of years	+/-
Climatic info.	1= affirmative, 0 = otherwise	+
Credit access	1= affirmative, 0 = otherwise	+/-
Household size	Number of members in a household unit	+/-
Access to sufficient water	1= affirmative, 0 = otherwise	+
education	Number of years	+
irrigation	1= irrigator, 0 = non-irrigator	+
Extension services	1= affirmative, 0 = otherwise	+

Farm income	Ghana cedis	+
fertilizer	value	+/-
Seeds	value	+
weedicide	value	+/-
labour	Man days	+
Off-farm income	Ghana cedis	+

3.5.5 objective four (determine the effects of household adaptation strategies on farm income)

This study considered the log-linear production function to determine the effects of household adaptation strategies on farm income. The model is specified below;

$$LnY=\beta+\beta_1X_1{}_{+}\beta_2X_2{}_{+}\beta_3X_3{}_{+}\beta_4X_4{}_{+}\beta_5X_5{}_{+}\beta_6X_6{}_{+v}\beta_7X_7+e \qquad 3.9$$

The predicted value of adaptation strategies from the multivariate probit model is added to the farm income equation to estimate the effect of adaptation strategy on farm income.

There are factors that affect both adaptation strategies and farm income which are not explicitly controlled for in the analysis, and which can be a source of endogeneity. Hence, an instrumental variables (IV) estimation framework was used to overcome this problem.

Where Y = Farm income

X_1= predicted value of adaptation strategies, X_2= fertilizer (value), X_3= seeds (value), X_4= Weedicides (value), X_5= Labour (man days), X_6= Age (years), X_7 = education (years), X_8= Farm size (Acres), X_9= Farming experience (years), X_{10}= access to sufficient water (dummy), X_{11} = household size (number of people in a household unit), X_{12}= irrigation (dummy) and X_{13}= number of crops cultivated (number)

3.5.6 Objective five (Profitability Analysis between irrigation and non-irrigation farmers)

A gross margin for an enterprise is its financial output minus its variable costs. Mathematically:

$$GM=TR-TVC \qquad 3.10$$

$$TR=PQ \qquad 3.11$$

Where, TR= Total Revenue

P=Price

Q= Quantity

TVC= Total Variable Cost

Total Revenue (TR) is the value of output while the Total Variable Cost (TVC) is the aggregation of the costs of land preparation, planting materials, seeds, planting, weeding, spraying and harvesting.

3.5.7 Objective six (Constraints Faced by Farmers)

The Kendall's Coefficient of Concordance was used to rank the constraints farmers face in the Mamprugu Moaduri District. The Kendall's Coefficient of Concordance is a non-parametric statistical procedure used to identify a given set of constraints or problems, from the most influential to the least influential as well as measure the degree of agreement or concordance among the respondents. The identified constraints were ranked from the most influential to the least influential using numerals, 1, 2, 3 ... n, in that order where n is positive integer. The total rank score for each constraint was computed and the constraint with the least score was ranked as the most pressing one, while the constraint with the highest score was ranked as the least pressing one. The total rank score computed was used to calculate the Kendall's Coefficient of Concordance (W), a measure of the degree of agreement between respondents in the ranking. The equation for the Kendall's coefficient is given as:

$$W = \frac{12[\sum T^2 - (T)^2/n]}{nm^2(n^2-1)} \qquad 3.12$$

where W = Kendall's Coefficient of Concordance

T = Sum of ranks for constraints being ranked

m = Total number of respondents

n = Total number of constraints being ranked.

W ranges from 0 to 1, where 0 implies perfect disagreement and 1 implies perfect agreement. The Coefficient of Concordance (W) was tested for significance in terms of the F – distribution. The F – ratio is given by;

$$F = [(m-1)\,W/\,(1-W)] \qquad 3.13$$

with numerator and denominator degrees of freedom of $(n-1)-(2/m)$ and $m-1[(n-1)-2/m]$ respectively

Test of hypothesis

The following hypothesis was tested:

Ho: Respondents do not agree on the ranking of the constraints in the Mamprugu Moaduri district.

The null hypothesis is rejected if the calculated F – value is greater than the tabulated F – value. Rejection of the null hypothesis implies that the respondents agree with each other on the ranking of the constraints they face in the Mamprugu Moaduri District.

CHAPTER FOUR

4.0 Results and Discussions

4.1 Introduction

This chapter discusses the socio demographic characteristics of respondents, household water security in the study area, adaptation strategies and effects of household water security on household adaptation strategies. Also, the effects of household adaptation measures on farm income was studied and lastly, the problems confronted by the farmers in the study area were identified and ranked using the Kendall's coefficient of Concordance

4.2 Socio-demographic characteristics of respondents

The Table 4.2.1 discusses the descriptive statistics of some sex, marital status and shocks According to the result shown in table 4.2.1 below, sex of the household head and marital status were all insignificant. Out of the total sampled household of irrigators, 91% were male-headed and 9% were female-headed. The chi-square value shows that the proportion of male headed households are higher for irrigation participants (91%) than for the non-participants (86%). Majority of the respondents under each category were married, representing 90% irrigators and 89% non-irrigators respectively.

Household respondents were assessed based on the shocks that were experienced within the last two (2) seasons. The findings revealed that a majority of the respondents (74.40%) who were exposed to shocks were the non-irrigators. This is because most of them were not adapting any strategies to ensure water use efficiency.

