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ASSESSING THE IMPLICATION OF AGRICULTURE WATER SECURITY FOR SOME ECONOMIC OUTCOMES OF SMALLHOLDER FARMERS IN THE UPPER EAST REGION OF GHANA

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FACULTY OF AGRICULTURE, FOOD AND CONSUMER SCIENCES

ASSESSING THE IMPLICATION OF AGRICULTURE WATER SECURITY FOR OME ECONOMIC OUTCOMES OF SMALLHOLDER FARMERS IN THE UPPER AST REGION OF GHANA

UNIVERSITY FOR DEVELOPMENT STUDIES

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[THESIS SUBMITTED TO THE DEPARTMENT OF AGRICULTURE AND FOOD ECONOMICS, FACULTY OF AGRICULTURE, FOOD AND CONSUMER SCIENCES, UNIVERSITY FOR DEVELOPMENT STUDIES IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTER OF PHILOSOPHY DEGREE IN AGRICULTURAL ECONOMICS]

SEPTEMBER, 2021

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DECLARATION

I, the undersigned hereby declare that this thesis entitled **"Assessing the implication of agriculture water security for some economic outcomes of smallholder farmers in the Upper East Region of Ghana"** is the result of my own original work, which has not been submitted for another degree in this University or elsewhere.

Paul Akparibo Azure …… ……..

(Student's name) **(Signature)** **(Date)**

Supervisor

I, hereby declare that the preparation and presentation of the thesis was supervised in accordance with the guidance on supervision of thesis laid down by the University for Development Studies.

Prof. Joseph Amikuzuno ……. ……..…… ……..…….

(Supervisor) **(Signature)** **(Date)**

Dr. Benjamin Tetteh Anang ……. ……

(Head of Department) **(Signature)** **(Date)**

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ABSTRACT

Climate change poses serious threats to water availability and therefore affects agriculture water. This has become a serious concern for Ghana, especially Northern Ghana where farming is solely rain-fed. This study was carried out to assess the implication of climate change-induced agriculture water security for smallholder farmers in the Upper East Region of Ghana. Both qualitative and quantitative research design were used for the study. The qualitative and quantitative data were obtained from 350 smallholder farmers from the Upper East Region. The Water Poverty Index (WPI) model was used to estimate the water poverty level of farmers in the study area. The findings from this model showed that only farmers in the Bawku West District (BWD) are water insecure while those in the Nabdam and Binduri districts are water secure. The Kendall's Coefficient of concordance was used to rank the identified constraints affecting smallholder farmers' water management practices. The findings revealed that drought, distance to water source and inadequate water resources were the major constraints farmers faced in managing agriculture water. The Multivariate Probit model was used to examine factors that influence smallholder farmers' adoption of water management strategies in the study area. The results revealed that sex, age, runoff/erosion, FBO membership, household size, extension services, credit and drought were the factors that influence the adoption of water management strategies. Finally, the Trade-off Analysis Minimum Data (TOA-MD) model was used to determine the economic impacts of efficient water management strategies on selected economic outcomes of smallholder farmers. The findings revealed different level of negative impacts of climate change on the net revenue per farm, poverty rates and per capita incomes under climate change without adaptation. When adaptation was considered, the magnitude of negative impacts was minimal, and the gains to most farmers increased significantly. This means that, if adaptation is accounted for, there are possibilities for farmers to benefit, given the right measures and availability of climate smart technologies.

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DEDICATION

I dedicate this work to my dad (Azure Awelinga), my mum (Azure Victoria Asaknab) and my loving wife (Dorcas Atugba). I would not have made it without your sacrifices and encouragement. I love you all.

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LIST OF ACRONYMS

FAO	Food and Agricultural Organization
GOG	Government of Ghana
MOFA	Ministry of Food and Agriculture
SSA	Sub-Saharan Africa
USAID	United States Agency for International Development
UN	United Nation
AWM	Agricultural Water Management
UNCTAD	United Nations Conference on Trade and Development
IFAD	International Fund for Agricultural Development
WEF	World Economic Forum
NIC	National Intelligence Council
UNESCO	United Nations Education, Science and Cultural Organizations
WPI	Water Poverty Index
UNICEF	United Nations International Children's Emergency Fund
WFP	World Food Programme
WRC	Water Resources Commission
NGOs	Non-Governmental Organizations
GSS	Ghana Statistical Service
MVP	Multivariate Probit
GDP	Gross Domestic Product
TOA-MD	Trade off Analysis Minimum Data
ADB	African Development Bank

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GSA	Guinea Savanna Agro- ecology
SDG	Sustainable Development Goal
PFJ	Planting for Food and Jobs
OECD	Organization of economic Co-operation and development
UNWD	Unconventional Nuclear Warfare Defense
USGS	United State Geological Survey
IWMI	International Water Management Institute
WASA	Water Smart Agriculture
UNCCD	United Nations Convention to Combat Desertification
UNISDR	United Nations Office for Disaster Risk Reduction
NWP	Netherlands Water Partnership
IBWRD	International Bulletin of Water Resources and Development
PHC	Population and Housing Census
QRD	Quantitative Research Design
UER	Upper East Region
ADRO	Anglican Diocesan and Relief Organization
BWD	Bawku West District
ND	Nabdam District
BD	Binduri District
FBO	Farmers Based Organization
GLSS	Ghana Living Statistical Service
WMP	Water Management Practice
CSIRO	Commonwealth Scientific and Industrial Research Organization

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NCAR	National Center for Atmospheric Research

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background

In Sub- Saharan Africa (SSA), the main occupation of majority of the population is agriculture, production in this region faces challenges that result in low yields due to its agro-ecological characteristics, making it so vulnerable to impacts of climate change (delay in the rainy season onset, irregularities rains) which leads to low yield resulting in food insecurity.

The greater part of agriculture in SSA is rain-fed in nature and very susceptible to drought (Ziba, 2015). Despite these challenges, agriculture still account for approximately 22.7% of Ghana's Gross national product (GDP) and employing a good number, about 54% of work force (GSS, 2012). The most critical constraints facing the future of agricultural production is the issue of scarcity of water for agriculture. Serdeczny (2015) noted that with the current trend of climate change, projections shows that West Africa will experience more climate change impacts, mostly on food production, ocean productivity, Severe risks to human health and food security. Africa is obviously more vulnerable to climate change and the related consequences that affect all industries, in particular human health and agriculture.

In order to enhance sustainable agriculture and good human health, effective water management needs to be ensured in order to obtain enough water for agricultural activities to combat climate change impacts on food security. Efficient agricultural water management is concerned with making water availability and accessibility for agricultural purposes (ADB, 2010). The current trend of population growth directly or

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indirectly is anticipated to intensify water demand which will eventually mount pressure on the finite water resources (Population Action International, 2011). This therefore raises concerns for future water security especially for agriculture.

The incidence of erratic rainfall has created uncertainty for agriculture, water security, food security and nutrition, and therefore irrigation water must be used as a supplementary source for agriculture. Agriculture water is very necessary in improving productivity, while reducing poverty and ensuring sustainable rural livelihood (Safilios-Rothschild, 2005).

The availability of agricultural water helps households generate more revenue, thereby increasing their economic resilience and also transforming livelihoods (Tucker & Leulseged, 2010). The current era of climate change has affected the beginning of the rainy season, mainly the delay and unreliable pattern of rainfall, thus negatively affecting rain-fed farming.

Climate change, food and water security have motivated a considerable number of studies (,Gariba 2018, Adiku *et al*. 2015, Owusu 2015, Ziba 2015, Amikuzuno and Hathie, 2013 etc). All concluded that livestock and crop yields declined drastically with no adaptation action to climate change. These studies however, could not address how agriculture water scarcity affect smallholder farmers' production, their net returns, per capita and welfare. It is therefore, very important to assess the water security of agriculture households in the Upper East region to raise awareness among farmers about the importance of water availability for farming and how they can manage water for agriculture activities and also to explicitly address water scarcity

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impacts on smallholder farmers livelihood, revenue, per capita income and net returns from their farming activities.

The study therefore sought to assess the implication of agriculture water security for smallholders farmers in the study area by determining water security level at the farm households, the existing constraints encounter by farmers in managing water, the major factors influencing smallholder farmers decision to adopt water management and finally the economic impacts of efficient water management strategies on selected outcomes of smallholder farmers. The water poverty index was used to determine the level of water security of small farmers households found in the area of study.

The Kendall concordance coefficient was then used to rank the identified constraints faced by farmers in the management of agricultural water, while the multivariate probit model was applied in determining the adoption of various water management strategies which help to conserve water for agricultural use. Finally, the Multipurpose Impact Assessment Model thus the Trade-off Analysis of Minimum Data (TOA MD) was used to determine the economic impacts of efficient water management strategies on selected economic outcomes of smallholder farmers.

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1.2 Problem Statement

In general, agricultural production faces negative climatic impacts, especially water scarcity at global level. Water scarcity results from climate change, which is of major concern to the world today, especially in developing countries where majority of the population relies solely on rainfall to grow food crops. Climate change is still expected to have detrimental effects on agricultural livelihoods, especially those in tropics and sub-Saharan Africa who largely dependent on agriculture, due to the numerous negative effects. Water scarcity is becoming extreme, and its availability for agriculture and related activities is decreasing dramatically due to climate change (Kbrom et al, 2016).

In Ghana, farmers' over-reliance on rain-fed and lack of adequate sources of irrigation to supplement production and mitigate the impacts of climate change have been identified as some of the production risks in the agricultural industry (MOFA, 2015). This affects the agriculture sector, which is the main livelihood source for approximately 80 percent of the rural populace of SSA (MOFA 2014). According to the Central Intelligence Agency (CIA, 2019), agriculture sector contributed 20% to Ghana Gross Domestic Product (GDP) in 2019. This shows that in terms of GDP, agriculture contributes significantly to its growth. The country recent performance have been imperative but there are concerns of sustainability since its performance begins to see a downturn and losing its prominence to the service sector in 2010 (Apam 2012).

In northern Ghana, the farming systems are largely dependent on rainfall rather than irrigation, and because of the unreliability of the rains, most rain-fed crops such as

maize, rice, sorghum, millet, groundnut and vegetables mostly do not perform well since the rains stop when most of the crops are still at the vegetative stage (Nyantakyi-Frimpong 2013). Empirical analysis in northern Ghana showed that there will be a significant reduction in crop yields, particularly rice, if there is an average increase in temperature and a corresponding decrease in rainfall. (Mabe *et al* 2014).

Amikuzuno (2013) noted that most of the farmers in Northern Ghana and the nation largely depend on rainfall as source of water for production and with the current trend of climate change, production has fallen drastically. Studies at farm level in Northern Ghana have shown that farmers' net farm incomes and poverty rates are highly sensitive and responsive to the impacts of climate change, and hence livelihood assets will be affected by high temperatures and reduced rainfall (Amikuzuno and Hathie, 2013). Unlike the Southern Ghana where there are two rainy seasons allowing for all year round cultivation, the North which is predominantly a savannah agro ecological zone, is characterized by poor soils, with single and erratic rainy season as well recurrent floods and drought (WFP, 2015).

Agriculture activities in the Upper East Region are faced with serious rainfall fluctuations, and other climatic threats. Adiku *et al*. (2015) confirmed that the declining and irregular rainfall distributions are expected to reduce yields of maize, millet, groundnut, rice and other food crops in the Savannah Agro Ecological (GSA) region of Guinea. Precipitation related to climatic variability affects the timing and duration of the cropping season, crop development and production which compounds the risks already faced by farmers (Jaegermeyr 2016). Steffen et al (2018) also noted that as temperature exceeds 1°C, it poses a serious and direct disruptions to

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agriculture, society, economies and the ecosystems. Gyamfi (2006) revealed that unreliable rains affect water availability for animals and crops which eventually leads to low yield and hence cause households to be food insecure. The increasing concerns about climate change, food and water security have motivated a good number of studies (,Gariba 2018, Adiku *et al*. 2015, Owusu 2015, Ziba 2015, Amikuzuno and Hathie, 2013 etc) all concluded that livestock and crop yields will decline drastically if there is no adaptation action to combat future climate conditions.

These studies could not address how agriculture water scarcity affects the smallholder farmers' production, their net returns, per capita and welfare.

This study therefore sought to fill some of these gaps by assessing the implication of agriculture water security for smallholders' farms in the study area, by determining water security level that exist in farm households, the possible constraints encountered by farmers in managing water, the factors influencing farmers decision to adopt water management practices and finally selected economic outcomes as a result of effective water management strategies.

The study mainly sought to assess the implications of agricultural water security for smallholder farmers in Upper East region of Ghana. The study therefore answered the following questions below in the area of study.

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1.2.1 Research Questions

1. How is the level of water security in the study area of farm households?
2. What are the potential constraints to smallholder farmers' use of water?
3. What factors influence smallholder farmers to adopt water management strategies?
4. What are some of the economic impacts of efficient water management strategies on selected economic outcomes of smallholder farmers?

1.2.3 Objectives

The main objective of the study is to assess the implications of agricultural water security in the study area for certain economic outcomes of smallholder farmers. These objectives were considered below for achieving the main objective.

1. To determine the level of water security of farm households in the region

2. To identify the constraints affecting smallholder farmers' use of water

3. To examine factors that influence smallholder farmers' adoption of water management strategies in the study area, and

4. To determine the economic impacts of efficient water management strategies on selected economic outcomes of smallholder farmers.

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1.3 Study Justification

The current water security issues pose a serious problem for farmers both locally and globally. The situation appears to be more severe in the SSA thus Ghana and especially Northern Ghana. The negative impacts of water security are akin to farmers. In achieving water security, there is a need for simultaneous action or measures to tackle the water security menace.

Given the prevailing poverty level of 54.8 (GLSS7, 2018) in the study area and the high dependence of the region's population on agriculture for living, it is economically wise to develop policies that target the improvement of farmers conditions. This research provided useful information that will help government develop policies towards improving agriculture water scarcity of smallholder farmers and their production activities. The study also provided realistic and detailed information on the overall water security issues for policy formulation and also contributed to achieving SDG (6) (ensuring water availability and sustainable water and sanitation management for all), with a specific target 6.4 (increasing water efficiency and thus reducing water scarcity).

Considering the above important issues that need to be addressed, There is a need carry out this research which will reveal the true nature of water security in the study area. The study also contributed to water security literature in the Upper East region by assessing the issue of water security in agriculture and its implications for some smallholder farmers' economic outcomes. Findings from the study are also expected to serve as baseline information for development practitioners, policy makers, farmers, NGOs, and researchers on further studies.

1.4 Study organization

This study consists of five chapters, chapter one focuses on introduction including background, statement of the problem and questions of research. Second chapter presents literature review on relevant studies related to this topic.

The study methodology is discussed in chapter three, clearly specifying the research design used, the research population, the sampling technique / design data collection and analytical methods. Chapter four deals with the presentation and discussion of the findings/ results whilst chapter five concludes the study with sections of summary, conclusion and policy recommendation.

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CHAPTER TWO

LITERATURE REVIEW

2.0 Introduction

The chapter reviews some literature on water security, agriculture water in general, agriculture water management, Agriculture and climate change, the impacts of climate change on health and water, climate change on food security, water security of farm households and finally on water scarcity and technologies.

2.1 Agriculture Water Management

In the past, traditional agriculture water management (AWM) used to focus on improving water use efficiency in large scale irrigation scheme with concern to control but not to manage water. (Mancosu, 2015) noted that water management strategies is key to increasing water productivity which is achieved by improving water management strategies like creating more irrigation schemes which can lead to a more efficient and sustainable agriculture water management.

On the contrary, improved AWM is more holistic with the aim to mitigate environmental costs and other related risks of irrigation such as erosion, salinization, land degradation, pollution, destruction of natural habitats etc (USAID, 2015). Creating awareness of farmers, educating and training stakeholders either face-to-face or through radio and television programs help build farmers and stakeholders capacity to manage water well (Owusu 2016). It is more important to improve farmers' knowledge, create their awareness and motivate them to practice improved AWM to address unchecked water problems.

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Improving AWM practices should be an approach at multiple levels; from households to basin and finally to national water law and policy, since management at landscape and watershed is necessary to mitigate floods and droughts which enhances resilience to climate variability and change (USAID, 2015). Natural vegetation, forest and wetlands act as water reservoirs during incidence of drought and as buffers during flooding. This ensures that water use and allocation within watersheds significantly increase production, equitable and evenly access to the water resources which helps increase food security. Agada (2016) noted that options for improving agriculture water (rain fed agriculture) includes increasing plant water availability, principally water harvesting strategies thus in-field water management strategies like soil conservation to optimize water availability for crops.

AWM practices includes water and soil conservation that help in reduction of soil erosion and increases groundwater infiltration, slope stabilization, terraces and bunds are some of common practices used to meet similar aims and objectives (USAID, 2015). In Ghana, agriculture is largely dependent on rainfall and the distributions, recent rainfall figures show declining trends with uneven/poor distribution from 1276mm in 2008 to 834mm (MOFA, 2016) hence there is need to adopt AWM in order to supplement production especially during drought, this can only be possible by encouraging agriculture water management to its realization. However, excessive demand, use and possible degradation of water is a threat to livelihoods sustainability especially those who dependent directly on it (FAO, 2014).

Agricultural water (AW) is the primary use of water in the form of water abstractions, rendering soil wet in crops and forests (UNESCO, 2004). The current trend of climate

change affects agriculture water, making it scarce, which directly affects agriculture. This therefore calls for the need to manage agriculture water to ensure sustainable farming and realization of other ecosystem services.

AWM encompasses different approaches, which include integrated watershed management, rainwater harvest, the use of small earth dams and weirs, surface (dams), watershed harvesting and soil profile storage and flow diversion (ACPC, 2013)

Managing water effectively requires how much water is available, how it is used, the impact of other sectors on water, and the understanding of how it affects future scenarios (Rebelo 2014). Water retention and percolation can be improved on the field by the use of the following practices: zero tillage, contour ridging, infiltration pits, mulching among others available to make water more readily available in the soil for plant growth, thereby increasing productivity and groundwater recharge (IFAD 2015).

With the above water management practices, water use in agriculture can face some constraints, which are grouped into two categories; consequently, due to changes in water quality due to climate change, water salinization and soil erosion due to heavy rainfall (OECD, 2014). Aside these constraints, climate change will also change agricultural land use and agriculture water availability, which in turn have consequences on water quality (OECD, 2014).

