

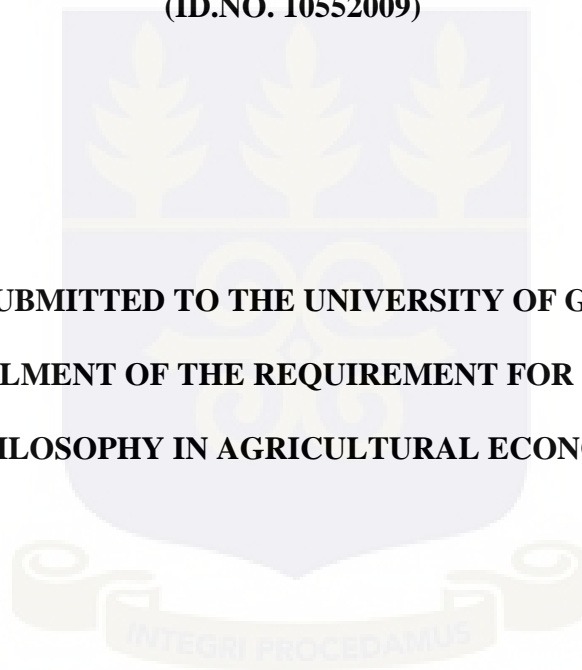
**THE ADOPTION OF THE PAVE IRRIGATION TECHNOLOGY (PIT) AND
FINANCIAL VIABILITY OF SMALLHOLDER VEGETABLE FARMING IN THE
NORTHERN AND UPPER EAST REGIONS, GHANA**

BY

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**THIS THESIS IS SUBMITTED TO THE UNIVERSITY OF GHANA, LEGON IN
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**DEPARTMENT OF AGRICULTURAL ECONOMICS AND AGRIBUSINESS
COLLEGE OF BASIC AND APPLIED SCIENCE
UNIVERSITY OF GHANA**

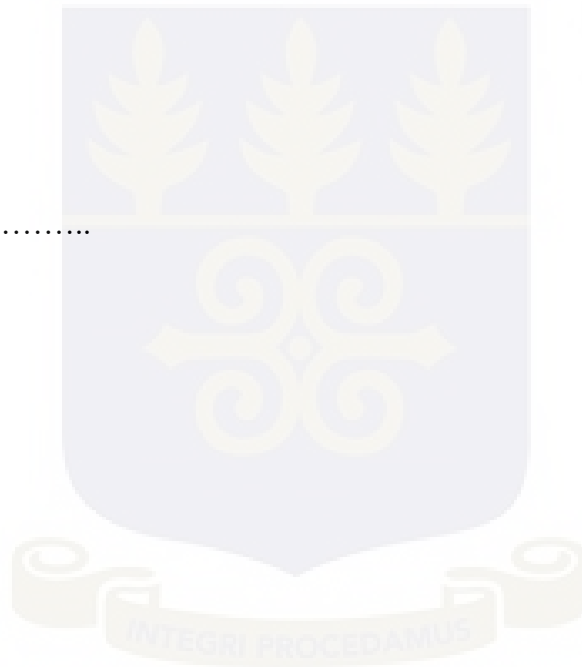
JULY 2017

DECLARATION

I Mohammed N. Ibrahim, the author of this thesis titled, “The Adoption of the Pave Irrigation Technology (PIT) and Financial Viability of Smallholder Vegetable Farming in the Northern and Upper East Regions, Ghana” do hereby declare that, with the exception of references duly cited, this work was undertaken by me from August 2016 to July 2017 in the Department of Agricultural Economics and Agribusiness, University of Ghana, Legon. I hereby declare that, this work has not been submitted either in part or whole for a degree or diploma in this University or elsewhere.

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This thesis has been presented for examination with our approval as supervisors:

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Professor Daniel Bruce Sarpong
(Major Supervisor)

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Dr. John Baptist Donsaanang Jatoe
(Co-Supervisor)

DEDICATION

I dedicate this work first of all to Almighty God for HIS guidance and protection. Secondly to my lovely parents, wife and son for their encouragement, love and support throughout the period of my study.



ACKNOWLEDGEMENT

First of all am so grateful to the Almighty God for giving me outstanding wisdom and guidance to do this work to a successful end.

I would also express my profound gratitude to my supervisors Professor Daniel Bruce Sarpong and Dr. John Baptist Donsaanang Jatoe. Their meticulous advices, patience, suggestion, systematic and consistent guidance have made this piece of work possible. Also, I thank all the lecturers in the Department of Agricultural Economics and Agribusiness, University of Ghana for their constructive criticisms and suggestions.

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My sincere appreciation also goes to all respondents and enumerators for sacrificing their time and effort to assist me get relevant information for this study.

Finally, am thankful to all my friends and loved ones for their endless encouragement and to all those that have contributed in one way or the other to the success of this work and so grateful.

God Bless you all.

ABSTRACT

The prevalence of climatic events, such as drought and floods in northern Ghana has contributed significantly to food shortages in the area. This prompted the need for appropriate alternatives to enhance food production and improve rural livelihoods. The PAVE Irrigation Technology (PIT) is rainwater harvesting technology being promoted by Conservation Alliance (CA), International Fertilizer Development Centre (IFDC) and International Water Management Institute (IWMI) in Northern Ghana to serve as source of irrigation water for dry season farming. The question is: as a new technology is it financially viable for vegetable production and what factors inform its investment and adoption decisions.