Table 4.2.1 Household Demographics (categorical variables)

Variable		**irrigators**		**Non-Irrigators**		**P value**
		Frequency	**percentage**	**Frequency**	**percentage**	
Sex	Male	91	91.00	86	86.00	0.268
	Female	9	9.00	14	14.00	
Marital status	Married	90	90.00	89	89.00	0.818
	Unmarried	10	10.00	11	11.00	
Shocks	Yes	30	27.00	76	74.40	0.000***
	No	60	54.00	22	21.56	
Access to credit	Yes	11	11.00	12	12.00	0.825
	No	89	89.00	88	88.00	
Access to climatic information	Yes	40	40.00	20	20.00	0.278
	No	60	60.00	80	80.00	
Access to extension services	Yes	50	50.00	15	15.00	0.000***
	No	50	50.00	75	75.00	

Source: Field Survey (2017)

The extension service is delivered to farmers mainly via Extension Agents (EAs) through sharing of modern agricultural knowledge and information to farmers in a better way. EAs are leading workers in day-to-day contact with farmers. The adoption of new technology, among others, was extension contact, availability of input supply, and access to credit is the important institutional services that were required to increase agricultural productivity. It was understood from previous studies that an increase in productivity is achieved through farmers' access to appropriate extension services. It is learnt that sample households in the study area do not have a better access to extension services that was illustrated by frequent visit of extension agents. This finding contradict the results of Betebo (2014). Hence, the result of this study is inconsistent with that study which revealed that majority of the irrigators and non-irrigators did not have access extension service.

Credit is an important institutional service to finance poor farmers for input purchase and ultimately to adopt new technology. However, some farmers have access to credit while others may not have due to problems related to repayment and down payment in order to get input from formal sources. Hence, some farmers avoid farm credit. The survey result indicated that only 11% of the irrigators and 12% of the non-irrigators had taken credit which is inconsistent with the findings of Takele (2008). Finally, majority of the respondents representing 92% and 89% of irrigators and non-irrigators respectively did not equally have access to enough climatic information

Table 4.2.2 Descriptive Statistics of continuous variable

Variable	**Irrigator**	**Non-Irrigator**	**Min**	**Max**	**T test**
	Mean				
Age	42.34	45.82	20	75	-1.82**
Education	8.15	9.33	0	21	-2.095**
Income from other sources	1463.5	193.78	100	5500	11.283***
Years of experience	19.30	18.26	2	58	0.671
Extension visits	3.49	1.77	0	8	7.200***
Household size	2.81	8.10	1	28	-11.681***
Farm size	8.35	7.71	2	28	0.585
Number of crops cultivated	2.26	3.09	1	4	-9.873***
Amount lost due to shocks (GH)	765.23	986.34	100	3600	-2.458***
Distance to farm (m)	61.35	47.51	10	302	10.132**
Farm income	5084	3612	250	35000	-2.333**

Source: field survey (2017)

The mean age of the heads of sample respondents was 42.34 years for irrigation users. For non-irrigators the mean age was 45.82 years. The age difference between the two groups is found to be statistically significant suggesting age has influence on the participation decision. This indicates that non-irrigators are averagely older than irrigators. Therefore, with significant critical t-statistic of -1.82, which is in conformity with Bacha et al. (2011). The summary result presented in the above table reveals that the mean education level of irrigator and non-irrigator were 8.15 and 9.39 respectively. The survey result reveals that educated people are associated with non-irrigation than irrigation. It was expected that households with better educational background are more likely to use irrigation.

The average farm experience of irrigation users and non-users were 19.30 and 18.26

years respectively. With regard to household size, the average household size per adult equivalent for the small-scale irrigation users and non-users is found to be 2.81 and 8.10, respectively. This result shows that it is statistically significant at 1%. The findings on household size contradicts the findings of Nhundu et. al., (2010). Furthermore, the result of the study revealed that farm size is insignificant. Farm size between the two groups is found to be statistically insignificant. The findings on farm size confirms that of Nhundu et. al., (2010). Their study revealed that irrigators were associated with larger farm sizes than the non-irrigators

Also, number of crops grown by irrigators and non-irrigators were on average of 2.26 and 3.09 respectively and statistically significant at 1%. An average distance to the farm by an irrigator is 61.35m and 47.51 for a non-irrigator. The study also revealed that irrigators were associated with higher farm income than the non-irrigators indicating an amount of GH 5084 and GH 3612 respectively.

Lastly, with regards to how much is lost to shocks, irrigators and non-irrigators lost an average amount of GH 765.23 and GH 986.34 respectively. This is statistically significant at 1 % level indicating that as the amount lost due to shocks increases, a farm household respondent is more likely to participate in irrigation

4.2.3 Cross-tabulations of water users and shocks

Shocks	**Irrigator**		**Non-irrigator**	
	frequency	percentage	frequency	percentage
Inadequate rainfall	20	20.00	31	31.00
Too much rainfall	51	21.00	36	36.00
Drought	8	8.00	11	11.00
flooding	21	51.00	22	22.00

Source: Field survey (2017)

The table above indicates the shocks exposed to by each of the water user category. The study revealed that majority of the irrigators representing 51%, reported flooding to be the main shock while only 22% of the non-irrigators reported on flooding as shock. Secondly, pertaining to too much rainfall, majority of the respondents (36%) were the non-irrigators whiles irrigators represented 21% of the response category. In the reporting of inadequate rainfall, majority of the response category (31%) were the non-irrigators while only 20% of irrigators were reported to have been affected. The least shock was drought of which the response represented only 10% irrigators and 11% of non-irrigators.