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2.2.0 Measuring water security and identifying appropriate index for study

Water scarcity in the previous decades was measured using varied approaches capturing the important aspects of pressures on water resources (Amikuzuno, 2019). The complexity nature of water security makes it difficult to define due to the different dimensions involved (Gariba, 2018). Water security is a relative concept that takes into account the imbalance between water supply and water demand, which differs because of local conditions. Water security and water scarcity are fundamentally dynamic in nature. Describing water security using more different or less complicated indicators have so many difficulties and associated with some uncertainties, which results in no consensus on measurement standards (Wossen et al., 2018).

The weaknesses of some indicators are as a result of focusing mainly on domestic and water withdrawal instead of the focus on actual water consumption and agriculture water (Dasgupta et al., 2017). Some of the commonly used approaches are the vulnerability index for water resources commonly referred to as the criticality ratio, the Falkenmark indicator, the social water stress index, the physical and economic scarcity indicators, and finally the water poverty index was used for this study.

2.2.1 Falkenmark Indicator

Since 1989, the approach has been proposed by Falkenmark, which is widely used to determine a particular locality's water stress or water security level. Falkenmark noted that the national water scarcity is by the per capita renewable water, with threshold values of 500, 1000 and 1700m3 distinguishing the different levels of water stress.

This approach was later used by (Widstrand 1992) and the (UN-Water 2006b) categorizing water security by considering it to be stress free (no stress), stressful, scarce and absolute scarce. Threshold of 1700m3 and 1000m3 were allowed per individual in a year. The table below presents the threshold with which water conditions are categorized.

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Table 1: water security indicators

INDEX	CONDITION/INDICATOR
>1700	Stress free
1000-1700	Stressful
500-1000	Scarcity
>500	Absolutely scarce

Source: Adopted from Kaiyatsa (2014)

Following this indicator, Water security is measured based on the amount of water available for domestic or agricultural use. Water scarcity means problem of less water available for farmers to access for agricultural production.

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2.3.0 Water poverty

A nation or region is said to be water poor, when that particular nation or region actually pay for the cost of clean and sustainable water (thus water free from pollution) for domestic use or agricultural purposes and to people all times (Kropp and Tekken 2012). Actually water poverty serves as a link that exists between water availability and its accessibility which is determined by the socioeconomic status of individuals or group of individuals.

Also water poverty exists when people do not have sufficient water for their basic needs. Thus they may have to cover long distance before they can access small quantity for usage. With this, domestically, is possible for people to be water poor because they have low income, as a result they cannot afford the cost especially to improve water sources.

2.3.1. Water poverty index

Water management is very important in ensuring water availability for agriculture purposes and domestic demand. There are many methods used to assess water scarcity, including the Water Poverty Index by (Ecology and Hydrology Centre, 2016) as a new holistic water management tool very relevant in determining water security both at household and community level, with possibilities of determining important areas for action and also for monitoring of progress in order to achieve targets.

Water security in most cases considered in relation to drinking water, agriculture water, sanitation and hygiene, based on this, UNICEF (2010) noted that merging water protection with national security goals is the best way to view water insecurity in a

stronger and more palatable way for rights-oriented organizations to tackle water scarcity canker, even though, UNICEF considered water security as synonym to water supply. Based on UNICEF's idea, (Calow and Mason, 2012) noted that using quantitative and qualitative thresholds in defining water security, will result in duplicate since both are the determinants for good data and results.

This study considers the concept of the water poverty index to be paramount since it is the main approach that we considered in the study area when assessing water security levels for small farm households. In production, water is very necessary as noted by McNamara et al (2010) that, among others, crop and livestock production, agro-processing, fishing, ecosystems are influenced by the water availability.

Water poverty index provides a simple and easy-to-use measurement indicator for the water sector. For best result, it can also be used for planning the water sector by water planners and managers. However, at the level of the community or the household, people can use it to their own problems in order to understand how water is best managed to meet their needs. The idea behind the Water Poverty Index is a combination of water access and accessibility measures, taking into account people's ability to access and use fully (Kropp and Tekken, 2012).

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The basis for classifying a community or region water insecure is based on the WPI scores obtained, a score of WPI above 50% means water secure and below 50% means water insecure. Sullivan (2002) as one of the early scientists to use the WPI noted that in normalizing the various scores, it is necessary weighting each by 0.2 as it is inclusive in the formula.

2.3.2 Estimating water poverty index

There are many approaches that are used in estimating water poverty. These approaches include the holistic approach, a simple time analysis approach and, lastly, the conventional composite index approach (Sullivan, 2002). These approaches will be described brief in this work.

2.3.3 The Conventional composite index approach

When using the composite index approach (Sullivan, 2002), WPI includes various components, including water availability, sanitation, access to safe water, and time to collect domestic water. Using the formulation below, the WPI is calculated based on this approach.

WPI= WsS + WaA + Wt (100-T)

Where; A is Water availability assessment adjusted as a percentage (percent), it is calculated using surface and ground water availability relating to all other domestic demand as well agriculture demand. (S) Is the percentage of population with access to safe water and sanitation. T is the time taken to collect water for the household use.

The WPI value is produced that falls between 0 and 100. A, S and T are defined between 0 -100. This formula is modified further as WPI = 1/3 (WaS + WsS + Wt (100-T)).

With the above formula, when the value of WPI is high, it depicts how low the degree of water stress. Water accessibility and the time spent in collecting water can be used as proxy for socioeconomic well-being as by (Sullivan, 2002)

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2.3.4 The Holistic approach

This approach is best used based on five main components, with each comprising several sub-components which are presented below:

Resources: This considered the physical component of availability of water taking account of both surface and underground**,** with water variability in mind as well quality of the available water.

Access: this component considers ability of human to use water for agriculture/domestic activities considering the distance to a safe source of water and also the time required to collect household water and other important factors. This comprises also water for irrigation especially during drought or dry season.

Capacity: People ability to manage water effectively for farming. The capacity is interpreted based on their income level that will allow them to afford water, their educational/experience level regarding water management and also their health status

Use: This component considers how water is used for agricultural activities.

Environment: This component considers people complain of land degradation, flood, and soil erosion.

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Mathematical Structure of WPI

WPI is calculated using the composite index approach. In this case we use the general expression below to find the five key components in combination:

WPI = (ΣwiXi)/ (Σwi) 2.2

The WPI value is the scarcity of water for that specific area / location

Xi for that particular location is the I portion of the WPI structure and Wi is the component weight that is applied to. Each component is composed of various sub-components, combined with the above technique and rewritten as:

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

The formula above is the mean weight of the five components comprising Capital (R), Access (A), Capability (C), Usage (U), and Environment (E). First, each variable is standardized in such a way that the values fall within the range of 0 to 100. This also implies, the resulting WPI value falls from 0 to 100. For the analysis purpose, the approach will be considered.

2.3.5 A simple time-analysis approach

(Sullivan, 2002) Simple time analysis approach is also another method used to determine WPI taking into account the time required to gain access to a specific amount of water needed for domestic purposes. This method actually fails to cater for ecosystem needs. Using this method, WPI is determined as follows**:**

WPI= T/100 m3

Where **T** is the time a person is required to collect water.

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2.4. 0 Managing water

2. 4. 1 Storage of water

Water is very important in agriculture since it has much influence in production, its management by storage however is the best way to ensure water availability even during unfavorable era of climate change. Storing water enhances economic growth and also helps mollify the poverty rate by making agriculture water available for farming when there is need for it (Nicol, 2015).

In most developing countries, water storage capacity is currently insufficient, even countries with abundant water have no capacity to store water for farming, particularly during the dry season, leaving most farmers helpless in the event of climate change (UNWD, 2015).

With Northern part of Ghana as example, where farmers solely rely on rainfall for their subsistence farming, become helpless during drought or in case of any other event. Insufficient water infrastructure has limited the ability of most farmers to cope with extreme events (droughts and floods) at an estimated cost of one third of growth potential (Sri Lanka, 2015).

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2.4.1. 0 Types of water storage

2.4.1.1 Ground water

Beneath the earth is a stock of water, with little or no evaporation at all, water can however be abstracted from underground such as wells or streams by the use of permeability of the rock (Fawag, 2015). Underground water can be improved by ensuring surface water availability to enhance infiltration by spreading surface water to increase water availability to crops (Suhag Roopal, 2018).

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2.4.1.2 Tanks and ponds

Tanks and ponds are built water storage facilities by individuals or communities which are lined or unlined, covered or uncovered cisterns built by Water storage by individuals or communities for agricultural or domestic purposes. These facilities are usually linked to rainwater harvest and storing in small volumes which are often filled either by surface erosion or runoff from different dug outs or dams (USGS, 2015).

2.4.1.3 Reservoirs

In the climate change era, the availability of water is crucial to production, but there are instances that a very significant quantity or proportion (more than 90%) of the available may be lost through evaporation (IWMI, 2009) which affects agriculture. There are many ways that enhances water storage, increase productivity, and improvement which enables greater crop production in a season especially during dry season, thereby decreasing reliance on rainfall for subsistence agriculture (McCartney and Smakhtin, 2010).

2.4.1.4. Drought tolerance

The main objective of ensuring or promoting water availability is to enhance agriculture productivity by encouraging water smart agriculture practices (WaSA) to help manage water for agriculture in order to increased crop production for every drop of water used.

With the current trend of climate change stress, drought-tolerant crops are therefore been promoted since these crops have the ability to withstand or adapt water stress during climate change which also have low nutrient adsorption as compare to any other physiological benefits or advantages to drive the necessary management practices (FAO, 2014).

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2.4.1.5 Mulch

Mulching involves the process of covering the topsoil with materials such as grass, leaves, crop residues and straw (Gomez et al 2015). Mulching enhances soil organism activity which helps to improve the soil structure for rainwater infiltration hence prevent surface runoff and aid plant growth. As the mulch materials decompose it increases the amount of organic matter present in the soil and also improves the consistency of the soil. According to Gomez et al (2015), mulching is very important in aiding the soil to perform its functions which include the following; protecting the soil from erosion, improving infiltration of rain and irrigation water, reducing evaporation, protecting feeding of organisms found in the soil, it also suppress weed growth as well prevent soil from soil heating. The functions of mulch are well presented in the figure below.

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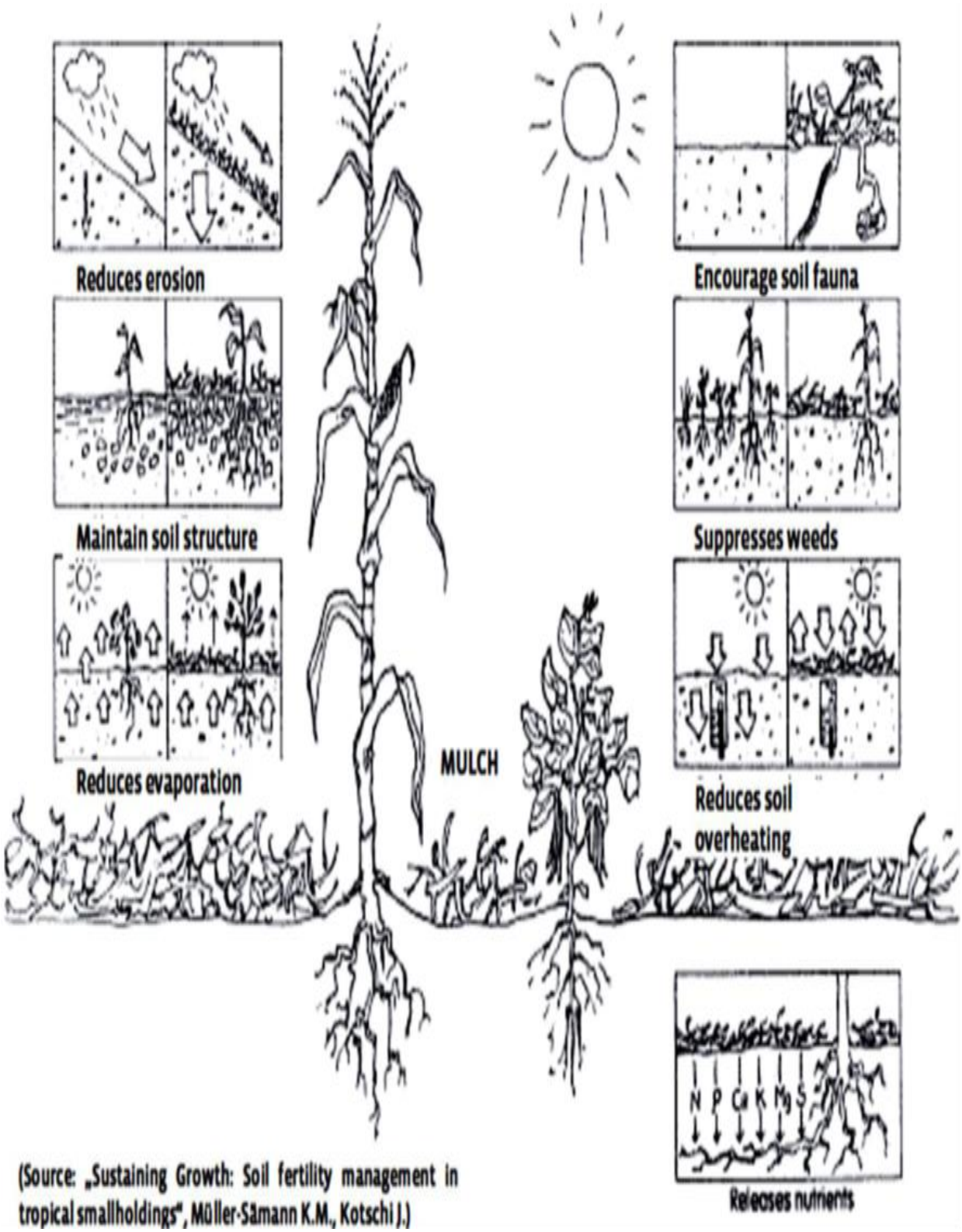

Fig 1. Role of mulching in ensuring water availability for farming

Source: Gomez et al (2015)

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2.4.1.6 Cover crop

The issues of climate change have come with serious extreme events like floods and droughts, which need attention. In addressing some of these challenges, cover cropping is practiced. Stanley Billelo (2016) noted that cover cropping helps improve water infiltration, water storage and recharging of aquifers and streams.

Cover crops are often crops planted between other crops with the aim to improve soil nutrients or quality and also to prevent erosion with the ultimate aim of reducing water drains off from the field. Cover crop biomass prevents direct impact of rainfall that may occur on the soil surface while allowing drops to infiltrate to the underground which enhances soil macro fauna habitat creation Stanley Billelo (2016).

In areas where there is a lack of water for crop growth, cover crops may serve as a mulch to maintain humidity by providing shade to cool the soil surface to minimize evaporation

2.4.1.7 Stone bund

Stone bunding is a technique practice by farmers to prevent soil erosion and runoff by Using stone to create a bond at a height of 20-30 cm from the ground, along the natural contour of the soil. Farmers in sub-Saharan West Africa use this commonly, with recommendation by various governments and non-government programs to promote its practice. The bonds of stone act as a shield for reducing water runoff, allowing rainwater to lie down, infiltrate and spread more evenly over the land. This helps to build a nutrient-rich layer of soil; which optimizes water and nutrient use efficiency thereby boosting crop production Farming First.org (2012).

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Fig 2. Stone bund practice by farmers in the Nabdam district.

Source: Field survey 2019

2.4.1.8 Irrigation

Irrigation simply is referred as the mechanical (artificial) supply or application of water to agriculture land for agricultural production process. Therefore irrigation system refers to all the equipment use to provide water to plants Victoria Government (2019). Irrigation farming provides important income source for disadvantaged rural and peri-urban farmers Chazovachii (2012).

Good irrigation is responsible for influencing the growth of plants from the preparation of seedbed, germination process, root growth or formation, utilization of

nutrients and yield quality. Selecting irrigation system which is best for your farming requires in-depth knowledge of the system which will meet the requirement in terms of uniform distribution to your land. In the process of watering some losses may occur as a result of wind drift, runoff and evaporation (Ankit Gupta 2010).

2.4.1.9 Types of irrigation

2.4.1.10 Surface irrigation

This type of irrigation system consists of furrows, basins and any other water on the surface use for irrigation, which is useful for farmers to irrigate their farms. This system has a lot of water wastage and poor water distribution, although uniformity distribution can be improved with various strategies.

2.4.1.11 Sprinkler systems

This type of irrigation system is also known to be the most efficient with pressurized version. The system requires less labor but requires a lot of equipment and energy, the advantage of this system is that there is greater control over the application rate, the quantity and also the timing. They are designed to reduce water loss, erosion, prevent frost damage and add the demanded humidity required for better plants growth. Sprinklers can be stationary, portable, semi portable, mobile or solid.

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2. 4.1.12 Drip irrigation system

This system is designed to directly deliver water to the soil surrounding the roots system on frequent basis which allows more infiltration of to the soil. The system is very productive but costly since expensive pipes or hoses are required to supply water. In designing the system, it is critical to make the drip system robust to function well for long. The good design will mean less water wastage and higher yields, this system provide the best uniformity distribution but require more materials.

2.5.0 Climate change and agriculture

Climate change greatly affects agricultural practices by rising the need for water, This decreases crop yields and also decreases the availability of water in areas where irrigation is most required or has a comparative FAO advantage (2016). Extreme climatic events resulting in inland and coastal flooding can directly affect the security of food and nutrition (Rao et al, 2016: FAO et al, 2018).

The IPPC noted with high confidence that, with regional variation Niang et al (2014), the overall impact of climate change on major crop yields in the African region is likely to be negative. Precipitation-related climatic variability particularly affects the timing and duration of the cropping season, crop development and production; and compounds the risks already faced by farmers (Jaegermeyr, 2016).

Smallholder farmers are recognized as the most vulnerable group to impacts of climate change because they rely solely on agriculture and livestock to survive (Dasgupta, 2014). Smallholder farmers around the world are more vulnerable to climate change because changes in temperature intensity, rainfall and possible extreme frequencies

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affect the production of animals and crops that directly affect their income, food and nutrition security and overall well-being (Vignola et al, 2015; Harvey et al, 2014b).

Agriculture is very sensitive to the variations in the various climatic variables most especially temperature and rainfall because they are the factors or production determinants, Climate change impacts are projected to affect different sectors of the economy; however, few sectors are as vital as the agriculture sector (Mendelsohn and Dinar, 2009).To this end, farmers will need to adopt smart climate agricultural practices to both sustain their current yield levels and sustainably boost total production (Amikuzuno and Hathie, 2013; Adiku et al., 2015).