The study is theoretically founded on the utility theory, with the assumption that smallholder vegetable farmers seek to maximise their farm incomes. Data was collected randomly from 380 smallholder vegetable farmers in three communities in the Northern and Upper East Regions where the technology was installed. The Net Present Values (NPV) and Benefit Cost Ratios (BCRs) from the three communities were estimated for the PIT's financial viability in vegetable production. A Probit model was employed to analyse the factors that influences the adoption of the technology. Willingness to pay amount and the factors influencing the willingness to pay (WTP) amount were analysed using an interval regression model.

The cost-benefit analysis revealed that vegetable production under the PAVE Irrigation Technology is financially viable. It was found that majority (88.4%) of respondents in the study area were willing to adopt the PAVE Irrigation Technology (PIT) and their willingness to adopt were influenced by age, formal education, access to extension, technology awareness, perceived reliability of the technology, gender consideration in management, training, perceived user friendliness and. The mean willingness to pay (WTP) value was found to be GHC 103.554(\$23.82)/0.3acres/ dry season which is higher than the proposed service fee of GHC 90(\$20.70)/farmer/season. It was found that, formal education, household size and other income sources, respondent experience of food shortage and mode of payment may have significant effects on the WTP amount. Also, financial constraints and market inaccessibility were found to be most pressing constraints that are likely to inhibit the adoption of the technology.

It was recommended among others that the government (MoFA and GIDA) and Non-Governmental Organizations (NGOs) complement the efforts of Conservation Alliance (CA) and their partners to establish more units of the technology to enhance food security and improve rural livelihoods.

TABLE OF CONTENT

DECLARATION	i
DEDICATION	ii
ACKNOWLEDGEMENT	iii
ABSTRACT.....	iv
LIST OF TABLES	x
LIST OF FIGURES	xi
LIST OF PLATES	xi
LIST OF ACRONYMS/ABREVIATIONS.....	xii
CHARTER ONE: INTRODUCTION	1
1.1 Background.....	1
1.2 Problem Statement	4
Plate 1. 1: A Picture of the PIT	6
Plate 1. 2: Material Used in the PIT Development	8
1.3 Analytical Framework.....	9
Figure 1.1: Analytical Framework.....	10
1.4 Research Objectives.....	11
1.3.1 Main Objective.....	11
1.3.2 Specific Objectives	11
1.5 Justification of the Study	12
1.6 Organisation of the Thesis	13
CHAPTER TWO: LITERATURE REVIEW	14

2.1 Introduction.....	14
2.2. Overview of Smallholder Rainwater Harvesting Irrigation Systems	14
2.3 Types of Irrigation Systems in Ghana	16
2.3.1 Conventional Irrigation Systems.....	17
2.3.2 Emerging Irrigation Systems	18
2.4 Irrigation Water Control and Management.....	19
2.5 Viability of irrigation Systems and Technologies	22
2.6 Theories of Technology Adoption	24
2.7 Empirical Studies on Agricultural Technology Adoption	26
2.8 Irrigation Water Pricing and Willingness to Pay (WTP).....	28
2.9 Constraints of irrigation technology adoption	35
2.10 Summary of Literature Review.....	36
CHAPTER THREE: METHODOLOGY	37
3.1 Introduction.....	37
3.2 Theoretical Framework.....	37
3.3 Methods of Data Analysis.....	38
3.3.1 Cost Benefit Analysis (CBA).....	38
3.3.2 The factors that Influence Smallholder Vegetable Farmers Willingness to Adopt the PIT.....	39
3.3.3 The Amount Smallholder Vegetable Farmers are Willing to Pay	44
3.3.4 Factors that Influence Smallholder Vegetable Farmers WTP Amount	45
3.3.5 Constraints of Adopting the PIT	50

3.4 Data Collection	51
3.4.1 Types and Sources of Data	51
3.4.2 Sampling Procedure and Sample Size	52
3.4.3 Sample Size Determination.....	52
Table 3.1: District, Community and Sample Size.....	53
3.4.4 Study Area	53
Figure 3. 1: Map of Study Area	55
Figure 3. 2: Map of Study Area with Major Rivers.....	56
CHAPTER FOUR: RESULTS AND DISCUSSIONS.....	57
4.0 Introduction.....	57
4.1 Socio-Economic Characteristics of Respondents	57
4.1.0 Gender of Respondents	57
Table 4. 1: Gender of Respondents by Community.....	57
4.1.1 Age Distribution of Respondents.....	58
Table 4. 2: Age Categories of Respondents.....	58
Table 4. 3: Age Categories by Community	58
4.1.3 Religion of Respondents	58
Table 4. 4: Religious Distribution of respondents	59
4.1.4 Marital Status of Respondents	59
Table 4. 5: Marital Status.....	59
4.1.5 Respondents Education.....	59