The table below shows the perceptions of farmers pertaining to how they are affected by water insecurity. The irrigators (31.31%) perceived it to be highly affecting their productivity whiles majority of the respondents representing 63% being non-irrigators perceived it to be highly affecting than the irrigators. This is due to the fact that most of the non-irrigators heavily rely on rainfed agriculture. So if there is an inadequate rainfall in the season, there becomes a challenge of addressing that.

Table 4.2.4. Water security on seasonal variations

Water insecurity	Irrigator		Non-irrigator		Total
	frequency	percentage	frequency	percentage	
Rainy season	29	29.00	10	10.00	39
Dry season	71	71.00	90	90.00	161
Total	100	100.00	100	100.00	200

Source: Field survey (2017)

Household respondents were asked to recall for the last two seasons, which season was water insecurity felt. The study further revealed that majority of the respondents representing 161 of which 44% of irrigators and 56% of non-irrigators reported dry season to be most water challenging season pertaining to crop production**.** The study further revealed that although the irrigators have more access to water than the non-irrigators but in dry season the water levels in the basin is reduced to a level that affects irrigation activities.

Objective One

4.3 estimate farm household Water security in the SKB

The Water Poverty Index (WPI) was deployed by the researcher to assess the household water security among smallholder farmers in the Sisili-Kulpawn Basin in the MMD

Table 4.3.1 household water security characteristics and WPI in the Sisili-Kulpawn Basin

WPI	Yagaba	Loagri	Kunkwa	Wiasi
Weights (0.2)				
Availability	52	36	30	26
Accessibility	40	30	8	22
Capacity	64	38	22	32
Use	100	100	0	0
Environment	30	34	66	62
WPI	**57.2**	**47.6**	**25.2**	**28.4**

Source: Field Survey (2017)

4.3.1 Weighting of WPI components

While other researchers have used the Principal Component Analysis (PCA) in the weighting of the WPI components, there have been recent critiques in the weighting by Gine and Perez (2017) and that all variables have equal importance hence the practice of assigning unequal weights to the components does not make sense since there is no evidence that it should be so. So the application of equal weights is done such that the sum of all the weights shall equal one (1). So dividing 1 by the five components, each component is assigned a weight of 0.2.

Access

This component shows access that people have to water for effective use and survival. Sources of water in both communities include wells and rivers. The results show that Yagaba and Loagri has a higher score (40) and (38) respectively on access whiles Wiasi (22) and Kunkwa (8) have lower scores. This is explained by availability of water in some sections of Yagaba and Loagri which increases people's access to water sources. In Kunkwa and Wiasi, households do not have access to irrigated lands. This limits people's access to water for irrigation. This study is in line with Kaiyatsa (2014).

Use:

Use indicators were not reported for non-irrigation household. Yagaba and Loagri are the irrigation which shows that households in these communities are irrigator while the Kunkwa and Wiasi communities were not reported because they were non-irrigation communities and hence were not engaged in irrigation activities.

Capacity:

This component indicates people's capacity to manage water resources, based on education and access to financing. Primary education is the level of education of most people in both communities. Their main sources of income include farming and small businesses.

The results show that Yagaba has a higher score (64) on capacity compared to Loagri (38). The higher score on capacity in Yagaba reflects a higher status in ability to manage water sources, and a better educational status than the residents in Loagri (38), Wiasi (32) and Kunkwa (22) which is in conformity with Sullivan et al., (2006).

Water is the major ingredient in irrigation farming. Therefore, involvement of farmers in irrigation agriculture in Yagaba and Loagri increases their income base which in turn increases their financial capacity to adapt good water efficiency strategies to manage water use as this also confirms the study of Kaiyatsa (2014).

Environment:

Irrigation households have higher scores on indicators that enhance their effectiveness to manage water, and also suffer less from environmental problems as in crop losses for the last five years. The results indicated that Kunkwa and Wiasi experienced high crop losses as they represent majority of the respondents of 66 and 62 scores respectively.

Resource:

This component indicates physical availability of surface and ground water taking into account rainy and dry seasons. The results indicated that resource availability in Yagaba and Loagri is higher than Kunkwa and Wiasi.

4.3.2 A comparison of WPI values in irrigation and non-irrigation communities

Because of its simplicity, the WPI appeals to policy-makers. A single number can be used to represent the water situation at a particular location. At the same time, underlying complexities need not be lost (Sullivan et al., 2003). Therefore, to reduce the complexity to policy-makers and other stakeholders, a pentagram was developed to show the values of five components in a visually clear way.

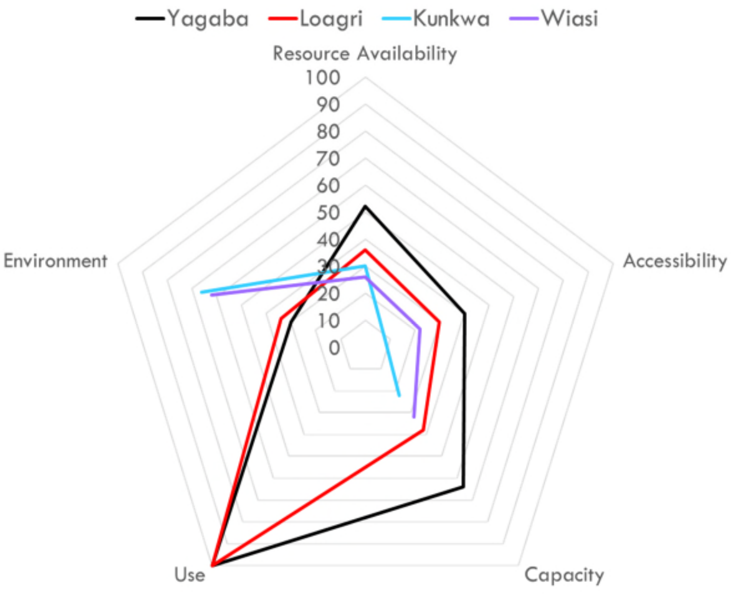

Fig 2. The WPI Pentagram **Source:** Field survey (2017)