Crop yields in Sub-Saharan Africa (SSA) are expected to decline by the mid-century (2050) as a result of climate change between 10 - 20 percent or even up to 50 percent (Adiku et al., 2015). The reason is that agriculture is predominantly rain-fed and therefore completely dependent on the unforeseeable weather.

Studies demonstrate that relationship between observed climatic variables and yields of crops which is an indicator of possible future global warming will be impacted severely (Mavromatis, 2015; Innes et al 2015). The impacts tend to be rising at global level (Iizumi et al , 2018). Several studies carried out with the goal of determining the impact of climate change on food and nutrition security (Hussain et al, 2016; Shrestha and Nepal 2016) Noted extreme climatic conditions are experienced everywhere with frequent flooding as well as consistent and prolonged drought periods (Manzoor et al, 2013; Hussain et al , 2016; Shrestha and Nepal, 2016). Recent years have seen the yields of staple crops such as maize, sorghum and fruit have shrunk uniformly across Africa, raising the food and nutrition insecurity gap (Ketiem et al, 2017).

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In Africa, particularly considering Nigeria, it is noted that the impacts of climate change on the livelihood of farmers sucking as arable crops are highly felt (Abiona et al, 2016; Ifeanyi-obi et al, 2016; Onyeneke, 2018). Generally, the impact is only not felt in Nigeria but also in other Sahel regions like Cameroon where malnutrition is on the rise partly due to climate change (Chabejong, 2016). Livestock diseases rise often exponentially when the temperature increases coupled with the variability in precipitation (Rojas-Downing et al. 2017). Climate change affects the diverse nature of animal production, from field grazing to the industrial sector (Rvera Ferre et al, 2016). The figure below shows the different ways in which climate change affects livestock.

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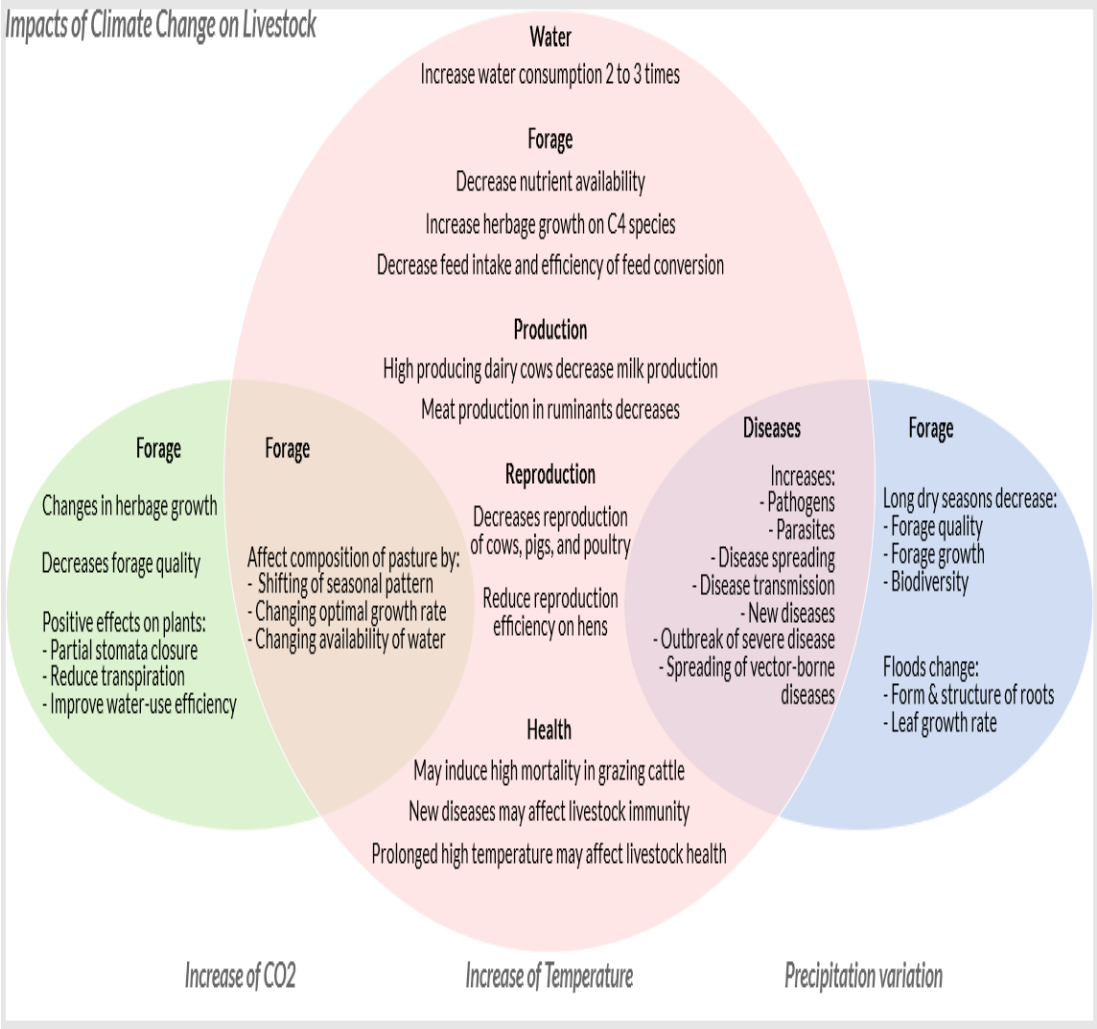

Fig 3.Climate change impacts on livestock

Adopted for use from Rojas-Downing et al 2017

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Climate change effects are expected to have long-term changes on climatic variables including precipitation, temperature etc. Climate change may also contribute to increased frequency and intensity of severe climatic events such as flooding, cyclones,

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and droughts. (OECD, 2014). Water conservation is the sustainable key to future food and nutrition protection as well as economic development in the SSA region. Although the region does not suffer from water scarcity, potential access difficulties and dry season shortages induce in some areas economic water scarcity and water conflict (Johnston, 2010). The anticipated increase in temperatures and also changes in precipitations is estimated that climate variability and climate change have a substantial impact or influence on livestock as well as crop systems. This will affect in particular the frequency and intensity of extreme events such as drought, floods and heat stress, particularly regions vulnerable to such events as Africa (OECD, 2014). The agriculture sector can only do well by adjusting to the impacts of climate change to help boost the resilience of food production to meet the increasing demand for food of the rising population with less water.

Climate change is likely to bring changes in weather conditions and new problems that need mitigation and adaptation for the sector (FAO, 2016). It is believed that the climate change impacts peoples livelihood will be severe in the subtropical and tropical and Africa as a whole, with the fact that poor smallholders farmers depend solely on agriculture with few alternatives (IPCC, 2001).

Studies have shown that global warming has caused agricultural productivity and food production to decline (Kurukulasuriya et al., 2006; Lobell et al., 2008). According to work by Ackerman and Stanton (2013), when precipitation patterns change as the world continues to warm, other areas get wetter and other places or areas get dry. The trends are difficult to predict, however, and current droughts in several parts of the

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world shed more light on the important role of rainfall changes (Ackerman and Stanton, 2013). Climate change has adverse effects on both agriculture and human life. The results in a poorer world are likely to be worse. In the long run, growing demand for food over the next century will result in increasing global food scarcity due to population and real income growth, and worsening hunger and malnutrition problems especially in developing countries (Wolfe et al., 2005; Stige, 2006, and Orindi et al., 2006).

Climate change have far-reaching implications for dairy, meat and wool production, especially as a result of its effect on grassland and rangeland productivity, according to the IFAD (2009). Changes in climate variability and climate change will impact livestock production systems around the globe, eventually affecting 1.3 billion poor people whose livelihoods depend entirely or partially on livestock (Thorton et al., 2013). The performance of agriculture in Ghana in terms of productivity and production still remain insufficient, despite the country's endowment with many natural and human resources, it failed to make progress for food security front. The reasons for the low performance could be attributed to poor production techniques, inadequate supply of water, low yielding, with other constraints prevent achievement of household food security (Gyamfi, 2006)

2.5.1 Climate change effects on food security

The latest trend in climate change predictions is negative and has a significant effect on food security pillars as a result of supply, food distribution, food use and stability, and the multiple interactions (FAO et al, 2018). The impact on these pillars was noted

(Bailey et al. 2015) on the various components of these pillars, thus availability (food production), access (food prices), utilization (nutritional quality) and stability (increasing extreme events). The general inference is that low-income producers and poor consumers are the most impacted because of the insufficient resources they need to invest in the adaptation and usage of various interventions (UNCCD 2017; Bailey et al 2015).

The above has led nutrient deficiency, worsening consumers especially parts of sub-Saharan Africa, which normally observed during issues of conflict and drought or flood incidence (FAO et al 2018). This has led to deficiencies of micronutrient also known hidden hunger which suggest prevalence usually one found in every three people in the globe (FAO 2013a; Tulchinsky 2010; Von Grebmer et al 2014).

The decline in crop yields is due to the direct effect of climate change on nutrient intake in particular the poor as a result of decrease in supply of nutritious crops (Lobell and Burke 2010; Thompson et al 2012). Rural folks mostly are usually affected in time of misfortunates or the consequences of climate change (Dasgupta et al, 2014)

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2.5.2 Impacts of climate change on human health and on water

With the current scientific analysis and understanding, supported by a body of observation and results of modeling, indicates a continuous atmospheric composition changes which further rising global mean temperature, changes in precipitation patterns, rising sea level, increases in severe weather conditions, and continuous in snow cover, ice and sea ice, prolonged drought, floods among other effects that will

affect the world and global agricultural systems (Molly Brown et al 2013). Kristina (2012) also noted that climate disasters such as storms, droughts and cyclones will occur more regularly and more violently, generating precarious living conditions such as food shortages and forcing migration, while current climate patterns remain stable. Climate change is seriously threatening water for agriculture; on the African side, this impact is likely to affect food security. This coupled with changing trend of land by urbanization and intensification of agriculture reduces the quality and quantity of wetlands, rivers and underground water due to change in land and water Wheater (2015).

Adiku *et al* (2013) in their analysis , it was found that low rainfall or drought resulting from climate change would result in moisture stress or insufficient moisture resulting in poor seed germination or no germination at all and also sprouting of cut-crops or seedling emergence growth periods critical to development affects crops. This affects food security, since rural livelihoods and food security are strongly linked to food security, water security, food security is therefore determined using how people can secure access their own agriculture production Nicol *et al* 2015. If this happens, it affects flowering and grain filling in cereals, and fruit formation as well, this reduce crop yield significantly leading to poor harvest.

A research by Wheater (2015) found that both the quality and quantity of surface and underground water supplies are affected by threats to domestic use, food production and marine life as a result of the impacts of climate change. Grafton (2011) found that lack of precipitation would result in pressure on agriculture as well as water supplies, and that the possible effects could be very serious, contributing to competition on

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water resources. Wheater and Nazemi (2014) noted society challenges of water can be addressed by a new paradigm that will interact between science and communities needs with this, science addresses issues relevant to water security.

It is worth that climate change also impacts crop yields by photosynthesis, this is because crop yields are essential end-product of photosynthesis. Adiku *et al* (2013) noted that any factor that affects photosynthesis process invariably affect crop yield. Incidentally, this photosynthesis and other atmospheric processes that are the very factors that brings about the entire environmental variability phenomenon, and climate change.

Despite the above, climate instability or climate change may have several different impacts on human beings and food security (Fanzo et al 2017; Watts et al 2018). Extreme temperatures, human metabolic processes and other physiological tension are some of the forms which may result in potential interactions of producing and consuming food (Watts et al 2018).

The effects of climate change on human health are very dangerous with severe accidents resulting from weather hazards and disasters such as floods resulting from heavy rainfall (Lindgren and McMichael, 2011). Where agriculture relies on manual labor, heat stress is projected to affect people working hours and also increase associated risk (Dunne et al. 2013). As noted in the work of (Watts et al, 2018), nutritional status of people interact with stressors making them susceptible to ill health, this is easy with extreme heat. Long unprotected exposure to high extreme temperatures usually bring heat cramps, other health conditions like heat stroke,

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fainting, heat exhaustion and deaths, which compromises activities of human (Smith *et al*. 2014). It should be noted that in Ghana and Kenya the association of extremely high ambient temperatures can cause death (Egondi et al 2012; Azongo et al 2012).

Under nutritional levels in sub-Saharan African regions it is projected that the warming will increase around 1.2-1.7C somewhere in 2050, the undernourished population will increase from 25 per cent -90 per cent compared to the current one (Lloyd et al 2011). The severely stunted children population estimated in 2010 to be 12-20% will reduce drastically by 40% without influence of climate change and 10% when there is climate change (Lloyd, et al 2011) With malaria, the intercomparison of malaria model reveals that there will be reducing in transmission in Sahel (Caminade et al, 2014).

Nutrient deficiency related sickness is expected to increase as noted by the IPCC where the overall effects of Climate change is projected to be negative on major cereal yields in the African region, with strong variations (Niang et al 2014), this means that Africa will experience nutrient deficiency diseases if production is not well planned. This is evidenced by FAO (2018) that hunger globally is increasing, with about 821 million in 20117 and around 804 million in 2016 as in a decade ago. Naturally occurring climate-related disasters drive nearly 26 million into poverty each year, exacerbate hunger and restrict potential access to scarce resources (CRED and UNISDR 2017).

West Africa by projection is to feel severe impact of climate change resulting in Declining food production involving ocean productivity with a high risk of food insecurity and a negative impact on human health and employment (Olivia et al . ,

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2016). Watts et al (2018) noted climate change impacts to have direct impact on the environmental breakdown like economic losses, lost in working hours as a result of extreme heat. Diamond (2017), noted also that climate change will have indirect emerging consequences from direct impacts like malnutrition as a result of population displacement due to environmental degradation. Droughts and floods will cause different form of water pollution like salinization of underground water, organic carbon, sediments intrusion, pesticide and pathogens (UN2010)

The effects of climate change on water are expected to face more on severe events such as flood and drought that deteriorate already existing water and sanitation. When rainfall in the long-term increases, there is a possibility of groundwater increasing, decreasing the natural process of purification thereby the risk of infections and exposure to toxic chemicals increase (UN, 2010).

On the side of domestic water needs, climate change indirectly increase the demand and competition over water resulting in high price for water (UN 2010). This high demand, results in water scarcity thereby increasing sectorial demands like agriculture, industrial and domestic water use (UN 2010). When environmental shocks severity frequency increases, it could erode human capacity in responding and recovering from instability, which leads to the permanent sub-optimal level of functioning (WEF, 2018)

The impacts of climate change will not everywhere be the same as those noted by Weber et al (2018), the impacts of climate change on the regions are worse, the temperature in Sub-Saharan Africa will rise significantly, as projected far below the mean global warming of 1.5 ° C and 2 ° C respectively. Kharim et al, (2018) in their

study noted that provided that the global mean temperature stays below 1.5 ° C, this ensures that regions between 15 ° S and 15 ° N with the forecast to witness increases in overnight high temperatures with more frequent and longer heat waves, which sub-Saharan Africa will probably fall victim to.

Whenever the temperature is above 2°C, the Sub-Saharan region will possibly become more droughts vulnerable and its associated consequences which may cause food security problems (Salem et al, 2017). Research by Klutse et al, (2018) noted also that averagely across West Africa, the mean rainfall decrease strong global warming of about 1.5°C, which will affect crops and hence food security, this means that climate change impacts will be negative in West Africa. (Palazzo et al 2017; Gaetani, 2016) confirmed that the effects of climate change in West Africa are identified as a region with more negative impacts due to the nature of the hotspot.

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2.6.0 Water security level of farm households

The issue of water scarcity is very critical, water scarcity can affect women if they have to spend a great deal of time and energy collecting water, with potential exposure to physical and sexual assault (Sommer et al 2015; Aipira et al, 2017). Before now, water was considered a free commodity and unlimited in quantity and always available whenever required (NWP, 2007). Nevertheless, the exponential population growth, pollution of water bodies and both rapid economic development and changes in climate have resulted in stress on natural water bodies (IBWRD, 2014).

Bakker and Cook (2012) in their study found out that, water security phrase frequently used denotes multiple challenges in the 21st century of water management.

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Wheater and Gober (2013) defined water management as sustainably using and protecting water resources, safeguarding water resource, its services for humans as well the environment and protecting against drought and flood. Water security is complex term with multi-dimensional and interdependent issues, this heightened water use competition at local, regional and international levels Gariba (2018). Aside this, flooding remains globally a serious and natural damaging hazard and with the current trend of population increase, associated risks increase UNESCO, (2012).

Water security becomes a challenging target since climate change and climate variability keeps increasing steadily, reliance on rainfall for agricultural production also raises the risks in the field, while undermining sustained output is undeniably not meeting food security Adiku, (2013)

Ghana has plenty of water resources, but the amount of water available changes significantly from season to season as well as annual variations. There is no uniform distribution of water resources in the country, the south-west (rain forest zone) is better with water resources than the northern and coastal areas / regions (WRC, 2012).

Water scarcity issues present very serious and threats to farmers/people, the planet as well an inclusive and sustainable development (FAO, 2016) According to Calow and Mason (2012), the significance of water in both social and cultural contexts cannot be overlooked, the intersection with existing loaded term ‘security’ results in some of the serious responses.

Water scarcity / security seen as a serious popping up geopolitical headline issue can tear across various parts of global economic systems / sectors, the World Economic Forum (WEF, 2011). The concept of water security implies minimizing effects of the

water scarcity. As noted by Grey and Sadoff (2007), availability of water for livelihoods, ecosystems, health and production of acceptable quality and quantity of water together with a reasonable level of water-related risks associated with people, economies and environments.

There have been concerns about water scarcity / security, despite some of the significant interventions (Wouters and Tarlocks, 2009; Wouters, 2010; Cook and Bakker, 2012) argued that word / term value had far less time to develop and polarize. The working definition of water security is centered on the availability of resources, but some degree underplays the issues of allocation and access but more aligns with the concept of physical water scarcity than with other manifestations.

While water security debates have not been discussed extensively, there have been some views on longer-established security concepts that link water security to national and human security, and as a result, the potential role of water in conflict has long been considered, often with reference to water scarcity (CoFR, US Senate, 2011). Specific cases of foreign conflicts with water as a key causative factor, or as a means of war, are rare (Yoffe, Wolf and Giordano 2001: 64).