Table 4. 6: Level of Education of Respondents	60
4.2 Viability of the PAVE Irrigation Technology in Smallholder Vegetable farming.	60
4.2.2 Costs Identification	61
4.2.3 Benefits Identification.....	61
4.2.4 Choice of Interest Rate.....	61
Table 4. 7: Results of Financial Cost-Benefit Analysis by Community.....	62
4.3 Factors Influencing Smallholder Vegetable Farmers’ Willingness to Adopt the PAVE Irrigation Technology (PIT).....	63
4.3.1 Willingness to Adopt the PAVE Irrigation Technology (PIT)	63
Table 4. 8: Willingness to Adopt	63
Table 4. 9: Result of Probit Model.....	64
4.3 Socio-Economic Distribution of WTP Bids	68
Table 4. 10: Distribution of Willingness to Pay Bids per 0.3 Acres per Month.....	69
Table 4. 11: Distribution of WTP Bids by Community.....	70
Table 4. 12: Distribution of WTP Bids by Gender	70
Table 4. 13: Distribution of WTP bids by Age.....	71
Table 4. 14: Distribution of WTP Bids by Educational Level.....	72
4.4. Estimating the Amount Smallholder Farmers are Willing to Pay	72
Table 4. 15: Monthly Median and Mean WTP Amount.....	72
4.6. Factors Influencing Smallholder Vegetable Farmers WTP Amount.....	73
Table 4. 16: Interval Regression Result.....	74
4.7 Constraints of Adopting the PIT in Smallholder Vegetable Farming	76

Table 4. 17: Likely Constraints of PIT Adoption	77
CHAPTER FIVE: SUMMARY, CONCLUSIONS AND RECOMMENDATIONS	78
5.1 Introduction.....	78
5.2 Summary of the Study	78
5.3 Major Findings and Conclusions	79
5.4 Policy Recommendations.....	81
5.5 Limitations of the Study and Opportunities for Further Research.....	83
REFERENCES	85
APPENDICES	94



LIST OF TABLES

Table 3. 1: District, Community and Sample size	52
Table 4. 1: Gender of Respondents by Community.....	57
Table 4. 2: Age Categories of Respondents.....	58
Table 4. 3: Age Categories by Community	58
Table 4. 4: Religious Distribution of Respondents.....	59
Table 4. 5: Marital Status.....	59
Table 4. 6: Level of Education of Respondents.....	60
Table 4. 7: Results of Financial Cost-Benefit Analysis by Community.....	62
Table 4. 8: Willingness to Adopt	63
Table 4. 9: Result of Probit Model.....	64
Table 4. 10: Distribution of Willingness to Pay Bids per 0.3 Acres per Month.....	69
Table 4. 11: Distribution of WTP Bids by Community.....	70
Table 4. 12: Distribution of WTP Bids by Gender	70
Table 4. 13: Distribution of WTP Bids by Age	71
Table 4. 14: Distribution of WTP Bids by Educational Level.....	72
Table 4. 15: Monthly Median and Mean WTP amount.....	72
Table 4. 16: Interval Regression Result.....	74
Table 4. 17: Likely Constraints of PIT Adoption	77

LIST OF FIGURES

Figure 1. 1: Analytical Framework	9
Figure 3. 1: Map of Study Area	55
Figure 3. 2: Map of study Area with Major Rivers.....	56

LIST OF PLATES

Plate 1. 1: A Picture of the PIT	6
Plate 1. 2: Material Used in the PIT Development	8



LIST OF ACRONYMS/ABBREVIATIONS

APIDP	Accra Plains Irrigation Development Project
AWM	Agricultural Water Management
BCR	Benefit Cost Ratio
BIS	Bontanga Irrigation Scheme
CBA	Cost Benefit Analysis
CVM	Contingent Valuation Methods
DRIS	Doho Rice Irrigation Scheme
DH	Double Hurdle
GHC	Ghana Cedis
GIDA	Ghana Irrigation Development Authority
IWM	Integrated Water Management
IWMI	International Water Management Institute
IRR	Internal Rate of Returns
IFDC	International Fertilizer Development Centre
LACOSREP	Land Conservation and Smallholder Rehabilitation Project
LPM	Linear Probability Model
MoFA	Ministry of Food and Agriculture
NPV	Net Present Value
OLS	Ordinary Least Squares
PIS	PAVE Irrigation Systems
PIT	PAVE Irrigation Technology
PC	Payment Card
RP	Reveal Preference
SADA	Savana Accelerated Development Authority
TAM	Technology Acceptance Model
USAID	United States Agency for International Development
WUA	Water User Associations
WTP	Willingness to Pay



CHARTER ONE

INTRODUCTION

1.1 Background

The quest to ensure food security and improve livelihoods in Africa in the face of climate change and climate variability has raised enormous concerns for irrigated agriculture. Hussain & Hanjra (2004) indicate irrigated agriculture has a potential of reducing poverty sustaining rural livelihoods and improving food productivity.

Ghana is endowed with both groundwater and surface water resources, making it suitable for irrigated agriculture. Evans *et al* (2012) indicated that Ghana's surface water and its largely untapped groundwater resources are capable of meeting both the domestic and irrigation needs of the country, if well managed. The irrigation potential of Ghana, thus areas that could be developed for irrigation including inland valley was estimated at 500,000 hectares however, the total (actual) area under irrigation was estimated to be 11,000 hectares in 2002. (Ministry of Food and Agriculture (MoFA), 2007)

The Government of Ghana and other stakeholders are contributing tremendously towards irrigation development. The implementation of the Accra Plains Irrigation Development Project (APID) which aims at producing about USD\$0.6 billion worth of agricultural produce per annum is a typical example of government's commitment to irrigation development in Ghana. Also, the contribution of NGOs is recognized in the implementation of Land Conservation and Smallholder Rehabilitation Projects (LACOSREP I&II) among others in Northern Ghana (Namara, *et al.*, 2010). The implementation of these projects lead to the construction of ninety (90) reservoirs and small dams out the 106 that were planned to enhance dry season farming, livestock watering and fishing in the Upper West and Upper East Regions

(Namara, *et al.*, 2010). Namara, *et al.* (2010), have classified irrigation typologies in Ghana to include conventional and emerging systems. The conventional systems are mostly supply driven, usually initiated and developed by the government and NGOs with the aim of ensuring food security, domestic water supply, and livestock watering. On the other hand, the emerging systems are usually initiated and developed by entrepreneurs and individual farmers with or without support from government and NGOs.