The pentagram presents Kunkwa and Wiasi as the neediest community in terms of capacity, use, access and environment. On the other hand, Yagaba and Loagri are the water secured areas. Consequently, there was a higher water poverty index score for Yagaba and Loagri representing 57.2 % and 47.6% respectively compared to Kunkwa (25.20) and Wiasi (28.4). According Sullivan et al. (2003) the highest value, 100, is taken as the best situation of been water secured while 0 as the worst situation of water security (50-100(water secured), 0-49 (water insecure)). Since water poverty index scores for Loagri, Kunkwa and

Wiasi communities are below 50, the level of water poverty in both communities is high. Only Yagaba community is proven to be water secured.

4.4 Objective two (examine households' adaptation strategies)

The ranking of different adaptation strategies used by Irrigation farmers to mitigate climate change were identified by the surveyed farmers. Out of 5 adaptation strategies, increased use of short duration crops was ranked first and thus most important, among farmers' adaptation strategies to water insecurity. This ensures that crops are not affected by the prolonged absence of rain water. This adaptation strategy confirms previous study by Entsminger et. al., (2014). Mulching was identified as the second-ranked adaption strategy. This rank confirms Obayelu et. a., (2014) but was ranked the least in previous studies conducted by FOA (2014). The third most important adaptation strategy was the use of Drought tolerant varieties. Improved farming activities (creating of bunds) was ranked fourth and the least was Adjusting to planting techniques.

Table 4.4.1 Adaptation strategies for Irrigation farmers

Adaptation strategy (Irrigators)	Level of Importance					
	High (3)	Medium (2)	Low (1)	No (0)	ASI	Rank
Short duration crops	25	30	18	27	153	1st
Mulching	26	23	21	30	145	2nd
Drought tolerant varieties	28	22	10	40	138	3rd
Improved farming techniques	14	12	54	20	120	4th
Adjusting planting date	15	18	30	37	111	5th

Source: Field Survey (2017)

Among the Non-irrigation farmers, the table below 4.4.2 indicates that Drought tolerant varieties, adjusting planting date and Improved farming methods were the most important adaptation strategies used.

Table 4.4.2 Adaptation strategies for Non-Irrigation farmers

Adaptation strategy (Non-irrigators)	**Level of Importance**					
	High (3)	**Medium (2)**	**Low (1)**	**No (0)**	**ASI**	**Rank**
Drought tolerant varieties	35	15	25	25	160	1st
Adjusting planting date	23	25	22	30	141	2nd
Improved farming techniques	21	16	40	23	135	3rd
Short duration crops	24	13	31	32	129	4th
Mulching	13	8	29	5	71	5th

Source: Field Survey (2017)

Other adaptation strategies mentioned were short duration crops and mulching which were ranked the least of the adaptation strategies among the non-irrigation farmers.

4.5 objective three (The effects of household water security on farm household adaptation strategies)

The multivariate probit model indicated a significant joint correlation x^2(10)=60.056, probability > x^2 = 0.0000 justifying the estimation of the multivariate probit model that considers different adaptation strategy as opposed to separate univariate probit models and consequently the unsuitability of aggregating them into one adaptation or no adaptation variable as was the case of Maddison (2007).

Table 4.5.1 Results of multivariate probit analysis of determinants of adaptation measures and the effects of Water security on adaptation strategies

Variables	Mulching	Drought resistant varieties	Short Duration crops	Improved Farming methods	Adjusting planting date
Sex	-3.103	0.779	-0.837	-0.182	1.441**
Household size	0.036	-0.011	-0.048	0.009	-0.026
Farm Size	-0.633**	0.012	0.082**	-0.009	-0.556**
Off-farm income	0.001**	-0.002	0.000	0.010	0.020
Farming Experience	-0.187*	0.023*	0.012	-0.004	0.107
Extension	0.186*	-0.050	0.016	-0.050	0.082
Number of crops cultivated	-0.192	-0.264	0.394**	0.151	0.334**
Water security (WPI)	0.214***	-0.901*	0.052**	0.029	-0.067**

rho21=rho31=rho41=rho51=rho32=rho42=rho52=rho43=rho53=rho54=0

*Chi2(10) = 60.056, Prob > chi2 = 0.0000, Wald chi2 (40) = 53.91. *, ** and *** significant at 10%, 5% and 1% respectively*

Rho21	-0.149	Rho41	-0.427**	Rho32	-0.278*	Rho52	0.012	Rho53	0.213
Rho31	-0.288**	Rho51	-0.135	Rho42	-0.107	Rho43	-0.347***	Rho54	0.066

Water security (WPI) proved to be positively significant with mulching and short duration crops. This means that water secured households are more likely to adopt mulching and short duration crops adaptation strategies. The study also revealed that households who are water insecure are more likely to adopt drought resistant varieties and adjust to planting dates. Water security plays a significant role in adoption of adaptation strategies.