Nevertheless, in recent history there have been well-documented instances of water playing a role in more regional conflict, extremism and political injustice (Pacific Institute, 2011), and Commentators reflect that this phenomenon is likely to be ongoing and intensifying (IISS, 2011). Based on hydrological standard index of water scarcity, it is concluded that the year 2025, about one-third of the world population will be living in more water scarce countries (UNESCO, 2004).

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2.7.1 Water security/scarcity and water technologies

Agricultural productivity currently in Africa is noted to be among the lowest in the world with food demand on the increase as population grows exponentially. Farmers accessing water for productive agriculture use is a major challenge for the millions of poor smallholder farmers, which represent majority of the producers in Sub-Saharan Africa (SSA). It's therefore very import to understand, augment and stabilize water supply and to simultaneously improve poor smallholder farmers access, including women access to land as well water Williams et al 2015.

A study by UNCTAD (2011) revealed that Africa is a region where poverty and water are complimentary, thus they are linked together. With the latest climate change pattern, the rainfall and the start of the planting season changes and consequently the crops with longer maturity periods are affected. Water storage and harvesting are necessary to supplement the unreliable rains. According to UNCTAD (2011), water storage is perhaps the greatest possible potential to improve water management.

Water harvesting or storage is associated the construction of dams, dung outs, use of poly tanks etc to ensure the availability of water for farming and other use. McCartney and Smakhtin (2010) stated that water storage at the surface includes natural reservoirs and wetlands whilst sub-surface storage consisting of underground water and soil water accessible by plants roots, ponds and tanks. Water storage ensures the availability of water by capturing water especially during rainy season when it is abundance and using it when there is water shortage. This makes it possible to supplement farms when there is drought or even irrigate in the dry season.

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Water storage can balance the demand and supply of water within the shorter period such as water storing from rivers flow and make it accessible to farmers Gariba (2018). Using this approach, water availability that could have gone unused or wasted is utilize and also increase the irrigation flexibility by improving timeliness and reliability of water supplies. Water recharge is linked to underground water and surface, with this, reservoirs and canals provide opportunities for recharging underground water and also provides buffer between water demand and supply use for irrigation UNCTAD (2011)

In Ghana, the story of water storage is mixed, reservoirs supplies water reliably to help diversifies farmers' crops and increase their income. However, some nearby reservoirs with similar conditions failed to realize any possible significant change (McCartney and Smakhtin (2010)

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2.8.0 Methodologies used to achieve Objectives

2.8.1 Water Poverty Index (WPI) model

Water is a very basic requirement for life and should be regarded as a necessity for sustainable development. Water is an integral and very significant part of social and economic development, however, it is scarcely available and also not evenly distributed on earth (Shalamzari et al., 2018). In determining water poverty level of farm households or farm level, the WPI model is best used. The WPI was formulated by Sullivan et al (2002) to take into consideration all aspects of water management. The WPI defines water poverty by considering five main components: capacity, access, use, resource and Environment. (Zhang et al., 2018). In their research, the WPI

is used to map and analyze the status of water scarcity in the Upper East Region, The WPI is a special tool used in analyzing water resources which has long history by (Sullivan, 2002).

WPI used in this study encompasses water resources availability to farmers, farmers' ability to access water for farming, farmer's ability to use the resource for productive purposes, and environmental factors impacting the ecology thus water. (Masoud, 2018) it is worth noting that the WPI model has been designed to integrate into a single five key problems/issues concerning water resources which are as follows; the resource (R) component which comprises surface, rain and ground water availability thus sources that farmers can get water for their farming activities. (Dug out, pond, dam, river, stream etc). Access (A) to water considers water for farming/irrigating crops, thus farmers' ability to get water for farming activities without any hindrance or restriction either by ownership or at a fee.

(WilK et al., 2013) noted that the Use (U) variable focuses on the purpose for which water is used for different productive sectors, farmers' ability to use the water whenever and how they need it, such as livestock usage and for agriculture. Capacity (C) comprises a number of indicators focusing on supporting or enhancing human development of the area, which comprises the education that they had, and some trainings on skills development in managing the water resource. The Environment (E) component includes all the natural makeup of the area. It combines variables such as the topography, biodiversity, environmental degradation, water quality and soil erosion, which are very key in determining the quality as far as the environmental is concerned. The WPI is best calculated using the composite index approach, the

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components of this approach are combined using the general expression (Sullivan, 2002).

WPI = $\frac{\sum wixi}{\sum wi}$

Where WPI in this study is the water poverty index value for Bawku West District, Binduri District and Nabdam District. While Xi is the various components such as Resource, Use, Capacity, Environment and Access for the study area. Wi is the applied weight to each component. The various components are composed of sub-components and are combined in order to produce the different components using the same above methodology.

The equation can be rewritten as below according to the components mentioned above:

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

WPI values of 50% approaching 100% indicates lower water poverty indices whiles values below 50% are indicating higher water poverty indices i.e water insecurity.

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2.8.2 Kendall's coefficient of concordance

Kendall's W-test (also known as Kendall's coefficient of concordance) is a non-parametric statistic (Kendal and Babington Smith, 1939; Corder and Foreman, 2009). It is basically the normalization of the Friedman test which can be used to assess agreement among different raters. The Kendall's coefficient of concordance (W) ranges from 0 (which means no agreement) to 1(complete agreement. (Azumah, 2019) used the Kendall's coefficient of concordance to rank a list of agricultural technology

transfer approaches in his research "agriculture technology transfer, adoption and technical efficiency of rice farmers in northern Ghana" which gave him good results.

(Aparicio et al., 2020) used the Kendall's coefficient of concordance to rank and compare the classical mean and median-based rank approaches based on social choice theory which revealed that the Kendall's coefficient of concord is a best tool for rating.

Having considered the above literature, the Kendall's coefficient of concordance was used to rank the identified constraints farmers faced. The constraint with the high score was ranked as the most pressing one, while the constraint with the lower score was ranked as the least pressing.

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2.8.3 Multivariate Probit Model for determining adoption water management practices.

The Multivariate Probit model is viewed as an extension of the probit model, as it allows simultaneous estimation of several probit models while allowing correlation of the error terms in those models (Greene, 2003). This means that the MVP is used to estimate different probit models which makes it possible for the error terms in the models to correlate. (Donkor et al., 2019) used the MVP to estimate the factors that influenced the adoption of improved agricultural technologies for production in northern Ghana and because of the fitness of the model, the factors were well and significantly estimated.

(Azumah, 2019) also used the MVP to estimate factors influencing adoption of improved agricultural production technologies. He was able to establish the correlation in the error terms by jointly modelling the effects of a set of covariates on each of the improved agricultural technologies and estimates a set of binary probit models. The inability or failure to account and correct for those interrelationships can lead to the estimation of biased results (Kassie et al., 2013).

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(Ahmed, 2015) also noted that the relationship between the adoption of different improved production practices is possible to be established, as well as potential correlations between unobserved disturbances. (Mbeyagala, 2021) used the MVP to assess the factors influencing the probability of adopting mungbean production technologies in Tanzania, Kenya and Uganda. The results show that the probability and extent of the adoption of mungbean production technologies are influenced by several factors (gender of the household, household size, farm size, livestock size, household assets, access to extension services and access to credit). The correlation in the error terms by jointly modelling the effects of a set of covariates on each of the factors. (Abay, 2016) also used the multivariate probit model, which enabled the researcher to quantify the complementarities between agricultural inputs, while also controlling for alternative forms of unobserved heterogeneity effects that may occur.

Considering the fitness of the MVP model used above for analyzing factors influencing adoption, the MVP model was used to analyze the factors influencing the adoption of water management strategies by farmers. The key water management practices considered in this study were crop rotation, cover cropping, stone bunding, drought tolerance crops, compost/mulch, irrigation and water storage.

2.8.4 Trade off Analysis of Minimum Data (TOA-MD) Model

TOA-MD model (Antle, 2011), noted that the TOA MD is a novel multi-dimensional impact assessment simulation tool that uses a statistical overview of a heterogeneous farm population to simulate the introduction and impacts of a new technology, a change in environmental conditions, and the provision of ecosystem services. (Claessens et al., 2012) used the TOA-MD model to compare two systems, as a result of climate change impacts, it was revealed that both the base system and the changed system (climate change) were perfectly estimated. (Valdivia, 2010) indicated that the TOA-MD model is designed to simulate what would be observed if it were possible to conduct a controlled experiment. Thus, the model simulates and compare two systems at a time, a base system (system 1) and a changed system (system 2) that is operated under altered conditions such that it provides different economic outcomes for farms.

(Antle et al., 2013) used the TOA-MD to analyze scenarios with future climate and technology adaptation, the researchers compared two systems at a time, a base system (system 1) and a changed system (system 2) that is operated under changed conditions such that it provides different economic outcomes for farms. They concluded that the impacts of a new technology, a change in environmental conditions is best analyzed using the TOA-MD.

(Ilukor et al., 2014) also used the TOA-MD in Uganda to assess the adoption potential of sweet potato technologies (drought resistant and virus free planting materials. They found that the TOA-MD was perfectly used to determine the impacts of a new technology on farmers operated under a changed environment and farmers under the base system

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(Ponnusamy et al., 2015) noted that using the Tradeoff Analysis model for multi-dimensional impact assessment, it is possible to answer questions related to climate change, climate variability and the potential impacts on production systems better. Thus the sensitivity of (1) current agricultural production systems sensitivity to climate change (i.e how current system will respond if the future climate is to be experienced now); (2) the impact of climate change on future agricultural production systems (i.e., defined by the agricultural production system as it would exist in the future and evaluate the impact of climate change) and (3) the efficacy of on-farm adaptations in alleviating the impact of climate change.

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CHAPTER THREE

METHODOLOGY

3. 0 Introduction

This chapter presents a description of the study area, types and sources of data, data collection procedures, the sampling technique and sample size; and the models used for analysis.

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3.1 The study area

3.1.1 Background and location of the Region

The study was carried out in the Upper East Region of Ghana, the region is bordered by Burkina Faso in the north, Togo in the east, Sissala East district to the west and south to North East. Upper East lies between longitude 00^{o} and 10^{o}W and latitudes 30^{o}N and 110^{o}N in the northeastern corner of the country.

Historically the region was part of what was once the Upper Region, on 1 July 1960, it was itself carved from what used to be the Northern Region. Throughout the Provisional National Defense Council (PNDC) regime the Upper Area was later split into Upper East and Upper West in 1983. Bolgatanga is the regional capital city. Other major towns include Bawku, Bongo and Navrongo (www.Ghanadistricts.com).

The region's topography is very flat with a few hills to the region's eastern and southeastern parts. The land area is roughly 8,842 sq km, which constitutes 2.7 per cent of the country's total land area (GSS, 2012).

3.2.2 Population and Size

Region Population and Housing Census (PHC) according to 2010 were estimated to be 1,046,545 with 506,405 being males and 540,140 females. The present Upper East Region population is estimated at 1,188,850 with 583,573 males and 605,277 females (GSS, 2012). The region has a population growth rate of 1.2 per cent compared to the 2.5 per cent national growth rate.

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3.2.3 Agriculture

Agriculture is the region's main economic activity, employing about 80 per cent of the population. Agriculture in the region is smallholder-based with approximately 90 percent of farmers growing less than 2 hectares (MOFA 2010)

Agriculture activities in the region are implemented using labor coupled with bullock efforts. However, there is little mechanized farming. The major food crops cultivated in the region are mainly the staple food crops, thus millet, sorghum, maize, groundnut, beans, and some dry season crops (tomatoes and onions). Food crop farms are intercropped while mono-cultivation is often associated with large-scale commercial farms for out grower systems (MoFA, 2016).

3.2.4 Soil and Drainage

The soil of the Area is "upland soil" mainly made from granite rocks. It is shallow and poor in soil fertility, with low content of organic matter, and mostly coarse textured. The valley areas include soils from sandy loams to salty clays.

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The valley areas have higher natural productivity but are harder to till, and are vulnerable to seasonal water logging and flooding. Drainage is primarily through the White and Red Volta, and Sissili (Regional Coordinating Unit, 2003).

3.2.5 Vegetation and climate

The natural vegetation is that of the savannah forest, characterized by low, sparse, drought-resistant trees and grass that is burnt in the long dry season by bushfire. Human interaction with ecology is important, resulting in conditions which are almost semi-arid. The sheanut, dawadawa, baobab, and acacia are the most common economic fruit trees.

One rainy season characterizes the climate from May / June through September / October. In this period the mean annual rainfall is between 800 mm and 1,100 mm. Between November to mid-February there is a long period of dry season characterized by cold, dry, and dusty harmattan winds.

During this period temperatures can be as low as 14 degrees centigrade at night, but during the daytime they can rise to more than 35 degrees centigrade. Nevertheless, the humidity is very low which makes the daytime high temperature less uncomfortable. The Area is absolutely within Africa's "Meningitis Zone." The area is within the onchocerciasis region, but with disease control, vast areas of previously abandoned farmland have been deemed suitable for settlement and agricultural use.

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3.2.6 Economic Activities

Agriculture, hunting, and forestry are the region's principal economic activity. About 80 percent of the economically active population is engaged in farming. Millet, maize, groundnut, beans, sorghum and dry seasonal tomatoes and onions are the major agricultural produce. Livestock productions are also important.

There are two major irrigation schemes, the 850-hectare Vea Project in Bolgatanga and the 2490-hectare Tono Project in Navrongo. Although they provide some 6,000 small-scale farmers with jobs in total. Other water retention systems (towers and dugouts) provide both domestic and agricultural water

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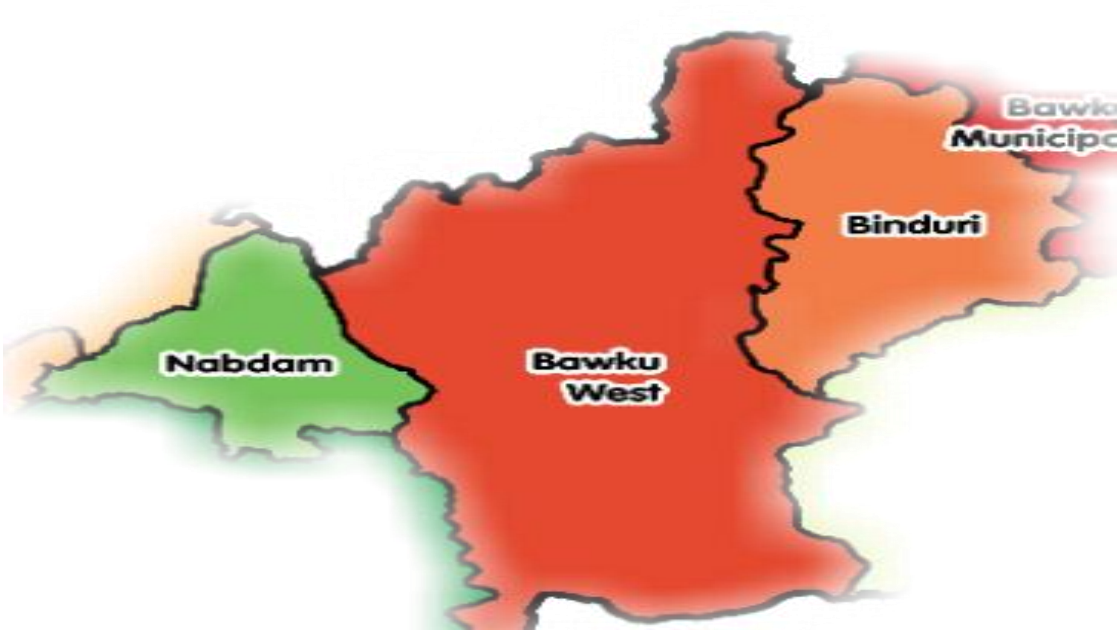

Fig 4. Map of the study area showing the Bawku West District, Nabdam District and Binduri District.

Source: Macabe5387 (2017)

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3.3 Definitions of Concepts

3.3.1 Smallholder Farmers

In Ghana, a smallholder farmer is viewed centrally as the one doing farming on small plots or acreage of land. The Food and Agriculture Ministry (MoFA, 2011) has defined smallholder farmers as farmers who farm less than 2 hectares of land.

Chamberlin (2007), however had a different view of a smallholder farmer which include other perspectives by categorizing the definition not only on land holding size but also on wealth status, the market orientation and the possible vulnerability to risk. Smallholder farmers have limited resource endowments in the agricultural sector relative to other farmers (Dixon, Tanyeri-Abur and Wattenbach, 2004).

Asuming-Brempong *et al.* (2004) noted that the definition of smallholder farmers should not be narrowed only to land holding size but should expand to encompass different resources and risk conditions. However, categorizing smallholder farmers based on landholdings is the most commonly adopted definition of smallholder farmers.

The working definition of smallholder farmer per this work refers to a farmer who cultivates less than 2 hectares of land, use less sophisticated tools, use both farmer's own or improve seeds and mainly rely on family members for labor for agricultural activities.

3.3.2 Agricultural water management

Agricultural Water Management (AWM) is concerned with making water available and accessible for agricultural purposes (ADB, 2010). It is noted that AWM comprises a variety of approaches, including the integrated watershed management, rain water harvest, use of dams, sub-surface dams, water-shed harvesting and soil profile storage and diversion flow (ACPC, 2013).

3.3.3 Agricultural Water security

Agriculture water security is the ability of a population to have access to adequate, reliable, acceptable and available water for production, sustaining human and ecosystem health. According to Grey and Sadoff (2007), water security refers to 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.

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3.4.1 Research Design

The study used both qualitative and quantitative research design (QRD) to collect data. This helps to provide clear characteristics associated with the sample at a specific point in time (Labaree, 2009). Quantitative research design is used to determine relationships between an independent variable (s) and a dependent /outcome variable (s) in a population based on which conclusions are made (Creswell, 2003). The qualitative aspect considered the qualitative characteristics of farmers like crop types, educational level, age, sex and occupation (on-farm and off-farm). And the quantitative research considered farmer characteristics like farm household size, total

land size used for cultivation, output from crops, productivity and revenue of smallholder farmers

3.5 Types of Data

Data for the study is both qualitative and quantitative; the qualitative data collected included crop types, educational level, age, sex and occupation (on-farm and off-farm). Quantitative data included farm household size, total land size used for cultivation by smallholder farmers, output of maize, rice, cowpea and millet, productivity and revenue of smallholder farmers in UER. Also data on water (resource availability, use of water, access, capacity and environment) were collected in the selected districts.