Over the years, smallholder vegetable farmers have relied on the conventional irrigation systems which require traditional lifting technologies in conveying and distributing water. Some of these systems include public surface irrigation systems, small reservoirs, and traditional shallow groundwater irrigation. Also, as indicated by Keraita *et al.* (2007), most smallholder vegetable farmers in Ghana use surface water for irrigation, since it is easily accessible and to some extent economical to farmers. However, surface water tends to be heavily contaminated and has serious health implications for consumers, since they are mostly collected from streams, storm water drains and gutters with greywater. Furthermore, surface water may not be a reliable water source for all year round irrigation, since most of these water sources dry up during the dry season and the few that have water cannot serve the demand of smallholder vegetable farmers. The irregularity of surface water supply has made smallholder farmers resort to groundwater systems usually wells in their own farms (Storm, *et al.*, 2010). Evans, *et al.* (2012), recommend the use of both surface water and groundwater irrigation options to widen benefits of irrigation to millions of smallholder vegetable farmers.

The challenges associated with the conventional irrigation technologies prompted the government of Ghana to promote groundwater irrigation systems with the use of contemporary lifting technologies. Groundwater Irrigation systems and other emerging irrigation systems are

appropriate for the cultivation of high-value crops such as vegetables, fruits, and trees, also with the unique potential of allowing farmers to access water on demand (Namara, *et al.*, 2010). Besides, groundwater usually has better quality water for safe irrigation than the surface water (Keraita, *et al.*, 2007). Also, Obuobie, *et al.* (2013) point out that the development of groundwater irrigation has the potential of providing many households the opportunity to improve their living standards, increase their income and reduce poverty.

Groundwater irrigation systems have several justifications in northern Ghana. The unimodal patterns of rainfall in Northern Ghana renders it the driest part of the country. This has led to the low percolation rate of rainwater into the ground. Hence, making shallow groundwater irrigation systems (such as shallow wells, dugouts, and small reservoirs) unreliable in the northern part of Ghana. As stated by Keraita *et al.* (2007), farming sites in some areas in northern Ghana has no chance of getting any shallow groundwater.

It has therefore, become imperative, to develop and promote reliable water harvesting and groundwater recharge technologies in that part of the country to expand the scope of groundwater irrigation. Obuobie *et al.* (2013) note that groundwater irrigation can be expanded to improve food security and enhance livelihoods through increase in food production and employment creation, if and only if appropriate and affordable technologies for groundwater storage are made available for irrigators. Furthermore, the low percolation of the runoff underground increases the risk of flooding in the area. Runoff erodes fertile top soil and increases the risk of flooding, as the runoff waters are transported into gullies (Schietecatte, *et al.*, 2005).

Therefore, the need for appropriate, reliable and low-cost irrigation technologies, coupled with the increasing incidence, length and severity of drought conditions in Ghana and more especially in Northern Ghana has called for the development and adoption of Agricultural Water Management (AWM) technologies. Evans *et al.* (2012), noted that a key element to reduce poverty and enhance productivity growth in Ghana, especially, northern Ghana is Agricultural Water Management (AWM). AWM encompasses a set of management practices that include watershed management, water capture, storage, conveyance, and application. This study focuses on water capture and its application in irrigation. According to Hussain (2007) and Namara *et al.* (2007), AWM technologies promise a substantial increase in agricultural productivity and household income.

It is in this light that, Conservation Alliance (CA), a Non-Governmental Organisation (NGO), in collaboration with PAVE Irrigation Systems (PIS) is promoting the use of an agricultural water capture technology which supports CA's double cropping double incomes vision. This technology is promoted in the Northern Region and Upper Region East through the implementation of the PAVE project under CA's Integrated Water Management (IWM) program. The project is aimed at enhancing food security and improving the nutritional status of poor farming households in selected districts in the Northern Region through the adoption of the PAVE Irrigation Technology (PIT).

This study, therefore, seeks to assess the financial viability of the PAVE Irrigation Technology (PIT) in smallholder vegetable farming in the Northern Region

1.2 Problem Statement

The increasing vulnerability of smallholder vegetable farmers to climate change has left them with no option than to look for reliable ways of managing agricultural water to enhance the

increase in crop yields, reduce poverty and widen their livelihood options. According to Evans *et al.* (2012), smallholder vegetable farmers in Ghana have adopted quite a number of agricultural water harvesting technologies in the form of hand dug wells, communal borehole irrigation, small reservoirs, and dugouts to ensure water availability for irrigation. Also, the government is complementing their efforts with the promotion of water saving techniques as a key strategy to raise the productivity of irrigation water from 30% to 80% within the next ten years (MoFA, 2011).