The sex of the household head proved significant with adjusting of planting date which confirms the findings of Deressa et al., (2009) that some male headed households were more likely to adopt climate risk coping strategies than female-headed households. But contradicts the findings of Ali and Erenstein (2017). Households associated with higher Off-farm income tend to adopt only mulching as a climate change adaptation strategy because of their ability to invest capital in new technology and methods to adapt to the climate risk. This finding is in conformity with Ali and Erenstein (2017). The association between household size and adaptation strategies proved insignificant which contradicts the findings of other studies (Croppenstedt et al., 2003; Deressa et al., 2009; Abid et al., 2015). Some studies believed that larger households have the ability to supply surplus labour to non-farm activities (Lanjouw and Lanjouw, 2001; Reardon et al., 2001; Rahut and Micevska Scharf, 2012; Gautam and Andersen, 2016) and the income generated could be invested in climate risk coping strategies.

Adaptation strategies were reported with a positive association between farm size excluding the use of drought resistant varieties and improved farming methods. This study confirms previous studies (Abid et al., 2015; Tiwari et al., 2009; Bryan et al., 2013) that Farmers with large landholdings are likely to have more capacity to try out and invest in climate risk adaptation strategies.

Access to extension services was positively associated with only mulching, which means that enhancing the availability of information of climate risk and adaptation options through extension services, enhances the adaptation of mulching and this confirms studies by Maddison (2007) and Nhemachena and Nhem (2007). Farming experience increases the probability of uptake of mulching and drought resistant varieties excluding short duration crops, improved farming methods (creating of bunds) and adjusting of planting date. Also, the number of crops grown increases the probability of uptake of short duration crops and adjusting of planting date excluding mulching, drought resistant varieties and improved farming methods.

4.6 objective four (determine the effects of household adaptation strategies on farm income)

The results from the regression using the Instrumental Variable (IV) approach reported R^2 as 0.58, implying a degree of 58% relationship among the independent variable. The adjusted R^2 shows that 47% of the variables can explain the model and the higher the adjusted R^2, the more significant the model. Therefore, the variables can significantly explain the model.

Table 4.6.1 shows a positive significant relation between farm income and Predicted adaptation strategies from the multivariate probit model. This means that a farmer who adopts adaptation strategies will increase farm income by 1.1% *ceteris paribus*, hence the effects of adaptation strategy is positively influencing farm income. Also, farm size was positively significant indicating that if farm size increases by one acre, farm income will increase by 16%, *ceteris paribus*. The findings on farm size contradicts the findings of Talukdar (2014) that farm size has no influence on farm income but is in conformity with the researchers a prior expectation. Labour positively influence farm income. The findings on Labour confirms other studies (Ike and Inoni, 2003) that labour plays a positively significant role in increasing farm income. Household size and weedicides were also significant which implies that as more of these variables are employed, there will be an increase in farm income, *ceteris paribus*. This contradicts the findings of (Talukdar, 2014) which revealed that household size does not influence farm income.

Table. 4.6.1 effects of household adaptation strategies on farm income

Farm Income	Coefficient	Std. Error	T
Predicted (adaptation strategy)	0.011***	0.013	2.88
Fertilizer	0.276	0.108	0.26
Seeds	0.159	0.111	1.44
weedicide	0.238**	0.109	2.16
Labour	0.171*	0.087	1.96
Age	0.225	0.254	0.89
Education	-0.049	0.677	-0.74
Farm size	0.169***	0.209	0.81
Farm experience	-0.163	0.147	-1.11
Household size	0.222*	0.133	1.67
Irrigation	0.580*	0.319	1.82
Number of crops cultivated	0.083**	0.409	2.04

Prob > F = 0.000, R^2 = 0.58, Adjusted R^2 = 0.49

The regression result further showed that, irrigators and the number of crops cultivated by a farmer were associated with higher farm incomes. This is because, irrigators are involved in all year round production which increases their income levels to a positively significant level (10%). Also, the number of crops cultivated by a farmer increases with farm income. This means that an increase in the number of crops cultivated will increase farm income by 0.8%, *ceteris paribus*. This is because, cultivating different crops bring about crop diversification and reduces shocks to farmers. This as a result ensures that farmer income is increased. Farming experience and education were not significant which contradicts the researchers a prior expectation and also contradicts other studies (Ike and Inoni, 2014). It was expected that farmers with higher educational levels and are more experienced in farming will be associated with higher farm income.

4.7. objective five (Profitability analysis between irrigators and non-irrigators)

Table 4.7.1 Gross Margin (GM) analysis

Activity **(per acre)**	**Rainy Season**		**Dry Season**
	Irrigator	**Non-irrigator**	**Irrigator**
Ploughing cost	390	537	426
Weeding cost	395	449	642
Spraying cost	306	172	336
Seeds cost	411	402	334
Harvesting cost	785	615	478
Fertilizer application cost	668	183	512
Total Variable Cost (TVC) of production	**3295**	**2484**	**3104**
Total Revenue (TR)	**5261**	**3604**	**5013**
Gross Margin (GM)	**1966**	**1120**	**1999**

Source: Field survey (2017)

From the table above, the profitability analysis of irrigators and non-irrigators were computed. The result revealed that higher profits were associated with irrigators than non-irrigators representing an amount of GH 1966 and GH 1120 respectively for the rainy season production. The physical availability and access to water allow farmers to scale up their field of operations, this eventually increases the cost of production. From the table above, irrigators had a higher TVC of GH 3295 than the non-irrigators who had GH 2484 for the rainy season production. But the irrigators are involved in all year round farming which makes them raise their income levels to a statistically significant level. In the rainy season production, irrigators (GH 5261) had more TR than the non-irrigators (GH 3604). The findings of this study confirms the findings of Nhundu et al., (2010) that irrigators were associated with high TVC, TR and GM than the non-irrigators. In the dry season production pertaining to irrigators, the findings from this study revealed that the TVC is lower than that of the rainy season but the GM associated with the dry season is higher than the GM in the rainy season.