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3. 5. 1 Source of Data

The data was gathered on the water security level of farm households, this was achieved by following (Shalamzari et all 2018) approach. The first component, thus data on resource was collected by considering the number of water source for farming (surface water i.e dams, wells and dams). Data on use was collected by considering livestock access to water and farmers' ability to irrigate. Data on the environmental component was collected on frequency of flood occurrence, erosion and desertification. Data on capacity was sourced by asking farmers literacy rate, access to health centers, households' income and access to electricity. And finally, data on access was collected on the ability to use the available resources. Data was also collected on the constraints that farmers face in managing water, data on factors

influencing the adoption of water management strategies as well as data on economic impacts of efficient water management on farmers were collected. The specific socio-economic variables of the sampled farmers included sex, age, education level, household size, income, expenditure, number of years in farming, credit access, extension services, were also gathered for analysis.

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3.6 Sample size and Sampling technique

3.6.1 Sample Size

In order to make conclusion from the study which reflects the true population under study, it is prudent to determine the appropriate sample size to be used for the study. A work done by Saunders *et al.* (2009), noted that drawing conclusions from larger sample sizes results in a high probability of accurately reflecting the true population under study. Upon the good results from large samples, there are several limitations resulting from the selection of large sample sizes. Hair (2006) and Saunders et al. (2009) noted also that the availability of funds, limited time and the type of statistical analysis among other reasons make it necessary for the selection of a sample from a population suitable of working within the research period. In selecting the sample size for this study, the study adopted Slovin's (1960) formula for calculating sample sizes given as ($n = \frac{N}{1+Ne^2}$).

Where n is the sample size to be estimated and N is the population size of the study area and *e* is the error tolerance. With 95% confidence level, 5% (0.05) margin of error was used to determine the sample size. By using 5% margin of error, a sample of size 399 was estimated as representative enough of the population to draw

conclusions. Another reason for choosing 5% margin of error is that by reducing the margin of error, the sample size was too high for the researcher considering the time frame and finance.

Applying the above formula to the study, the sample size was estimated as follows:

$$n = \frac{189436}{1+189436\,(0.05)^2} = 399$$

The estimated sample size for the study was 399 but 370 was collected because of cost. This number was further reduced to 350 for the study as a result of incomplete responses.

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3.6.2 Sampling technique

The appropriate sampling method to select a sample of farm households for data collection is very significant since that will enable one to get the true and/or totally representative of the population which ensures quality data and results hence helps inform policy recommendation and also influence NGOs behavior as noted by (Abdulai 2017). Based on this, the multi-stage sampling approach was employed to select respondents for the study.

The first stage used purposive sampling to select districts whose characteristics are homogeneous in nature and based on this, the Nabdam, Binduri and Bawku West districts were selected. In the second-stage, each district was stratified into four to enable the researcher cover the district wholly and the stratified sampling technique was then used to select four (4) communities in each of the three (3) districts. In the final stage, the simple random sampling was adopted to select 29 farmers from each of the selected communities making the total number of 350 farmers for the interview.

The nature of the stratification and the survey cost involved, the 29 farmers was to minimize cost and also make it safer to ensure good and quality data is collected.

3.7 Data Collection Methods

In meeting the objectives of the study, personal interviews were conducted with the aid of semi-structured questionnaires administered to knowledgeable members of sampled households to gather relevant information to be able to achieve the study objectives.

To gather much information as possible needed to achieve the objectives of the study, the questionnaire was both open and close ended questions. Researchers also used personal observations that were significant in obtaining information for the study.

The data collected was treated with strict confidentiality and because of that names of the farmers did not appear anywhere in this research.

3.8 Conceptual and theoretical framework

The study used econometric techniques to achieve the study objectives. The water security level was analyzed using the water poverty index (WPI). Where the final WPI is presented as the water poverty index value for Bawku West District, Binduri District and Nabdam District. Secondly, the constraints faced by farmers in their farming activities are ranked using the Kendall's Concordance Coefficient. In examining factors influencing smallholder farmers' adoption of water management in the study area, the multivariate Probit model was used. Also in determining the economic impacts of efficient water management on selected outcomes of smallholder farmers, the Tradeoff Analysis of Minimum Data (TOA-MD) model was used. The

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WPI conceptual framework adapted for this study is from Betebo (2014), where water management is conceptualized into two basic strategies, thus the irrigation component and adaptation component. The adaptation component considers measures or practices that farmers use to ensure that there is water for farming.

These measures include; cover cropping, constructing stone bunds, mulching and application of organic matter by farmers to ensure that they conserve water. These practices have been in existence and intensified with the advent of climate change. Farmers therefore, have to adapt strategies or measures to ensure that there is available water which is accessible to them for farming.

The irrigation component takes into account of irrigated farms, either using harvested water or water from dug-outs where possible, to supply water to their farms to enable crop production both in the rainy and dry season.

When these two strategies are met, it means that farmers can have access to available water for farming both in the rainy and dry seasons. This therefore makes them to be water secure, and hence improves their agriculture activities.

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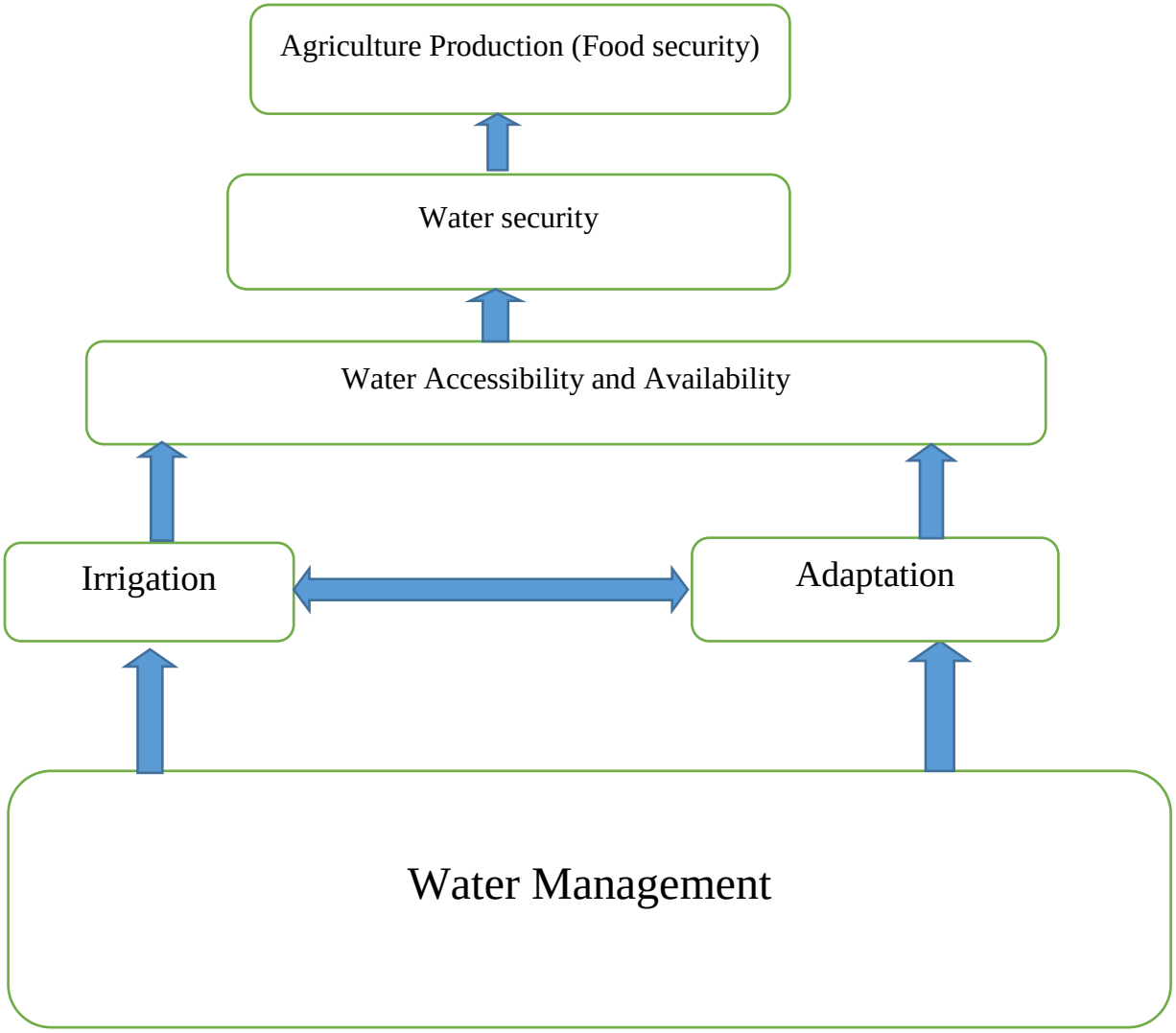

Fig: 5 Conceptual framework for WPI

Source: Author's conception

Water poverty evolved as a result of research conducted by WWF Nepal (2012) on water resource assessment at the global scale which was measured as a combination of resource availability and the ability of people to access the resource. With this, people are classified as being water poor if they cannot get sufficient water to carry on with their basic needs. Humans are also poor, if they need to walk long distances to get water.

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The WPI was formulated by Sullivan et al (2002) to take into consideration all aspects of water management. Therefore, the WPI defines water poverty by five components: capacity, access, use, resource and Environment.

Cook et al (2007) used the Bayesian Networks to calculate values for the above-mentioned five WPI components, which connect water and deprivation in Ghana's Volta Basin. Lawrence et al (2002) conducted a comparative analysis, describing the WPI of different countries from all over the world. As part of the Disaster Management sub-component, Castelazo et al (2007) incorporated flood risk vulnerability as a variable into the capacity component.

Van der Vyver and Dawid (2010) Water Poverty Maps for some areas in South Africa were computed and developed by WPI. WWF Nepal (2012) noted that WPI is a very effective water management resource, very useful in identifying areas with high or low rates of water deprivation, proving useful in the design of water-related policies and also one of the best tools for studying climate vulnerability.

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3.8.1 Theoretical Framework of WPI

The theoretical framework used for the WPI was adapted from WWF Nepal (2012) which is in line with the Center for Ecology and Hydrology (2016) and Matshe et. al (2016).

WPI in this study encompasses water resources availability to farmers, farmers' ability to access water for farming, farmer's ability to use the resource for productive purposes, and environmental factors impacting the ecology which water sustains.

In summary, the model has been designed to integrate into a single five key problems/issues concerning water resources and they are as follows; The Resource (R) component comprises surface, rain and groundwater availability thus sources that farmers can get water for their farming activities. The resource can be dug out, pond, dam, river, stream etc. Access (A) to water takes into consideration water for farming/irrigating crops, thus farmers' ability to get water for farming activities without any hindrance or restriction either by ownership or at a fee. The Use (U) variable focuses on the purpose for which water is used for different productive sectors, farmers' ability to use the water whenever and how they need it, such as livestock usage and for agriculture. Capacity (C) comprises a number of indicators focusing on supporting or enhancing human development of the area, which comprises the education that they had, and some trainings on skills development in managing the water resource. The Environment (E) component includes all the natural makeup of the area. It combines variables such as the topography, biodiversity, environmental degradation, water quality and soil erosion, which are very key in determining the quality as far as the environmental is concerned.

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3.9.0 Method of Data Analysis

3.9.1 Determining the water security level of farm households in the study area- Water Poverty Index (WPI)

To determine water security level of farm households in the study area, the Water Poverty Index (WPI) was used. The WPI is best calculated using the composite index approach. The components of this approach are combined using the general expression.

$$\text{WPI} = \frac{\sum wixi}{\sum wi}$$

WPI is the water poverty index value for Bawku West District, Binduri District and Nabdam District. Xi is the various components such as Resource, Use, Capacity, Environment and Access for the study area. Wi is the applied weight to each component. The various components are composed of sub-components and are combined in order to produce the different components using the same above methodology.

The equation can be rewritten as below according to the components mentioned above:

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

WPI values of 50% approaching 100% indicates lower water poverty indices whiles values below 50% are indicating higher water poverty indices i.e water insecurity.

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3.9.2 Measurement of water poverty components in the Bawku West District, Nabdam District and Binduri District.

In measuring water security, five key problems/issues concerning water were considered and they include:

i. **The Resource (R) component:** The Resource (R) component data was measured by asking farmers the available sources of water they use for farming. These included the following options rain or precipitation, surface, groundwater and dug-out, considering the seasonal and inter-annual variability.

ii. **On the accessibility (A)**, data was measured by considering farmers ability to get water for farming without restrictions, thus the availability of the water in enough quantity for farming throughout the season satisfactorily.

iii. **The Use (U)** Variable focuses on the purpose for which water is used for various agricultural purposes. Data on this component was measured by asking farmers whether their livestock are able to drink the water, whether farmers use the water for irrigation and other agriculture activities.

iv. **Capacity (C)** consists of a number of human development metrics, this was operationalized/measured on the field by considering farmers educational background, capacity building trainings or seminars farmers attended on water management and finally farmers' ability thus availability of income and fitness (health status) to manage water.

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v. **Data on the environment (E)** Variables like topography, biodiversity, environmental and water quality affects water stay duration on the farm and soil erosion, were obtained.

This was measured by asking farmers whether there has been flood incidence, soil erosion, bush fires and possible desertification (tree felling) in the area.

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3.9.3 To find out the constraints affecting smallholder farmers water management - The Coefficient of Concordance of the Kendall was used.

By applying this approach, the constraints faced by farmers in their farming activities are ranked using the Kendall's Concordance Coefficient. Kendall's Concordance Coefficient is a non-parametric statistical method used to classify/rank a given set of constraints or problems facing farmers, from the most influential to the less influential, and calculate the degree of agreement or harmony between farmers. Using numerals the constraints found were ranked from the most critical to the least important.

The total rank score was determined for each constraint, and the constraint with the high score was ranked as the most pressing one, while the constraint with the lower score was ranked as the least pressing.

Calculating the Kendall's Coefficient of Concordance (W), which measures the degree of agreement between farmers in the ranking, was done using the total rank score calculated from results.

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

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 (Kendall's Coefficient of Concordance) Varies between 0 and 1. Where 0 = perfect unanimity and 1 = partial consensus.

3.9.4 In examining factors influencing smallholder farmers' adoption of water management in the study area-Multivariate Probit model was used.

The research looked at the Multivariate Probit (MVP) model in the review of factors affecting the adoption of water management strategies by farmers. The key water management practices considered in this study are crop rotation, cover cropping, stone bunding, drought tolerance crops, compost/mulch, irrigation and water storage. The Multivariate Probit model is viewed as an extension of the Probit model, as it allows simultaneous estimation of several Probit models while allowing correlation of the error terms in those models (Greene, 2003). The variables for this study are discrete in nature, and using the OLS technique to model the determinants of farmers' adoption of water management strategies will lead to inefficient estimates.

It is worth noting that there might be correlation in the error terms and ignoring these correlations across the errors terms would to inefficient coefficients and thereby erroneous inference (Hsiao, 2003). Correlation occurs when some unobserved

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characteristics (intrinsic management skills) are included in the error terms, which influence adoption of water management practices.

When positive correlation occurs in the error term, it is interpreted as evidence of complementary that exist between the management strategies, while negative correlation is interpreted as evidence of substitution (Asfaw et al 2016; Ndiritu et al., 2014) this only holds on the assumption that unobserved heterogeneity is not correlated with explanatory variables.

$Y_{ik}^{*} = \beta_k X_{ik} + \alpha_k A_{ik} + \varepsilon_k$…… (1)

$Y_{ik} = 1\ if\ Y_{ik}^{*} >$ … … … … … (2) $0\ and\ otherwise$

Y_{ik}^{*} is a latent variable which captures the observed and unobserved preferences associated with the k^{th} improved agricultural technology.

Y_{ik} Represents the binary dependent variables.

A_{ik} Represents plot characteristics to account for unobserved heterogeneity.

β_k and α_k are parameters estimated.

ε_k Represents the multivariate normally distributed stochastic error term (Wooldridge, 2003).

X_{ik} is the parameter estimated

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3.9.4.1 The hypothesized variables from the MVP

Potential variables which were expected to influence household's adoption of water management are captured in the table below.

Table 2 Description, measurements and the expected signs of explanatory variables (Multivariate probit model)

Variable	Description	Measurement	Expected sign
		Dependent variables	
C. Rotation	Crop rotation	Dummy: 1 yes; 0=otherwise	+
C. cropping	Cover cropping	Dummy: 1 yes; 0=otherwise	+
S. bund	Stone bund	Dummy: 1 yes; 0=otherwise	+
D. tolerance	Drought tolerance	Dummy: 1 yes; 0=otherwise	+
C/mulch	Compost/mulch	Dummy: 1 yes; 0=otherwise	+
Irrigation use	Irrigation usage	Dummy: 1 yes; 0=otherwise	+
W. storage	Water storage	Dummy: 1 yes; 0=otherwise	+
		Explanatory Variable	
Sex	Sex of farmer	Dummy: 1 male; 0 = female	+
Age	Age of farmer	Years	+/-
FBO	farmer membership of FBO	Dummy: 1 yes; 0=otherwise	+
Maristat	Farmer marital status	Dummy:1= yes; 0 if otherwise	+/-
HH. size	Farmer household size	Continuous	+/-
Extension	Extension services received	Dummy: 1 yes; 0=otherwise	+
Credit	Farmer access to credit	Dummy: 1 yes; 0=otherwise	+
Drought	Drought experienced	Dummy: 1 yes; 0=otherwise	+
Excess rainfall	Excessive rain experienced	Dummy: 1 yes; 0=otherwise	+/-
Education	Number of years in school	1 = Primary, 2 = JHS, 3 = SHS, 4 = Tertiary, 5 = None	+
Water availability	Water availability for farming	Dummy: 1 yes; 0=otherwise	+/-
Runoff/erosion	Experience soil erosion	Dummy: 1 yes; 0=otherwise	+

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3.9.5 Determining the economic impacts of efficient water management on selected outcomes of smallholder farmers Trade off Analysis of Minimum Data (TOA-MD) model was used.