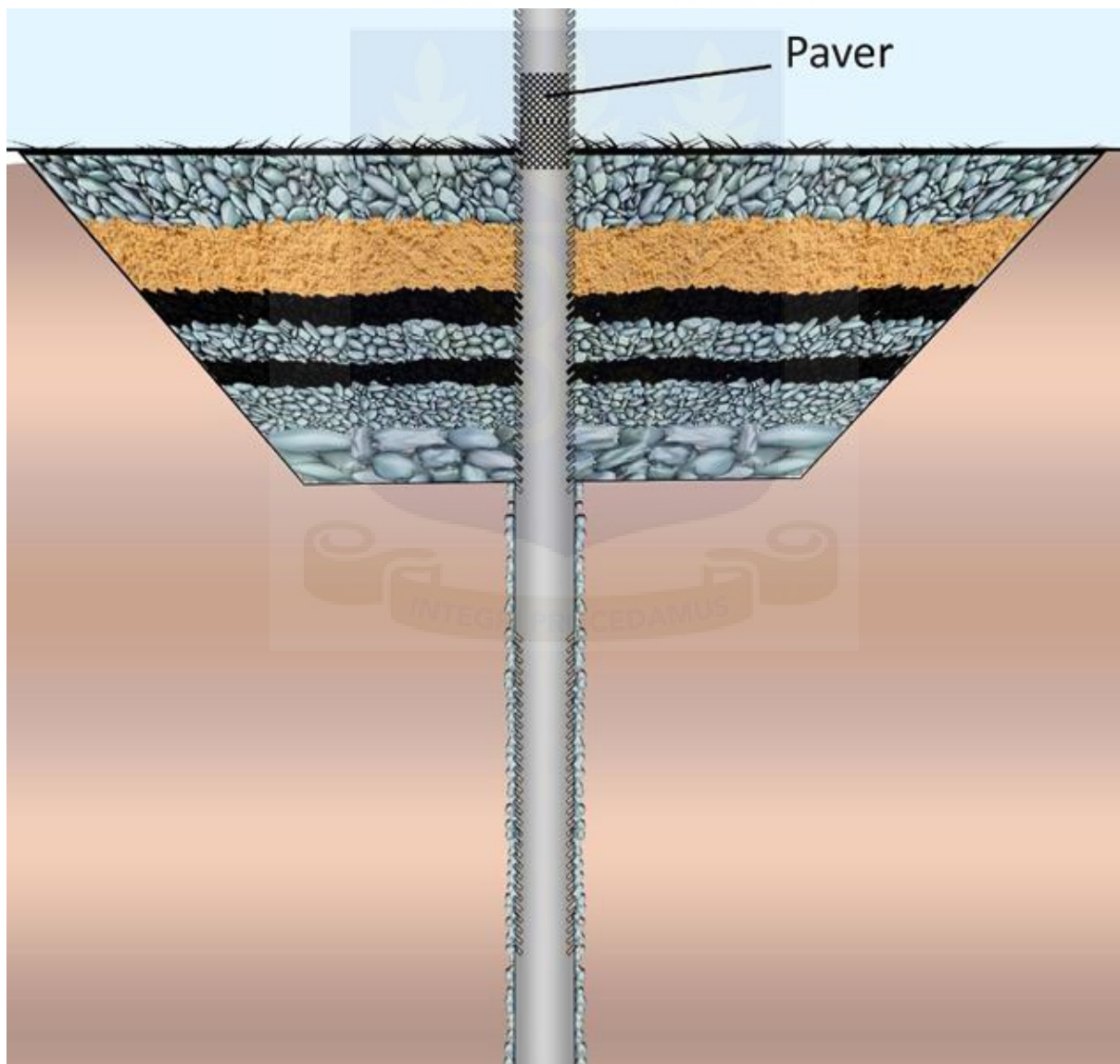
Despite these efforts, there is still a dire need for reliable water harvesting irrigation technologies in the country, especially in northern Ghana, since most of the smallholder vegetable farmers located in these areas still produce a crop once in a year. As a result, there is substantial widespread of seasonal food insecurity in the area, suggesting the need for investing in multiple AWM technologies to make a difference in the life of millions of smallholder farming households (Evans *et al.* 2012). Hence, the development of a locally adaptable low-cost water harvesting irrigation technology will serve as a viable alternative to the conventional irrigation schemes (Samuel & Mathew, 2008).

It is in this line that, the PAVE Irrigation Technology (PIT) is developed and promoted in the Northern and Upper East Regions to provide smallholder vegetable farmers the opportunity to farm at least twice in a year without experiencing water shortages, and to a larger extent help reduce the frequency of flooding in the area and its impact on their food security.

PAVE Irrigation technology (PIT) is a rain water harvesting, aquifer recharge irrigation technology that injects excess water underground during the period of rainy days and floods. This is aimed at storing water for dry season farming and also supplementing irrigation during

short rainy periods. Depending on the prevailing soil layers, and the nature of aquifer, one unit of PAVE technology has the capacity to inject an estimated 4-40 million liters of water underground. Water harvested can be stored underground for about 6 months (180 days) giving smallholder farmers the opportunity to farm throughout the dry season. To purify the water that is being injected underground, the construction of PIT takes into consideration several layers of carbonization (Conservation Alliance, 2016). Plate 1.1 is a picture of the PAVE Irrigation Technology.

Plate 1. 1: A Picture of the PIT



Source: Conservation Alliance (2016)

PIT is a context based technology meaning that (1) its design, development and installation are dependent on the prevailing conditions within the target sites; (2) local materials such as stones, sand and charcoal among others are needed for the construction of the PIT, hence the PIT can be constructed in any country since these material can easily be obtained; (3) Pumps are used for the extraction of water from the irrigation system to the fields. So far Conservation Alliance (CA) has conducted flooding and waterlogging assessments, community education, geological and hydrological studies in communities within the project area. Also, about 10 units of the PAVE Irrigation Technology have been installed in selected target districts (Conservation Alliance, 2016). Plate 1.2 illustrates some of the materials used in the development of the PAVE Irrigation Technology.