4.8 objective six (Constraints faced by farmers in the study area)

The result from the Kendall's Coefficient of Concordance showed that Inadequate water, inadequate extension services and Inadequate access to credit were the main production constraints in the study area (as shown in Table 4.8.1 below). Unpredicted weather, low soil fertility and limited market access were the least occurring production constraints in the study area. A study conducted by Entsminger et. al., (2014) revealed that water availability issues were the main problem faced by farmers. Agricultural production systems have been highly reliant on water, especially for irrigation, while rivers, rainfall, groundwater, etc., have been used as a source of this irrigation water. Available water is hard to manage for crop production due to frequent natural disasters such as floods and droughts in the study area. Different GOs, NGOs and even farmers have been working on the water issues. The findings on unpredicted weather and inadequate access to credit are serious constraints farmers also face in Bangladesh (Entsminger et.al.,2014).

Table 4.8.1 constraints faced by farmers

Constraints	**Overall Rank**	**TWS**	**Rank scores of constraints**					
			1	**2**	**3**	**4**	**5**	**6**
Inadequate Water	1st	400	93	50	41	0	0	14
Inadequate extension services	2nd	454	47	83	53	8	10	0
Inadequate Access to credit	3rd	480	50	62	62	15	0	10
Unpredicted Weather	4th	676	12	66	56	6	20	40
Soil fertility	5th	773	0	21	41	62	0	60
Limited Market access	6th	880	0	25	41	60	7	72

W = 0.3, Fcal = 73.6, Ftab = 2.21 (5% significance level) TWS = total weight score

The null hypothesis (Ho) that there was no agreement among the respondents over their ranking of the constraints was rejected at the 5% significance level because the calculated F-value (73.6) was greater than the critical F-value (2.21). Hence there was agreement among respondents on the ranking of the constraints. The Kendall’s Coefficient of Concordance analysis showed that 30% of the farmers were in agreement with each other on the ranking of the constraints.

CHAPTER FIVE

5.0 SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Summary and Major findings

The results of the study showed that, agriculture in the SKB is predominantly rain-fed where smallholder farmers are exposed to the erratic nature of the climate variables and the consequences that follows. A wide range of rain-fed crops including maize, cowpea, rice, millet and a variety of vegetables are cultivated; among which maize and cowpea are predominantly cropped.

In using the Water Poverty Index (WPI) approach to assess the water security levels in the SKB; the study revealed that, Yagaba community was the only water secured community with a WPI of 57.2% whiles Loagri, Kunkwa and Wiasi were water insecured communities representing 47.6%, 25.2% and 28.4% WPI respectively.

The water poverty Index pentagram also indicated that Loagri and Yagaba were the communities with physical availability of water, more access to water and have higher capacity to ensure water use efficiency by means of adaptation. Kunkwa and Wiasi were the communities with higher crop losses during the last two (2) seasons and with difficulties assessing water for irrigation.

Results from the Adaptation Strategy Index (ASI) revealed that, among the irrigators, the use of short duration crops, mulching and drought tolerant varieties were reported to be the first, second and third most used adaptation strategies in the area. Adjusting to planting date and the use of improve farming techniques were the least strategies adapted by the irrigators. Among the non-irrigators, the use of drought resistant varieties, adjusting to planting date and improved farming techniques (creating of bunds) were the most used adaptation strategy whiles mulching and the use of short duration crops were the least ones used. In the study area, shocks were reported by farmers and these shocks were; too much rainfall, drought, flooding and inadequate rainfall. As a result of these shocks most farmers (192 respondents) reported a crop loss. The crops affected where; millet, beans, maize, vegetables and rice.

In this study, the multivariate probit model was used to estimate the determinants of adaptation strategies and the effects of water security on adaptation strategies in the study area. Evidence from the results of this model indicate that water security plays a significant role in adoption of adaptation strategies. The study revealed that water security is positively influencing the adoption of mulching and short duration crops but negatively associated with drought resistant varieties and adjusting planting date. The study also revealed that sex of the household head, off-farm income, farm size, years of farming, access to extension services and number of crops cultivated were also affecting adoption of adaptation measures.

The study researched into the effects of household adaptation strategies on farm income and the results revealed that, the predicted value of adaptation from the multivariate model was highly significant and positively associated with farm income. The more a farmer adopts an adaptation strategy, the higher the farm income, *ceteris paribus.* Results from the study revealed that weedicide, labour, farm size, irrigation, household size and the number of crops grown also had positive influence on farm income.

Results from the study showed that irrigators had more gross margin than non-irrigators representing GH 1966 and GH 1120 respectively in the rainy season whiles irrigators have higher GM in dry season than the rainy season.