The research adapted Antle's TOA-MD model (2011), which noted that the TOA MD is a novel multi-dimensional impact assessment simulation tool that uses a statistical overview of a heterogeneous farm population to simulate the introduction and impacts of a new technology, a change in environmental conditions, and the provision of ecosystem services.

The strength of the TOA-MD model used in this study is that, it is designed to simulate what would be observed if it were possible to conduct a controlled experiment. Thus, the model simulates and compare two systems at a time, a base system (system 1) and a changed system (system 2) that is operated under altered conditions such that it provides different economic outcomes for farms (Antle and Valdivia, 2010).

In this experiment, a population of farms is offered the choice of continuing to use the current or "base" production system (System 1), or choosing to adopt a new system (System 2). TOA-MD is designed to be used with survey, experimental, simulated data, together with technological and socio-economic scenarios derived from experts and stakeholders.

Under system 1, farmers are initially operating a base technology with a base climate. This combination is defined as system 1. System 2 is defined as the case where farmers operate using a changed technology under a changed climate.

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If some farmers are worse off economically under the changed climate, they are said to lose from climate change. Overall gains and losses due to climate change can be measured by the proportion of farmers made worse off following climate change (Antle, 2011).

The model specification is as follows:

- Climate change without adaptation

System 1 = base climate, base technology, System 2 = changed climate, base technology

- Climate change with adaptation:

System 1 = base climate, base technology, System 2 = changed climate, adapted technology

- Adoption of adapted technology with climate change:

System 1 = changed climate, base technology, System 2 = changed climate, adoption of the adapted technology

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Each of these options can be done with any combination of policies, including water management policies.

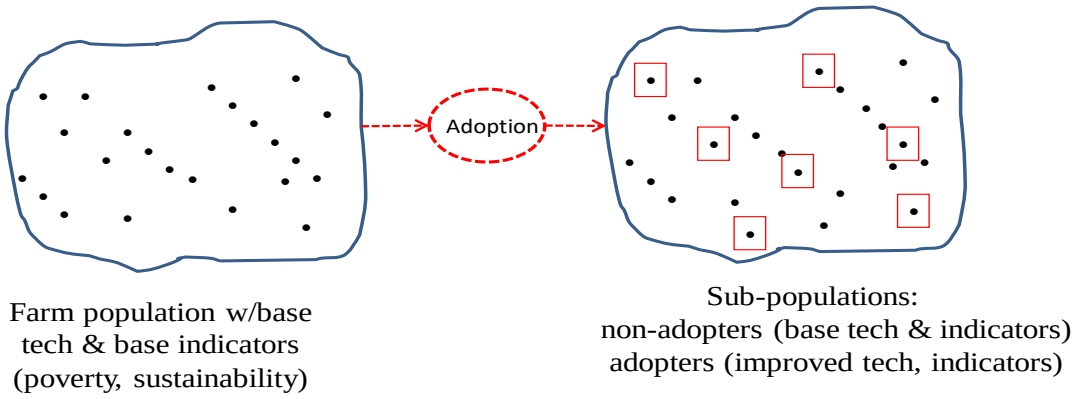

Figure 6: Structure of the TOA-MD model (Antle and Valdivia, 2010)

Let assume that a farmer at site (s) using a production system (h) with inputs prices (p) earns returns/ha equivalent to $V_t = V_t(s,h)$ each season. When the production system changes, due to a technology or climate change or both, expected returns also change at each site.

The impact of shifts from system j to system k on a farm's returns is$\omega(p,s,j,k) = V(p,s,j) - V(p,s,k)$. Thus, if $\omega(p,s,j,k)$ is positive it represents the loss associated with switching from system j to system k, and if negative it represents the gain from switching from system j to k. Let $\phi(\omega|p,j,k)$represent the spatial distribution of gains

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or losses in the population of farms indexed by s. The percentage of farms with $\omega(\mathrm{p,s,j,k}) < a$(with a an amount in Ghana cedis per hectare) is $r(a,p,j,k) = 100\int_{\infty}^{a}\varphi(\omega\backslash p,j,k)d\omega$

The TOA model normally examines five key climate model scenarios – the Hadley Centre Model (HADCM), the Canadian Global Climate Model (CGCM), National Centre for Atmospheric Research (NCAR) model, the Model Interdisciplinary Research on Climate (MIROC) and the Commonwealth Scientific and Industrial Research Organization (CSIRO) model.

In this study, the Commonwealth Scientific and Industrial Research Organization (CSIRO) model is used. The model is used because of its ability to predict farm returns, poverty rate and crop yield changes for SSA by 2050 when there is no adaptation even under climate change as noted by (Nelson et al., 2009).The study therefore used this model to outline the economic impacts of efficient use of water on the smallholder farmers in BD, BWD and ND.

Though the TOA model is best for this study, the weakness is that, the model cannot be used where it is not possible to have a base and controlled system for simulation. This makes it difficult/impossible to compare the two systems.

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CHAPTER FOUR

RESULTS AND DISCUSSION

4.0 Introduction

This chapter presents the results of the study based on the analysis of data collected from the field. It also provides a detailed discussion of the results, relating and comparing them to results of past and similar studies and drawing the possible implications for policy and development.

4.1 Farmers' Demographic and Socio-economic Characteristics

This section presents the socio-demographic and economic characteristics of the farmers interviewed. These include the sex, age, educational background, household size and marital status.

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Table 3 Demographic and socioeconomic characteristics of farmers

Characteristic	Frequency	Percentage (%)
Sex		
Male	283	81
Female	67	19
Education		
No formal education	237	68
Primary	42	12
JHS	56	16
SHS	9	3
Tertiary	6	2
Household size		
0-5	120	34
6-11	140	40
11+	90	26
Age		
20-30	65	19
31-40	87	25
41-50	100	29
51-60	50	14
60 and above	48	13
Mean age		**44**
Marital Status		
Married	250	71
Single	53	15
Divorced	6	2
Widowed	41	12

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Demographics characteristics are important variables of farmers, shaping many facets of their lives and have been found be indicators of farmers' attitude towards agricultural activities.

The sex distribution of individuals interviewed represent household heads/members who have detail information about the household i.e. household composition, property ownership and farm sizes. About 81% of farmers interviewed were males while 19% were females. This means that males dominate in the farming activities in the study area, which affirms findings of (SEND Ghana, 2014) that productive resources like land are highly accessible by men in Northern Ghana.

The relative high number of females' involvement in farming is as result of NGOs (ADRO, World vision) and some social/economic groups like the village saving groups (Adaaka group) where women take loan to support themselves in their farming business. These NGOs in the districts support farmers, especially female farmers, this actually influence women involvement in farming in the study area.

In terms of education, the research revealed that about 68% of the respondents as shown in the table above had no education at all representing the highest number, whereas 16% of the respondents had JHS education. It can also be seen in the table that those who had SHS and Tertiary education are 2.57% and 1.71% respectively.

The study revealed that household size of 11 and above was 45% representing the highest membership, while household size of 6-11 is 40.8% representing the second highest in terms of membership and the last household size was from the range of 0-5 being 14.2%. Many memberships in a household is important since that provide family labor in farming and other activities.

The results showed that farmers interviewed who are from the age range of 20-30 is 19% of the total population, this means that youth in the area are actively involved in farming activities. Farmers who fall within the age range of 31-40 are 25% of the population. The study also revealed that 29% of the population falls between the ages of 41-50. About 14% of the population falls in the age range of 51-60 and those who are 60 and above are 13%. The mean age of 44 is close to findings by Ziba (2015), who revealed an average age of 42.6 years for farmers in the UER, and also to(Adams and Ohene-Yankyera 2014;Baidoo *et al.* (2016)) who reported a mean age of 47.29 for Northern Ghana in their study.

On the marital status of respondents, married respondents were the predominant group representing 71.43%. On the other side, single respondents were 15.14% while divorced and widowed respondents were 1.71% and 11.71% respectively.

The socio-demographic results showed above have influence on farmers' decision to adopt water management strategies as well influence the water security level of households in study area. The economic outcomes of farmers and the constraints they face are determined by their socio-demographics.

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4.2 Livestock ownership

Respondents were interviewed on livestock ownership and it revealed that 95% of the respondents rear animals while 5% do not rear animals. Farmers revealed that the purpose of keeping these livestock is for economic, traditional as well as livelihood assets, thus farmers sell their animals in times of shortage to buy food or farm inputs to start the planting season.

The system under which these animals are kept is mainly the semi-intensive system where animals are housed in the night and are allowed to roam day time to feed during dry season. However, in the rainy season, the animals are tethered or herded by boys/herders to prevent them from grazing on crops.

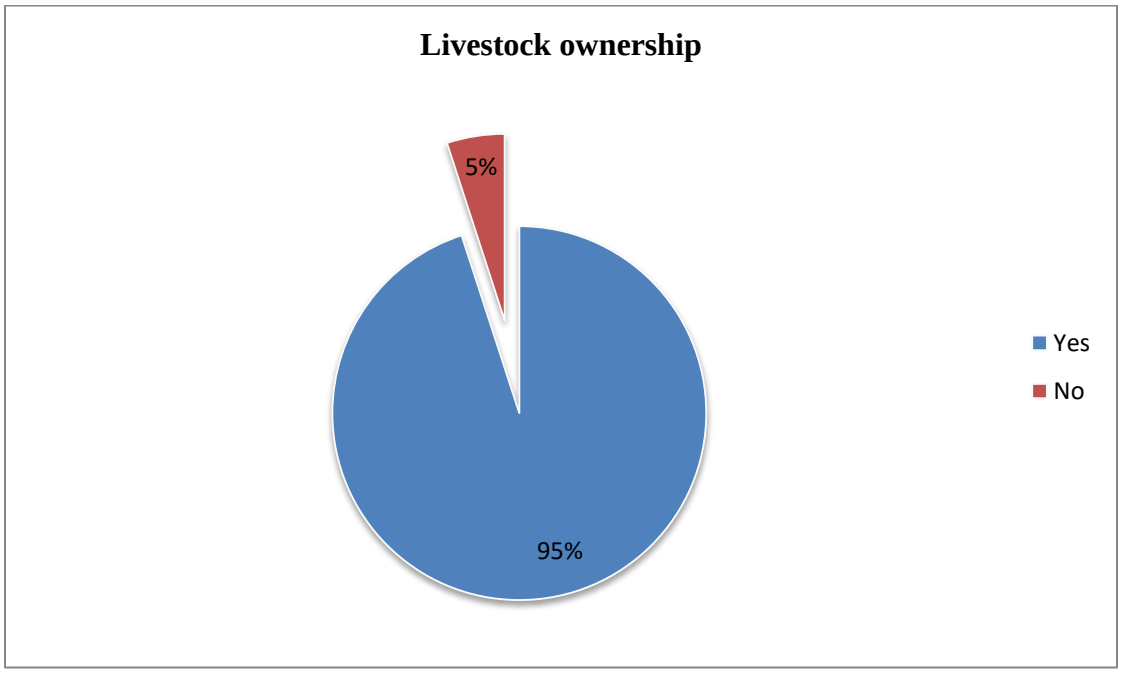

Fig 7: Livestock farmers owned

Own estimation from field data, 2019

The animals that farmers reared include; goats, sheep, cattle, pigs and various kinds of poultry as seen in the figure below. Farmers who reared poultry were 45%, which confirms Ayeah (2019) that most farmers in northern Ghana keep poultry as the commonest asset to rely on in times of need. The results also revealed that farmers who rear goats, cattle, sheep and pigs were 21%, 10%, 19% and 5% respectively. Rearing livestock presents an option for farmers keeping these livestock to rely on as livelihood assets to combat water scarcity impacts, water scarcity, climate change as well extreme events. Farmers sell some of the animals to pay children school fees, buy farm inputs and also use the animal droppings to fertilize the farms. Some of the farmers also use these animals to perform sacrifices to please their gods.

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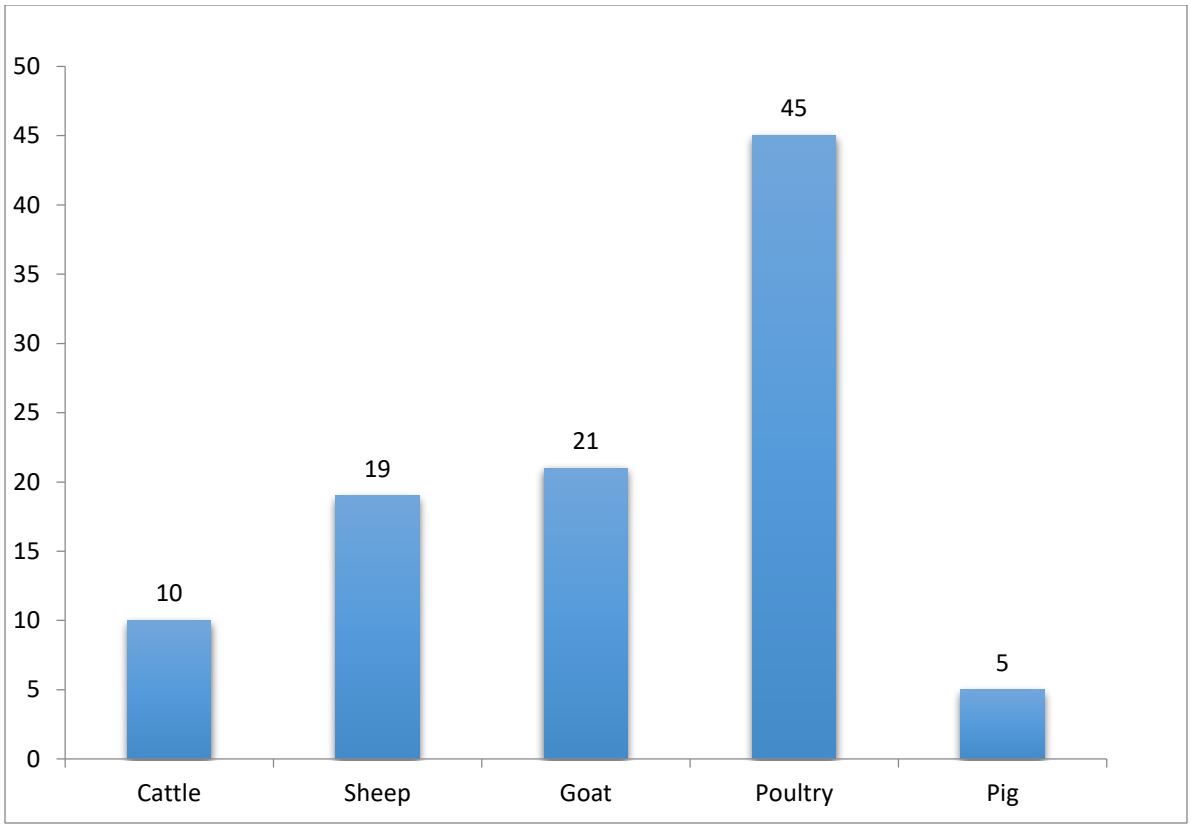

Fig 8: Animals owned by farmers

Own estimation from field, 2019

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4.3 Income from livestock rearing

Farmers make income from the sale of their animals, as animals are assets to them. The average income farmers make from the sale of cattle is GHs2528 per annum, with a minimum income of GHs700 and a maximum income of GHs7520 respectively per annum. On sheep, farmers make average income of GHs351 per annum with a minimum income of GHs80 and maximum income of GHs1800. Averagely, farmers also make GHs294 from goats, with minimum income of GHs75 and the maximum income of GHs1250. The average income realized from the sale of fowls is GHs97, with a minimum income of GHs10 and a maximum income of GHs250. Last but not the least, farmers made averagely GHs331 as income from guinea fowls with a minimum income of GHs10 and maximum income of GHs1500.

The above findings about livestock income is consistent with Baidoo *et al* 2016 who noted in their work in the Yendi municipality that livestock production has positive effect on household income and therefore has the potential to alleviate poverty among rural people in Ghana. The table below depicts the figures above.

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Table 4: Income from livestock rearing

Variable	Observation	Mean	Std. Deviation	Min	Max
Cattle	112	2528.125	1804.321	700	7520
Sheep	124	351.613	321.73	80	1800
Goat	200	293.975	261.08	75	1250
Fowl	238	97.101	57.39	10	250
Guinea Fowl	261	331.48	235.98	10	1500

Author's own estimation from field data, 2019

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4.4 Water security level of smallholder farm households in the Nabdam District, Bawku West District and Binduri District-Objective one

The Water Poverty Index (WPI) model is used to assess the agriculture water security level among smallholder farmers existing in the study area. The WPI comprises five main components which are Resource (R), Access (A), Capacity (C), Use (U) and the Environment (E). These components were assessed based on their indicators. It is worth noting that a high score in the individual component do not necessarily reflect in the overall score in the water poverty index result as it is seen table 5 below.

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Table 5: Water security level of smallholder farmers in the Nabdam district, Bawku West District and the Binduri District

District	Components					
	R	**A**	**C**	**U**	**E**	**WPI**
Weight	0.2	0.2	0.2	0.2	0.2	
BWD	70	45	30	60	28	46.6
BD	65	38	43	80	38	52.8
ND	67	75	45	97	32	63.2

Source: Field survey 2019

Resources as a component of water poverty index, refers to the physical availability of surface and ground water, including both rainy season and dry season. From the individual component results, it is seen that in terms of the resource, Bawku West district had the highest score of 70, clearly depicting water security in that component. This means in terms of the resource element, Bawku West is endowed with many water resources that farmers can access for dry season farming.

This was clearly evidenced on the field, when a farmer *(Mr. Agebere) in Googo in the BWD* noted that *"they do not have problem with water since they farm through the year using the White Volta''*. The Nabdam district scored 67 points, placing second in terms of water resources accessibility after Bawku West district, while the Binduri

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district had the lowest score of 65 points. However, one would have expected that since Binduri district is closed to the White Volta, it should have had a high score just like Bawku West but the findings prove otherwise. The access indicator measures the extent of access to water for human use, it does not account for only the distance to water source, but also the time needed to get water for irrigating crops.

The study revealed that communities' accesses to water are the dams, wells and rivers. Under this component, Nabdam District scored highest with 75, indicating water security in that component, followed by Bawku west district 45 while the Binduri district had the lowest score of 38. One would have expected BWD to be water secure in terms of access since it is secured in terms of the resource component but BWD was constrained by pumping machines to access the water for irrigation. This means that in terms of the access component, the Bawku West and Binduri Districts are water insecure and ND is water secure in terms of access. This is as a result of the ILSSI project in the ND which supported the farmers with irrigation equipment.