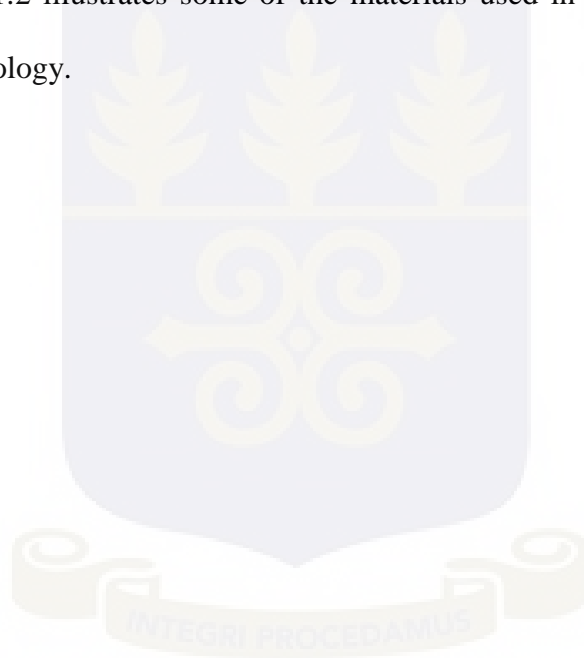
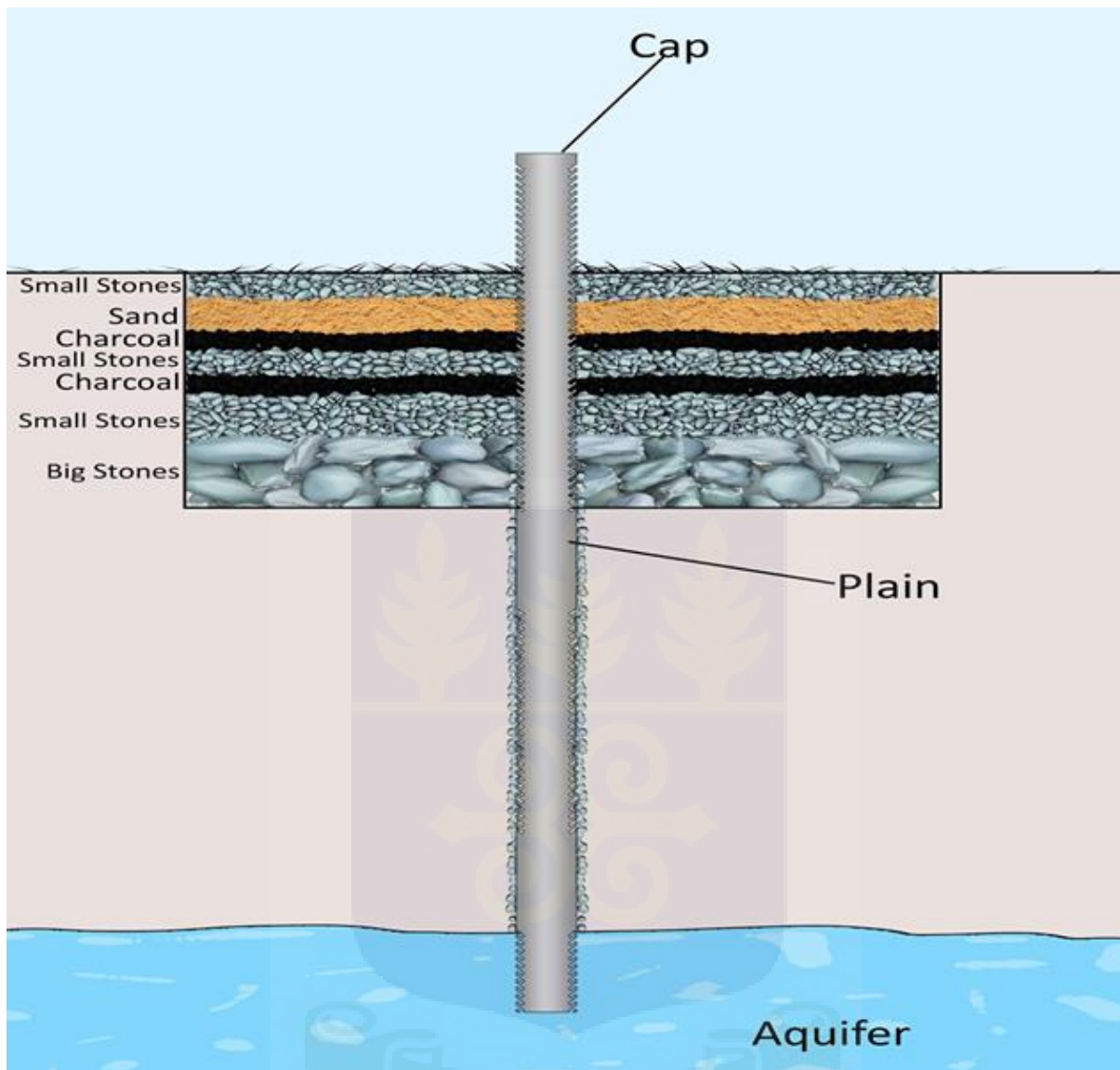


Plate 1. 2: Material Used in the PIT Development



Source: Conservation Alliance (2016)

However, as a new technology and privately installed, a key factor for its adoption is its viability in smallholder vegetable farming and farmers' willingness to cover operation and maintenance cost over a period. According to Zakaria *et al.* (2014), sufficient information on farmers' willingness to pay for irrigation water is necessary for the implementation of water pricing policies and for precise cost – benefits analysis of investment projects in water supply. Thus knowledge about smallholder farmers' willingness to pay for irrigation water, helps us to ascertain the financial viability of irrigation technologies.