Using the Kendall's Coefficient of Concordance, the constraints of the farmers were ranked. Inadequate water availability, inadequate extension visits, unpredicted weather, inadequate credit access, inadequate market opportunities and soil fertility issues were identified as the problems confronted by the farmers in the study area. The results indicated that inadequate water availability for irrigation was ranked first, followed by inadequate extension visits reported by farmers to be the second most severe constraint in the study area. Inadequate access to credit was ranked as the third most severe problem faced by the farmers whiles unpredicted weather was also reported in the study as the fourth most severe constraints of farmers. Inadequate market opportunities and Soil fertility were the least problems reported by farmers

5.2 Conclusion

Agricultural systems in the study area comprise of lowland bush fallow farms (flood lands) and upland bush fallow farms. Uplands are cultivated during the peak of the raining season. Seasonal flooding of lowlands by the Sisili-Kulpawn River allows the lowlands to be cropped twice; before and after the floods. This allows smallholder farmers to cultivate twice within a cropping season (Early- and late- cropping season). The floods also leave behind more fertile soil which offers farmers the opportunity of increasing their yields. Despite these advantages, smallholder farmers are faced with the challenges posed by the erratic nature of rainfall and unpredictable flooding of farms at the lowlands by the Sisili-Kulpawn River. Farmers who farm the uplands are faced with long period of drought during the dry season. Climate change will increase the vulnerability of these smallholders by worsening their challenges and this will elevate poverty levels.

Adoption of adaptation strategies to mitigate the resulting adverse climate change impacts has become a more critical issue in the livelihoods of smallholder farmers. Adaptation of improved strategies such as irrigation technology will serve as a supplementary source of water to dry season farming in the SKB will help to reduce smallholder farmers' dependency on rainfall as well as enhance livelihood through additional agricultural production outside of the rainy season. This will help counteract the adverse impacts of climate change on income gains, and poverty rates. The consequences of climate change on agricultural production will be worse if smallholder farmers in the SKB continue be exposed to the constraints discussed earlier.

The study found out that, livelihood outcome variables like income are sensitive to the climate change. This will reduce yields, income and resilience of farmers in the study area but good adaptation strategies will be required to minimize such effects. Emphasizing on the use of adaptation strategies to climate change is therefore crucial for the improvement of farmers' resilience and also for the sustainability of the agriculture sector in the SKB, Northern Ghana and the country as a whole.

5.3 Recommendations

The presence of the Sisili-Kulpawn River offers a potential for the establishment of irrigation/supplementary systems to support dry season farming in the SKB especially, an ongoing irrigation project initiation by IWAD will help to alleviate farmers' dependency on rainfall as well as enhance livelihood through additional agricultural production outside of the rainy season. Also provision of infrastructure such as water storage/harvesters and storm shelters will help in water security.

Due to the high variability and seasonality of the rainfall events, access to information on the climate, extension and technological services becomes very crucial. MOFA and other stakeholders like IWAD should be able to assist farmers to know correct timing for planting (access to weather information services) to prevent/reduce loss of crop through flooding and/or delay in rains. In this regard, smallholder farmers will be able to build their resilience. This means targeting the above key factors viz extension service provision, credit and market access interventions by policy can lead to a sustainable livelihood to small holder farmers in the SKB.

Research institutions, NGO's and other stakeholders in agriculture should be able to provide a capacity building training to smallholders on adaptation strategies such as varieties with early maturation; drought tolerance; high resistance to pests and diseases, improved farming methods like creating of bunds and conservation agriculture and sustainable land management such as crop diversification; adoption of mixed farming systems; crop rotation and adjusting planting dates. This will help build the resilience of farmers to climate change.

Using the adaptation strategy and constraints rankings as guidelines, policy makers and development practitioners can target actions in accordance with priorities. Further, continued studies by these agents using the methodological framework employed here for instance the Water Poverty Index can be used to continuously update priority areas in terms of water security and identify which particular water poverty component requires immediate attention.

APPENDIX I
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APPENDIX II

QUESTIONNAIRE

I am a student from the department of Agricultural economics in the University for Development Studies (UDS), as a partial fulfillment of the Master of Philosophy in Agricultural Economics; I am undertaking a research on farm household water security.

I cordially request that you provide information to the best of your knowledge and I assure you that no information will be processed using names of informants.

Thank you for taking time out of your schedule to participate in this survey aimed at assessing the economic impact of climate change on smallholder farmers in your community. I wish to assure you that the information provided will be used strictly for research and not for any other purpose and your privacy will in way be comprised

Do I have your permission to start the interview………………………...?
(a) Yes (b) No
If No, kindly move to next respondent

Socio-demographic characteristics of respondents

No.	Q 1. Community	Q3	Q4	Q5	Q6	Q7	Q8
	Q2.						
	Name of household member	Main Occupation	Age	Sex	Marital status	Education (years)	How much do you earn from other sources
		Code, if not 7 skip to next person	Number	code	code	Number	number
1							
2							
3							
4							
5							
6							
7							

HH size…………………………...?

No	Q3		Q3		Q3		Q3		Q3
1	Student	5	Trader	9	Vendor	13	Fisherman	17	No second occupation
2	Unemployed	6	Traditional healer	10	Taxi driver	14	Apprentice	18	Hunter
3	Sick	7	Farmer	11	Butcher	15	Teacher	19	Others (specify)
4	Retired	8	Tailor	12	Health worker	16	Security		

Q5	1	male	2	female
Q6	1	married	2	Not married

Section A: Assess farm households water accessibility

Q9. How did you get the irrigated land? (**Users only)**

Inherited from family	1
Gift from relatives	2
rent	3
Share cropping	4
Government redistributions	5

Q10. What is your opinion on irrigation? (**Users only)**

Useful but expensive	1
Not useful	2

Q11. How much do you pay as a user fee to access irrigation facility? (Users only)

Sum in Ghana cedis	

Q12. Do you have access to sufficient water?