The capacity indicator considers the effectiveness of people's ability to manage water resource, this is interpreted in terms of income, membership of water users' association, education and training to manage water resources. The Nabdam District had the highest score of 45. This is as result of the education and training that farmers received from the ILSSI project in the district, which confirms Gariba (2018) that farmers' capacities are improved when they are given education and training. The Binduri District had the second highest core of 43 while the Bawku West District had the lower score of 30, the low scores are as result of lack of capacity building or training for farmers. With the capacity component, all the districts are water insecure.

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The use component considers the ways in which water is used for agriculture purposes. It also includes livestock use of water and irrigation. From the results, though ND scored second in resource, it is secure in water access because of the ILSSI project that built their capacity by given training which improve the use component with the highest score of 97, followed by BD 80 while BWD came last with 60. The high score of ND district is as result of the farmers' knowledge gained from the training on water use (irrigation). This confirms work done by Kaiyatsa (2014), who noted that farmers are able to irrigate their farms when they have full use of water resource.

The environmental component evaluates environmental integrity related to water and ecosystem. It includes the topography of the area, which has direct influence on erosion and flooding. From the result, it is seen that the Binduri district had the highest score of 38, followed by the Nabdam district 32 and the Bawku West district had the least score of 28. It is worth noting that in terms of the environmental component of the assessment as noted by Sullivan et al (2003), all the districts are water insecure.

Finally, drawing conclusions based on the individual component scores which give the overall score for the WPI.Both ND and BD score 63.2 and 52 respectively which is above the benchmark of 50, indicating water security while BWD score 46.6 which is below the benchmark (50) hence water insecure

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4.5 Constraints affecting water usage by smallholder farmers in the Bawku West District, Nabdam District and Binduri District

Objective two thus constraints affecting water usage by smallholder farmers was addressed and presented below.

The results of Kendall's W-test of the constraints affecting water usage by smallholder farmers in the study area are shown in the table 6 below. The high significant Kendall coefficient of 46.6%, shows a strong concordance in the constraints that farmers face in using water for agricultural purpose (W=0.466, p = 0.000), with the strong concordance, this allow us to reject the null hypothesis that there is no agreement among the rater.

Drought came first in terms of the ranking of the constraints that farmers face, followed by distance to the water resource and thirdly inadequate water resources in the study area. Drought ranking first confirms (Quddus et al., 202) who noted that drought is a serious production constraint and the only solution is irrigation. The inadequate water resources identified is in line with (Begna, 2020) who noted that agriculture productivity is limited by many diverse factors, both biotic and abiotic which included inadequate water resources and soil acidity.

The constraints identified and ranked above actually affirms the findings in section 4.7 where all the districts do not have the capacity to manage agriculture water for farming and also all the districts lack the environmental conditions necessary to ensure water availability. This affects farmers' productivity and net returns making them more vulnerable to bad economic and social conditions which confirm USAID Feed

the future (2017) report that the economic hardship is high mostly in Upper East Region especially Nabdam District.

It can also deduce from the findings that silted nature of the water source, water use fees and strict rules of water regulatory bodies were the least constraints farmers faced. These constraints negatively affect farmers' ability to access water for farming activities as it is in the case of the Bawku West and Binduri Districts in section 4.7.

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Table 6: Constraints faced by farmers in managing water in the Nabdam District, Bawku West District and Binduri District

Constraint	Mean rank	Ranking
Drought	4.49	1st
Distance to water	3.98	2nd
Inadequate water resource	3.96	3rd
Silted nature of water resource	2.95	4th
Water use fee	2.51	5th
Strict rules of water regulatory bodies	2.20	6th

Number of observation = 344 Kendall's W=0.466, df=5, Chi-Square=802.158, P-value=0.000

Author's own estimation from field data, 2019

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4.6 Multivariate probit regression analysis of factors influencing the adoption of water management practices

Objective three examining the factors influencing smallholder farmers' adoption of water management strategies was addressed using the above model.

The issue of climate change has led to so many adverse conditions that farmers are faced with. Farmers therefore have to adopt different strategies as a way to minimize the impact of climate change. As noted by Chalmers et al (2017), adoption is path dependent where strategies adopted earlier informs farmers' present decisions on subsequent strategies in the future.

It is necessary to use a good model to estimate these strategies, which take care of exogenous factors on the adoption strategies while permitting the error terms of each strategy to correlate. When these interrelations are not corrected, it can lead to biased estimates (Kassie et al, 2013).

The multivariate probit model is therefore used to determine the factors that influence the adoption of water management strategies since it jointly identify these factors influencing the probability of adopting each of the WMP strategies and at the same time accounting for interdependency.

The table below presents the results from the MVP model.

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Table 7: Results of multivariate probit regression analysis of factors influencing the adoption of water management practices

Covariate	C. rotation	C. cropping	S. bund	D. tolerance	C. mulch	Irrigation	W. storage
Sex	0.392**	-0.231	-0.128	0.101	-0.122	0.877***	0.037
	(0.032)	(0.235)	(0.469)	(0.588)	(0.511)	(0.001)	(0.848)
Age	-0.013*	0.0001	-0.021**	0.016**	0.011	0.001	0.013*
	(0.065)	(0.982)	(0.002)	(0.026)	(0.105)	(0.939)	(0.070)
ɜO	-0.078	0.599***	-0.029	0.028	0.320	1.439***	0.017
	(0.663)	(0.001)	(0.880)	(0.894)	(0.110)	(0.000)	(0.935)
aristat	-0.067	0.055	0.117	0.141	0.195	0.161	-0.053
	(0.719)	(0.780)	(0.515)	(0.467)	(0.290)	(0.499)	(0.777)
H. size	0.003	-0.004	0.036	0.007	0.005	-0.079***	0.022
	(0.900)	(0.860)	(0.131)	(0.786)	(0.849)	(0.009)	(0.367)
tension	0.286	-0.020	0.554**	0.189	1.139***	-0.279	0.904***
	(0.161)	(0.924)	(0.012)	(0.394)	(0.000)	(0.308)	(0.000)
edit	-0.136	-0.241	0.686***	0.036	0.504***	1.142***	-0.754***
	(0.460)	(0.203)	(0.000)	(0.846)	(0.006)	(0.000)	(0.000)
ought	-0.122	0.476*	0.233	0.053	0.456*	-0.677*	0.076
	(0.663)	(0.082)	(0.346)	(0.848)	(0.070)	(0.028)	(0.766)
cessive	-0.326	0.535**	-0.303	0.085	0.072	-0.463	0.033
nfall	(0.198)	(0.029)	(0.218)	(0.727)	(0.779)	(0.133)	(0.895)
lucation	-0.183	0.191	-0.289**	0.166	0.001	-0.470**	0.233
	(0.247)	(0.241)	(0.053)	(0.290)	(0.997)	(0.022)	(0.136)
ater	0.233	0.233	-0.151	0.176	-0.256	0.972***	0.060
ailability	(0.235)	(0.235)	(0.393)	(0.356)	(0.164)	(0.000)	(0.752)
unoff/ero	-0.203	-0.203	0.210	0.245**	0.076	-0.287**	0.132
on	(0.121)	(0.121)	(0.103)	(0.056)	(0.564)	(0.051)	(0.302)

Likelihood ratio test of rho21 = rho31 = rho41 = rho51 = rho61 = rho71 = rho32 = rho42 = rho52 = rho53 = rho63 = rho73 = rho54 = rho64 = rho74 = rho65 = rho75 = rho76 = 0: chi2(21) = 103.134 Prob > chi2 = 0.0000

Author's own estimation from field data, 2019

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Sex of respondent revealed positive association to both crop rotation and irrigation in managing agriculture water. This means that male farmers are likely to practice crop rotation and also irrigation than their female counterparts. This is because of resource endowment and the intensive nature of the work. This was also noted by Ragasa et al, (2013) that male farmers are more likely to adopt new technologies than their female counterparts due to labor availability and endowment of the male farmers. This therefore means that policies to encourage crop rotation and irrigation should target male farmers since they are more likely to adopt than the female farmers due to their resource endowment and labor availability.

Age of the respondent turned out to be negatively associated with the practice of crop rotation and stone bund but positively associated with the drought tolerant crops and water storage technologies. The finding is consistent with Baiyegunhi (2015) work where he noted that young farmers easily adopt technology than the older farmers in South Africa.

This suggests that younger farmers are more likely to adopt crop rotation and stone bunds compared to their older counterparts possibly because they are more innovative and keen on trying new technologies and methods to improve their net returns, thus their welfare. This finding is consistent with Akhter et al (2017). The reason could also be that creating stone bunds is tedious and requires a lot of the energy that the younger farmers possess. The finding also fits well in the theory of human capital; young farmers have the high chance of taking up new technology and applying it to everyday life (Sidibe, 2005).

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FBO membership of respondents is positively associated with cover cropping and irrigation, which means that farmers who belong to FBOs are more likely to adopt cover cropping and irrigation than their counterparts who do not belong to FBOs. The reason is that group membership help in the dissemination of information or new technologies to farmers, thereby creating their awareness of improved technologies like irrigation to supplement their crops in times of drought. Also farmers get access to credit to do their farming activities when they belong to a farmer group. This is in line with Israel (2019) that FBO membership makes it easy for farmers to access information and credit.

Household size was measured by considering the number of people who live together and eat from the same pot with one household head adapted from GLSS6 (2014). The results showed that household size is negatively associated with irrigation. The implication is that small household sizes are more likely to adopt irrigation as a water management strategy to counter water scarcity than their counterparts with large household sizes. The reason is that, a farmer with large household size spends more on family upkeep instead of adopt irrigation.

From the results, it is seen that extension is positively associated with stone bunds and compost/mulching. This means that farmers who have access to extension services are more likely to adopt stone bunds and compost/mulching, as a strategy to manage water scarcity than their counterparts who do not have access to extension services. The reason is that extension agents teach them the need to adopt smart practices to counter water scarcity. This confirms Nhemachena *et al* (2014) who noted that the access to

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extension services significantly increases the probability of taking up a new technology.

Credit access is positively associated with stone bunds, compost/mulching and irrigation which is in line with Chalmers *et al* (2017) that credit is a major determinant of technology adaptation as a water management practice. However, credit is negatively related to water storage, this means farmers who are constrained by credit are less likely to adopt water storage, this reaffirms Nonvide (2017) and Mulwa (2017) in their study using the Multivariate Probit model who also found that farmers have lower probability of adopting water and soil conservation management strategies when they have access to credit. Rather, farmers who have access to credit are likely to adopt stone bunds, compost/mulching and irrigation than their counterparts who do not have access to credit, with the reason that the strategies require capital

The result shows that drought is positively associated with cover cropping and compost/mulching but negative association with irrigation. This means that farmers who experience drought are likely to adopt cover cropping and compost/mulching than their counterparts who do not experience drought. Expectations are high that as one experience drought, the best alternative is to irrigate but the result rather revealed otherwise. As seen in section 4.7, most farmers in all the districts lack the capacity and the environmental conditions to irrigate except few, hence majority resort to cover cropping and compost/mulching.

Education has negative association with both stone bunds and irrigation, which means that people who do not have formal education are more likely to adopt stone bunds and irrigation than their counterparts with formal education. The reason could be that

those with formal education do not have time to do stone bund and irrigate. The result revealed that runoff/erosion has positive association with drought tolerant crops but negative association with irrigation. This means that farmers who experience runoff/erosion are likely to plant drought tolerant crops to counter the adverse conditions associated with runoff/erosion.

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4.6.1 Pairwise correlation coefficients of water management strategies from the MVP model

The pairwise correlations results of water management practices from the multivariate Probit model are presented below in the table. The likelihood ratio test (chi2 (21) = 103.134), Prob< 0.0000 of independence of the error terms of water management strategies is highly rejected. The alternative hypothesis of mutual interdependence among the water management practices is accepted.

The mutual interdependence among the use of stone bunds, crop rotation, drought tolerance crops, irrigation, cover cropping, compost/mulching and water storage by farmers backs the use of the Multivariate Probit model compared to the use of the independent probit models use to predict adoption of water management practices.

The joint interdependence among water management practices show that the likelihood of adopting any of the water management practices is co-dependent on the farmer's decision of whether to adopt another water management practice or not.

All the pairwise coefficients of the correlation between the regressed error terms are positive, except compost/mulching and crop rotation, water storage and crop rotation,

irrigation and cover cropping, and finally water storage and cover cropping whose coefficients were not even statistically significant.

Table 8: Pairwise correlations of water management practices

Water management Strategies	Correlation Coefficient	p-value
Cover Cropping and Crop Rotation	0.223**	0.015
Stone and Crop Rotation	0.359***	0.000
Drought Tolerant Crop and Crop Rotation	0.195**	0.027
Compost/Mulching and Crop Rotation	-0.023	0.808
Irrigation and Crop Rotation	0.109	0.330
Water Storage and Crop Rotation	-0.152	0.106
Stone Bund and Cover Cropping	0.256***	0.002
Drought Tolerant and Cover Cropping	0.134	0.155
Compost/Mulching and Cover Cropping	0.009	0.924
Irrigation and Cover Cropping	-0.079	0.480
Water Storage and Cover Cropping	-0.058	0.529
Drought Tolerant Crop and Stone Bund	0.036	0.712
Compost/Munching and Stone Bund	0.342***	0.000
Irrigation and Stone Bund	0.194*	0.067
Water Storage and Stone Bund	0.297***	0.001
Compost/Mulching and Drought Tolerant Crop	0.271***	0.001
Irrigation and Drought Tolerant Crop	0.094	0.414
Water Storage and Drought Tolerant Crop	0.191*	0.035
Irrigation and Compost/Mulching	0.357***	0.000
Water Storage and Compost/Mulching	0.276**	0.001
Water Storage and Irrigation	0.199*	0.053

Likelihood ratio test of rho21 = rho31 = rho41 = rho51 = rho61 = rho71 = rho32 = rho42 = rho52 = rho53 = rho63 = rho73 = rho54 = rho64 = rho74 = rho65 = rho75 = rho76 = 0:
chi2(21) = 103.134
Prob> chi2 = 0.0000
Author's own estimation from field data, 2019

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4.7.0 Descriptive Statistics of Base System Variables Used in the TOA MD Analysis

The Table below shows the disaggregated results across the two strata of farms thus farms who undertake water management practices (WMP) and farms who do not undertake water management practices (non-WMP). From the variables presented; farm costs, revenues and net per farm returns were computed per each farm and average across the strata of farms using the equations below:

$C = c(x, p)$ and $R = r(q, w)$ (1)

Where x and q are vectors referring to input and output quantities, and p and w refer to their respective price vectors. The cost incurred is the sum of seasonal rent on land, price per unit of seed, wage rate of labor, rent to capital inputs and other direct expenses. The capital variable is calculated as the sum of the cost of hiring animals and mechanical power for land preparation per farm, while other expenses captured as direct cost are calculated as the sum of fertilizer, herbicide and pesticide.

Revenue is also determined as a product of price of farm produce and quantity sold, consumed or given out. Net revenue was determined as $\pi = R - C = r(q, w) - c(x, p)$. These revenues and cost were determined for maize, sorghum, rice, millet and livestock.

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Table 9: Descriptive Statistics of Base System Variables Used in the TOA MD Analysis

Parameter/Strata	Farmers with WMP			Farmers without WMP		
Farm characteristics	**Mean**	**SD**	**CV%**	**Mean**	**SD**	**CV%**
Household size	9.36	2.88	30.81	10.08	3.43	34.05
Farm size	2.48	1.56	63.28	1.8	0.77	50.6
Off-farm income	557.58	490.56	87.97	528.57	435.73	82.40
MAIZE						
Yield(Kg)	6.98	4.82	69.02	3.93	4.72	120
Cost (GHs)	467.80	371.95	79.51	275.81	244.03	88.47
Rev (GHs)	2115.19	1906.47	90.13	1339.70	1672.39	124.83
NR (GHs)	1647.39	1620.34	98.36	275.81	244.026	88.47
SORGHUM						
Yield (Kg)	1.524	1.008	66.21	1.2126	0.9193	75.806
Cost (GHs)	73.50	6.38	8.68	76.286	6.993	9.167
Rev (GHs)	279.88	200.71	71.71	251.54	108.48	43.13
NR(GHs)	273.95	196.56	71.76	244.69	109.74	44.85
RICE						
Yield (Kg)	13.96	11.10	79.49	5.023	4.74	94.46
Cost (GHs)	163.68	106.09	64.82	169.23	117.63	69.51
Rev (GHs)	845.53	669.192	79.145	708.18	661.98	93.47
NR (GHs)	681.85	625.53	91.74	538.95	596.86	110.74
MILLET						
Yield (Kg)	1.52	1.05	69.177	1.146	0.6769	59.05
Cost(GHs)	87.043	31.38	36.057	104.143	36.64	35.182
Rev (GHs)	546.01	407.01	74.54	631.88	401.143	63.48
NR (GHs)	530.186	409.35	77.21	597.68	406.34	67.99s
LIVESTOCK						
Cost	152.47	102.78	67.41	114.54	88.12	76.93
Rev	2337.6	1823.65	78.04	1930.51	1306.91	67.93
NR	2185.13	1762.28	80.65	1817.15	1251.58	68.88

Author's summary from field data, 2019

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In the table 9 above, the analysis considered four staple crops (sorghum, rice, millet and maize) and also livestock measured in tropical livestock units. Two strata of farms were considered for the study. Stratum 1 referred to here as non-WMP farms are purely rain-fed farms that do not practice water management. Stratum 2 known here as WMP farms, are those that practice water management like irrigation.

With this study, it is assumed that WMP farms will be better off under increased temperature and reduced precipitation than non-WMP farms. Under this era of climate change, water management is an important adaptation strategy and possible determinant of economic outcomes for these farmers.

The above results revealed that WMP farms benefit more than non-WMP farms except the case of millet where the returns of non-WMP farms (GHs 597.68) are higher than WMP farms (GHs 530.19). This result is against the a-prior expectation that all gains from WMP farms are more than non-WMP farms. However, the finding is consistent with Shivhare et al 2019, Tiwari et al 2016 and Tounsi et al 2017 who noted that millet is drought and stress resistant and therefore its yields are not much affected by drought and other harsh weather conditions.

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4.7.1 Economic impacts of efficient water management strategies on selected economic outcomes of smallholder farmers.