1.3 Analytical Framework

For an enterprise or any business venture sustainability, there is the need for sufficient profits. As producers, smallholder vegetable farmers are interested in investments that will yield maximum farm profits. As critical as it is, smallholder vegetable farmers and other investors are interested in whether vegetable production under irrigation using a particular water storage facility or water harvesting technology will be viable.

Also, (Ministry of Food and Agriculture (MoFA), 2007) indicated most irrigation facilities in Ghana are operating less than their design capacities due to poor operation and lack maintenance. This can be attributed to poor revenue generation from these irrigation technologies, hence, leading to their rejection.

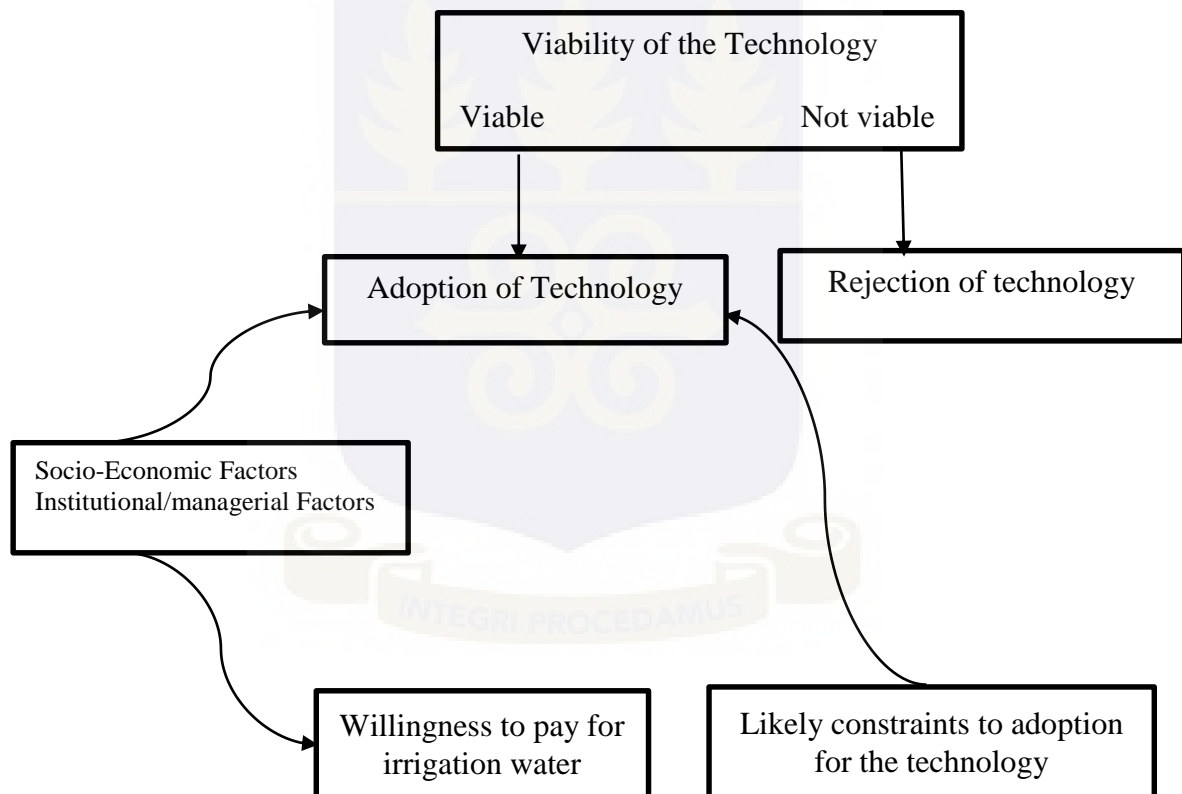
This study, therefore, examines smallholder vegetable farmers WTP for irrigation water under PIT towards proper operation, maintenance and ultimately the sustainability of the technology in their communities.

As a new technology smallholder vegetable farmers will want to know whether it is viable to produce vegetables using the technology, as this will inform their decision either to adopt or reject the technology. Knowledge on the viability of the technology will enable its adoption by a group of smallholder vegetable farmers (Early adopters), then the rest (late adopters) will follow suite. Nzomoi *et al.* (2007), indicated that it is apparent that potential adopters of every new technology will always consider the financial implication of the technology, thus it's relevant, efficiency and viability.

To ensure full adoption of the technology, the early adopters should be willing to Pay (WTP) an amount towards the operations and maintenance of the technology. This will help decrease

the uncertainties about the new technology. Hence, pave the way for other smallholder vegetable farmers (the early majority, late majority, and the laggards) to adopt the technology. Figure 1.1 explains the analytical frame work of the study. It presents the way by which this study provides relevant information to both providers of the technology and potential adopters of the technology. It looks at the factors that are likely to influence smallholder vegetable farmers decision to adopt the PAVE Irrigation Technology (PIT) likewise the factors that are likely to influence the amount they will be willing to pay (WTP) for irrigation water under the technology and the likely constraints of adoption.