Yes	1
No	2

Q13. What are the available sources of water for local farmers?

Tube well	1
Canal water	2
Rain	3
Others (specify)	4

Q14. Are you satisfied with the availability of water throughout the year?

Yes	1
No	2

Q15. How far is your irrigated plot from the source of irrigation water?

Number in meters

Q16. How far is your irrigated land from your residence/home?

Number in minutes	

Q17. In which of the crop seasons did you face water availability issues?

Raining season	1
Dry season	2

Section B: Economic impact of household water security on farm household livelihoods

Q18.

Size of the field (in Acres)	Is the farm owned by the household?	In whom is ownership vested?	How many crops were grown in the last 12 months	What crops were growing on this farm during the last 12 months					
	Yes, with document=1	Insert person ID from page 1		1st season			2nd Season		
	Yes without document=2			Crop 1	Crop 2	Crop 3	Crop 1	Crop 2	Crop 3
	No=3			code	code	code	code	code	code

Code					
1	Beans	7	Onion	13	Leafy vegetables
2	Rice	8	Pepper	14	Kenaf
3	Groundnut	9	Potatoes	15	Yam
4	Millet	10	Sorghum	16	Other vegetables
5	Maize	11	Soybeans	17	Cassava
6	okra	12	tomatoes	18	Others (specify)

Q19. Which of the following were reported during the last season cultivation?

Shock									
	In the last year, did any of these affected your household	Was any crop affected	Crop 1	Crop 2	Crop 3	How much did you lose because of the event?			How much GHc did you lose because of the event?
						Crop1	Crop 2	Crop 3	
	Yes=1,	Yes=1 No=2 >> next question	1	2	3	<25%=1	<25%=1	<25%=1	GHC
	N0=2 >>next item		code	code	code	25-50%=2	25-50%=2	25-50%=2	
						51-75%=3	51-75%=3	51-75%=3	
						>75%=4	>75%=4	>75%=4	
Inadequate rainfall									
Too much rainfall									
Drought									
Flooding									
Others (specify)									

Code					
1	Beans	7	Onion	13	Leafy vegetables
2	Rice	8	Pepper	14	Kenaf
3	Groundnut	9	Potatoes	15	Yam
4	Millet	10	Sorghum	16	Other vegetables
5	Maize	11	Soybeans	17	Cassava
6	okra	12	tomatoes	18	Others (specify)

Q 20. Fill the tables below;

Activity	Man days	frequency	Unit cost	Value
Ploughing				
Weeding				
Harvesting				

Q 21.

Activity	Value
Improve seeds	
Water fee	

Q22. Did you use the inputs below? Is yes fill in the table below

Activity	No. of bags	Unit cost	Value
fertilizer			
manure			

Q 23. How long have you been in the main occupation?

Number in years	

Q 24. How much do you earn from farming last season?

Number in GHC	

Q25. Do you have access to climatic information?

Yes	1
No	2

Q26. Do have access to extension services?

Yes	1
No	2

Q27.

Extension visits (number of visits)	

Q28. Do you have access to credit?

Yes	1
no	2

Q29. Household type? In terms of water resource development intervention

Beneficiary	1
Non-beneficiary	2

Q30. if a beneficiary, how long have you been in irrigation agriculture?

Experience in years	

Q31. Which of the available sources of water are more convenient for farming activities?

Tube well	1
Canal water	2
Rain	3
Others (specify)	4

Q32. What type of irrigation method do you use?

Surface/Flooding	1
Furrow	2
drip	3
Bucket/hose/watering can	4
Others (specify)	5

Q33. Why do you practice the above mentioned irrigation method?

slope of the land	1
soil type	2
Labour shortage	3
to use the water efficiently	4
Type of crop grown	5

Q34. Which crop type do you produce using the irrigated land?

Main crops	1
Vegetables	2

Q35. To what extent is water shortage affecting your livelihood?

Highly affecting	1
affecting	2
Less affecting	3

Section C: Adaptation Strategies

Q36. How do you cope with water insecurity issues?

....

Q37. What measures do you follow to ensure efficient utilization of water?

Mulching	1
Improved crop varieties	2
Cover cropping	
Use recommended irrigation technology (drip)	3
Improved farming methods	4
Don’t use any method	5
Others(specify)	6

Q38. Fill in the table below using the following codes;

0=not important, 1= low importance, 2= medium importance and 3= highly important to rank the following adaptation strategies.

Adaptation strategy	code
Mulching	
Drought tolerant varieties	
Short duration crops	
Improved farming techniques	
Adjusting planting date	

Adaptation strategy index

Section D: Constraints farmers face

Q 39. Fill in the table below using the following codes;

0=not important, 1= low importance, 2= medium importance and 3= highly important to rank the following constraints farmers face

constraints	code
Inadequate water	
Inadequate extension visits	
Inadequate access to credit	
Unpredicted weather	
Limited market opportunities	
Soil fertility issues	

Problem confrontation index

Q40. What are your suggestions to help improve water security……?

END OF INTERVIEW