This section presents the impacts of efficient water management on smallholder farmers and the general impacts of water scarcity on smallholder farmers' average net revenues, per capita incomes and the poverty rates (percentage of the farm population living on less than $1.00/day).

This was done using the results of non-WMP farms (i.e. farmers who do not manage water even under water scarcity) and WMP farms (i.e., farmers who manage water under water scarcity) across the CSIRO model using system 2 (where there is water scarcity i.e. reduced rain, high temperature due to climate change and farmers adopt water management). System 1 is considered to be the baseline (where we assumed no climate change, hence no adoption of new technology). These estimates are presented below.

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4.7.2 Net farm revenues, per capita incomes, and poverty rates among smallholder farmers in BW, BD and ND

As water availability for farming reduces because of climate change, the expectations are that farmers will face the associated consequences like low yield leading to low income and high poverty rates. The anticipation is that farmers being rational will try to reduce these impacts by adopting water management strategies. The results from the CSIRO model revealed the benefits of adopting water management. The expected average net returns for farmers who adopt WMP is GHs 6145 and non-WMP is GHs 3640. Similarly, the poverty rates are lower for WMP farms (9%) compared to the non-WMP farms (31%).

These results benefits the WMP farms with both net returns being high and poverty rate being low, the approach is based on the fact that even though the impacts of water scarcity may not be felt immediately, non-WMP farms will surely feel the impacts more than WMP farms. Knowledge of poverty rate and the net returns give fair idea of

the level of farmers' vulnerability and resilience to water scarcity and the associated impacts.

Considering the per capita income, WMP farms average net returns is GHs 784.07 and non-WMP farms net returns is (GHs 461.50). This means that averagely farmers who practice water management as a way of coping with climate change (water scarcity)get higher income than farmers who do not practice water management. The implication is that even though there is water scarcity due to climate change, farmers who practice water management will be more robust, resilient and better off than non-WMP farmers because of the adoption of water management strategies, which improves their income and hence welfare.

The per capita income of farmers is known to be the best indicator of farmers' welfare and therefore the source for farmers' resilience to stress such as water scarcity due to climate change (Dube et al. 2013). The direct implication of farmers' income decline is that their resilience to stress and other shocks generally are affected resulting in negative change.

Because of the negative impacts of climate change affecting water availability for farming, if farmers adopt water management it increases their water use efficiency and improve their resilience against water scarcity, poverty rates and other economic indicators of farmers will decline. The poverty rates were estimated to be 9% for WMP farms and 31% for non-WMP farms, this means that WMP farms are better off with averagely low poverty rate (9%) compared to non-WMP farms, where the average poverty rate of 31% is high. The net returns, per capita income and poverty rates results are presented in the table below.

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Table 10: Impacts of water scarcity on net returns, per capita income and poverty rates in the BD, BWD and ND in the Upper East Region of Ghana

Stratum	Net returns per capita (GHS)	Per capita income (GHS)	Poverty rates (%)
	NO ADAPTATION		
Non-WMP	2707.84	358.26	50
WMP	3853.66	516.02	28
All farms	**2964.39**	**429.26**	**40**
	ADAPTATION		
Non-WMP	3640.15	461.50	31
WMP	6145.06	784.07	9
All farms	**4201.02**	**606.66**	**21**

Author's summary from TOA data, 2019

The estimated gains and losses expressed as percentage of mean net revenue suggest that WMP farms in BW, BD and ND on aggregate will benefit more than the non-WMP farms, if the current production systems and trend are maintained. Based on the above findings, farmers are advised to adopt water management strategies since that increase their income level as well reduce their poverty level, hence improve their general wellbeing.

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4.7.3 Percentage gainers, gains, losses and net losses for smallholder farmers in the Binduri District, Bawku West District and Nabdam District in the Upper East Region

The percentage of farmers whose future net revenues and per capita income increase as their poverty level fall due to switching from system 1 to system 2 because of water scarcity are hereby referred to as percentage gainers. As seen below in the table using CSIRO model scenario, the results show that WMP farms had higher percentage of gainers than non-WMP farms. Gainers accounted for 89% under WMP farms and 45% under non-WMP farms. This clearly depicts that water management practices are expected to have a more profound effect on the livelihood of smallholder farmers who adopt system 2 under changing climatic conditions than farmers who do not adopt.

Table 11: Percentage gainers, loss, gains and net loss for smallholder farmers in the BD, BWD and ND in the Upper East Region of Ghana

Stratum	Percent gainers	Gains (%)	Loss (%)	Net Loss (%)
		NO ADAPTATION		
Non-WMP	46.92	24.13	29.27	5.15
WMP	42.41	10.33	16.69	6.37
All farms	**44.76**	**19.77**	**429.26**	**5.53**
		ADAPTATION		
Non-WMP	81.64	66.86	6.68	60.18
WMP	98.87	75.93	0.13	75.79
All farms	**89.89**	**69.73**	**4.61**	**65.12**

Author's summary from TOA data, 2019

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As seen in the table above, farms which manage water gained more and lost less compared to those that failed to manage water. The aggregate losses is huge (25%) for non-WMP farms and relatively small (5%) for WMP farms. This means that managing water when there is climate change reduces the aggregate loss that farms are likely to encounter and this increases farmers' gains. Assuming the effects of water scarcity as a result of climate change in agricultural system increases in the BW, BD and ND, the results suggest that aggregate percentage of gainers for non-WMP farms will be about 45% of the population of farms while the aggregate percentage of gainers will be about 89% for WMP farms and the aggregate losses will be 25% for non-WMP farms and 5% for WMP farms in the study area.

The analogy is that water management buffers farms from the negative effects of reduced precipitation and increased temperature, and guarantees farm productivity. The analysis shows the importance of adopting water management as a mitigating strategy for water scarcity caused by climate change.

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CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.0 Chapter outline

Key findings from the study are summarised and presented in this chapter. Relying on these key findings, conclusions are drawn and recommendations are made for policy makers and also for further research on similar area of study.

5.1 Summary of Key Findings

Results of the water security analysis in the study area showed that BD and ND are water secure with water poverty indexes of 52.8 and 63.2 respectively while BWD is water insecure with the water poverty index of 46.6. Having computed the final WPI as seen above, it was necessary considering the various components scores. In terms of the Resource component, the Bawku West District is endowed with water resources with the highest of score 70, followed by Nabdam district (67) while the Binduri district had the lowest score of 65.

On the access component, the results revealed that dams, wells and rivers were accessible to farmers for supplementary farming. Under this component, the Nabdam District had the highest score of 75, followed by the Bawku West District 45 and the Binduri District had the lowest score of 38. This means that farmers in the Nabdam District have more access to water than their counterparts in the other districts.

Results on farms capacity to manage water revealed that the Nabdam District had the highest score of 45, the Binduri District had the second highest core of 43 and the Bawku West District had the lowest score of 30. Also on the use component, the results showed that the Nabdam District had the highest score of 97, followed by the

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Binduri District 80 and the Bawku West District had the least score of 60. Results on the environment component just like the other components also revealed that the Binduri District had the highest score of 38, followed by the Nabdam District 32 and Bawku West District had the least score of 28. The combinational analysis revealed that both the BD and the ND are water secure while the BWD is water insecure.

On the aspect of constraints affecting water use, the results revealed that drought, distance to water resources and inadequate water resources were the main constraints while the silted nature of water sources, water use fees and strict rules of water regulatory bodies were the least constraints.

Empirical results from the Multivariate Probit model showed thatFBO membership thus farmers who were members of FBOs had the higher likelihood of water management strategies and same applies to the others (access to extension services, credit access, drought, runoff/erosion) this means that the probability of adopting water management strategies increased.

The TOA MD descriptive results revealed that the potential benefits accruing to farms who adopted WMP are more than farms that do not use efficient WMPs. However, the returns from millet was high for WMP farms (GHs 530.19) than non-WMP farms (GHs 597.68) With off-farm income, those who practice water management had more mean income of GHs 557.58 whiles those who do not practice water management had GHs 528.57. It is also seen that the mean returns of WMP farms from maize (GHs 1647.39) is higher than farms that do not practice water management (GHs 275.81). The rice result also revealed higher returns (GHs681.85) for WMP farms than non- WMP farms (GHs 538.95).

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Also the average income from livestock is high for WMP farms (GHs 2185.13) while farms that do not manage water average income is (GHs 1817.15). Generally, the average income for WMP farms is GHs 557.58 and non-WMP farms also get GHs528.57.

The results also revealed that the percentage gainers thus farmers whose future net revenue, per capita income increases, whiles their poverty level reduces due to switching from system 1 to system 2. This shows that under CSIRO model scenario, farmers who practice water management had higher percentage of gainers than farmers who do not practice water management. Gainers accounted 89% for WMP farms, and 45% for non-WMP farms respectively among the entire population of farms.

Poverty rates among smallholder farms were estimated, that is percentage of farm populations living on less than $1.00 per day due to climate change. At the disaggregated level, farmers who practice WMP have a poverty rate of 9% and 31 % for non-WMP farms. This means that the impact of climate change will definitely increase poverty rates in the near future. In a different way, climate change will pose serious additional threat to these poor smallholder farmers by significantly decreasing crops and livestock yields, assuming they remain on the use of the base technology under the changed climate.

Results on expected net revenues per farm, per capita incomes, and poverty rates showed the average net returns per farm using the CSIRO scenario model, and per capita income is higher for WMP farms than non-WMP farms. The average net farm

revenue and mean per capita income were approximately GHS6145 and GHS3640 for WMP farms and non-WMP farms in the model respectively.

5.2 Conclusions

By assessing the implication of water scarcity at the farm level of smallholder farmers in the study area, it is conclusive that both Binduri District farmers and Nabdam District farmers are water secure while Bawku West District farmers are water insecure. Because of water scarcity, farmers living in BWD and region at large are encouraged to develop the habit of managing water since they are more vulnerable to the impacts of water scarcity.

The study also concludes that the major constraints farmers face are drought, distance to water source and inadequate water resources. On combating water scarcity, it is observed that, drought, sex, FBO membership, access to extension services and credit access are the major factors influencing farmers adoption of water management.

Additional conclusion is that farmers who adopt water management practices are economically better off than farmers who do not adopt water management, with low poverty rate.

Final conclusion is that climate change affects surface water availability everywhere in the study area and further reductions in rainfall and increase in temperatures will negatively affect livelihood assets.

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5.3 Recommendations

The following recommendations are made based on the findings of this study,

i. Government policies on water in the BD, BWD and ND should target constructing more water source for farmers to supplement their farms especially during drought and also for dry season farming especially for farmers in Bawku West District to boost their income.

ii. Also, the few dams in the study area should be desilted to contain more water for farming possibly through the one village one dam project to ensure water availability.

iii. MOFA, NGOs, research institutions and other stakeholders in agriculture should provide capacity building training for farmers on adaptation strategies suck as stone bunding, crop rotation, cover cropping, use of compost etc to build resilience of farmers on water scarcity.

iv. Policy measures which promotes water management like mulching, use of compost, stone bund etc should be encouraged since they help increase the surface water availability. This can be done through the ministry of food and agriculture extension agents at the district level to improve water availability for farming.

v. The government of Ghana, through MOFA should integrate water management policy in the agriculture sector for extension agents to implement the practice to smallholder farmers since WMP strategies increase net returns, per capita income and reduced poverty rate among farmers. By doing so, government

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takes a step closer to reducing poverty and improving farmers' welfare which is key in the modernizing Agriculture in Ghana project.

vi. One key important adaptation strategy for policy makers and farmers will be the introduction of more water management strategies to offset some of these negative effects of water scarcity on agricultural productivity which will improve net farm incomes and finally reduce poverty rates in the study area.

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APPENDIX

University for Development Studies

Department of Agricultural and Resource Economics

A survey to assess the Implication of Agriculture Water Security for Smallholders Farmers in The Upper East Region of Ghana

Dear respondent, as part of my M.Phil. Research at the University for Development Studies Nyankpala campus, I am undertaking a survey to assess the implication of agriculture water security for smallholder farmers in the Upper East Region of Ghana. I would be grateful for your participation in the completion of this questionnaire. Please answer as frankly as possible, confidentiality is assured.

Date of survey	
Enumerator's name	
Respondent's name	
Respondent's phone number	
District of survey	
Name of community	

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SECTION A: SOCIO-DEMOGRAPHIC INFORMATION

1. Sex of respondent	Male = 1 Female = 2
2. Age of respondent	
3. Are you the household head	Yes = 1 No = 2
4. If no, how old is the household head?	
5. Relationship to household head	Spouse = 1 Child = 2 In-law = 3 Others = 4
6. Marital status	Single = 1 Married = 2 Divorced = 3 Widowed = 4
7. Educational level of respondent	None = 0 Primary = 1 JHS = 2SHS = 3 Tertiary = 4
8. Religion	Islam = 1 Christian = 2 Traditional = 3 Other = 4
9. Household size	Total…. Male…… Female……
10. Number of children	Total…... Male…... Female……
11. Do you belong to FBO/farmer's group	Yes = 1 No = 2
12. Do you have access to Agric. extension	Yes = 1 No = 2

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13. Do you have access to credit	Yes = 1 No = 2

14. Please indicate whether or not you own any of the following assets and the quantity owned

Asset	**Response (1=Yes, 0=No)**	**Quantity**	**Asset**	**Response (1=Yes, 0=No)**	**Quantity**
Hoe			TV		
Cutlass			Tractor		
Donkey cart			Mobile phone		
Bullock plough			Radio		
Bicycle			Watering can		
Motor bike			Knapsack sprayer		
Tricycle			Radio		

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SECTION B: WATER SECURITY LEVEL OF FARM HOUSEHOLDS FOR FARMING

15. What are the available sources of water you use for farming?

    a. Well = 1 b. dam = 2c. Rain = 3 d. pipe = 4 e.borehole = 5f. Others (specify) = 6

16. Do you have access to sufficient water for farming throughout the year?

    a. Yes = 1 b. No = 2

17. Do you experience drought during the farming season?

    a. Yes = 1 b. No = 2

18. Do you experience excessive rainfall during the farming season?

    a. Yes = 1 b. No = 2

19. Do you have enough water/rain for farming throughout the year?

    a. Yes = 1 b. No = 2

20. Are you satisfied with the availability of water for farming throughout the year?

    a. Yes = 1 b. No = 2

21. Do you practice irrigation on your farm?

    a. Yes = 1 b. No = 2

    If No, skip

22. How did you get the irrigated land?

    a. Inherited from family = 1 b. Gift from relatives = 2 c. rent = 3d. Share cropping = 4

    e. Government redistributions = 5

23. What is your opinion on irrigation?

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a. Useful but expensive b.Not useful

24. Do you have access to sufficient water?

a. Yes = 1 b. No = 2

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

SECTION C: CONSTRAINTS THAT AFFECT WATER USAGE BY SMALLHOLDER FARMERS

26. What are some of the district policies that affect water use in this community?.....

.....

.....

.....

27. What are some of the beliefs that affect water usage in this community?.....

.....

.....

.....

28. What are some of the processing factors that affect water use in this community?.....

.....

.....

.....

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29. What are the management practices that affect water use in this community?.....

.....

.....

.....

30.

Fill in the table below by ranking how the following constraints affect water usage negatively in your community

0=not important, 1= low importance, 2= medium importance, 3= important 4 = very important 5 = very very important and 6 = not important at all

Constraints	**How it affects water**	**Code**
Inadequate water resource		
Distance to water source		
Water user fees		

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Drought		
Strict rules of water regulatory bodies		
Silted nature of water resource		

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SECTION D: FACTORS INFLUENCING SMALLHOLDER FARMERS' ADOPTION OF WATER MANAGEMENT

31. Does the incidence of climate change influence your decision to adopt water efficient management practices?
    a. Yes = 1 b. No = 2
32. If yes, how?.....
    .....

33. Does income level determine your decision to adopt water management?

    a. Yes = 1 b. No = 2

34. If yes, how?.....

    .....

35. How important are the following are factors in influencing your decision to use efficient water management practices on your farm?

Factor	1 = not important 2=fairly important 3 = important 4 =extremely important	Nature of Influence
Runoff/erosion		
Pollution		
Urban growth		

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Household size	
Gender	

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SECTION E: ECONOMIC IMPACTS OF EFFICIENT WATER MANAGEMENT PRACTICES ON FARMERS' PRODUCTIVITY AND SOME ECONOMIC OUTCOMES

37. System I (base practices without water management)

Inputs used in the production of some staple food crops

Maize (land size)……	Input	Quantity	Unit price	Total cost
	Fertilizer (Kg)			
	Seeds (Kg)			
	Pesticides (litres)			
	Herbicides (litres)			
	Tractor/bullocks			
	Labor (hired)			
Rice (land size)…….				

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	Fertilizer (Kg)			
	Seeds (Kg)			
	Pesticides (litres)			
	Herbicides (litres)			
	Tractor/bullocks			
	Labor (hired)			
Millet(land size)……				
	Fertilizer (Kg)			
	Seeds (Kg)			
	Pesticides (litres)			
	Herbicides (litres)			
	Tractor/bullocks			
	Labor (hired)			
Sorghum(land size)……				
	Fertilizer (Kg)			
	Seeds (Kg)			
	Pesticides (litres)			
	Herbicides (litres)			
	Tractor/bullocks			

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	Labor (hired)			
Vegetables (land size)…….	Fertilizer (Kg)			
	Seeds (Kg)			
	Pesticides (litres)			
	Labor (hired)			

Quantity harvested and amount realized

Crop	Qty harvested	Unit price	Total amount
Maize			
Rice			
Millet			

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Sorghum			
Vegetables			

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38. Generally, how is your assertion about your output before water management and after you adopted water management?.....
.....
.....
.....

SECTION F: HOUSEHOLD INCOME

39. Do you rear any livestock? Yes ( ) = 1 No ( ) = 2
40. What is your reason for rearing livestock?……
……
41. Do you generate income from the sale of farm manure? Yes ( ) = 1 No ( ) = 2
42. How much do you earn from the sale of manure?.....

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43. Please provide information on income from livestock production in the past 12 months

Livestock type	**Current number**	**Number sold in the last 12 months**	**Total income from livestock sale**	**Reason for keeping livestock**
Cattle				
Sheep				
Goat				
Chicken				
Guinea fowl				

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44. Non-farm household income sources throughout the year

Source	**Amount**
Remittance	
Non-farm business	
Others……..	

THANK YOU VERY MUCH FOR YOUR TIME

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