Figure 1.1: Analytical Framework



Source: author's construction.

Whilst similar soil and water conservation technologies are promoted in Africa without considering their performance and viability under different production environments (Kassie, et al., 2008), this current study seeks to understand financial viability of the PIT, since the absence of financial viability will lead to poor patronage and hence, low adoption. As indicated by Doss (2006), understanding the profitability of the technologies will help us understand

adoption decisions better. To achieve this, the study seeks to provide answers to the following questions;

1. Is smallholder vegetable farming under the PAVE Irrigation Technology (PIT) financially viable in the Upper East and Northern Regions?
2. What are the factors influencing smallholder vegetable farmers' willingness to adopt the PAVE Irrigation Technology (PIT) in the Upper East and Northern Regions?
3. What is the amount Smallholder vegetable farmers are willing to pay for irrigation water under PAVE Irrigation Technology (PIT) in the Upper East and Northern Regions and what factors influences the amount?
4. What constraints are Smallholder vegetable farmers likely to face in adopting the PAVE Irrigation Technology (PIT) in the Upper East and Northern Regions?

1.4 Research Objectives

1.3.1 Main Objective

The main objective is to assess the viability and factors influencing the adoption of the PAVE irrigation Technology in smallholder vegetable farming in the Upper East and Northern Regions.

1.3.2 Specific Objectives

The specific objectives of the study are to,

1. Determine the financial viability of smallholder vegetable farming under the PAVE Irrigation Technology (PIT) in the Upper East and Northern Regions.
2. Determine the factors that influence smallholder farmers' willingness to adopt to adopt the PAVE Irrigation Technology (PIT) in the Upper East and Northern Regions
3. Estimate the amount and factors influencing smallholder vegetable farmers' willing to pay for irrigation water under PAVE Irrigation Technology (PIT) in the Upper East and Northern Regions

4. Identify the constraints that Smallholder vegetable farmers' are likely to face in using the PAVE Irrigation Technology (PIT) in the Upper East and Northern Regions.

1.5 Justification of the Study

Although several empirical studies have been conducted on the economics of irrigation and water control technologies in Ghana and elsewhere, no such study has been conducted on the PAVE irrigation technology because it is relatively new. There is, therefore, limited evidence on the financial viability of the PAVE technology as well as farmers' willingness to adopt. This study will contribute to the debate on the economics of technology adoption with empirical evidence from the case of PAVE technology in the Northern and Upper East Regions of Ghana. Furthermore, analysing and ascertaining the financial viability of the technology will serve as a guide for investing in the technology. This among other factors will provide stakeholders with relevant information on whether to invest in the technology or not. Notable among such stakeholders are Savana Accelerated Development Authority (SADA), Ministry of Food and Agriculture (MoFA), Non-Governmental Organisations (NGOs) and private investors.

Besides, knowledge on the factors that influence the adoption of the PAVE Irrigation Technology will serve as guide for Conservation Alliance and other interested stakeholders to design and implement appropriate interventions to enhance its adoption. Adoption of the technology by smallholder farmers will contribute to achieving government's objective of enhancing food security and improving rural livelihoods.

Also, empirical knowledge on the amount smallholder vegetable farmers are willing to pay is a requirement for the successful design and implementation of water pricing policies. The absence of such knowledge may hinder the sustainability of promising water control technologies, such as the PAVE Irrigation Technology. The results of this study will establish farmer willingness to pay amount for irrigation water under the PAVE Irrigation Technology

and the factors explaining the adoption of the technology. This will guide facilitators of the PAVE irrigation technology on how much to charge for irrigation water under the technology. The findings of the study will also unearth the constraints confronting smallholder vegetable farmers in using the technology. Based on this relevant interventions can be designed to support smallholder farmers with the needed services. This will go a long way to improve adoption rates, and hence reduce the risk associated with irrigation farming under the technology.

It is anticipated that results of the study will contribute to the literature in technology adoption, especially on privately installed irrigation systems in Ghana and also serve as the basis for further research.

1.6 Organisation of the Thesis

The study is organized into five main chapters. Chapter one composed of the study background, the problem statement, research questions, and objectives as well as justification of the study. Chapter two deals with a review of relevant literature on the study whiles Chapter three describes the methodology of the study and how they are used to achieve the specific objectives. Finally, whiles Chapter four presents and discusses results of the survey conducted, Chapter five provides a summary of the findings, conclusion and suggested recommendation for policy purpose, limitations of the study and suggestions of research gap for future research are also provided.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter presents a review of relevant literature on the topic under study. It brings forth an overview of rainwater harvesting irrigation systems, types of irrigation systems in Ghana, irrigation water control, and management, the viability of irrigation systems, factors influencing agricultural technology adoption and willingness to pay for irrigation water. Also, it covers the method of analysis of these studies. The chapter, therefore, provides a benchmark for the discussion and comparison of the results of this study to major findings of other studies.

2.2. Overview of Smallholder Rainwater Harvesting Irrigation Systems

Climate variability coupled with the growing world population has increased the scarcity of water. This has made apparent the need for water harvesting technologies to help increase water availability to satisfy the increasing demand for both agricultural and domestic water needs. As a result, governments in some parts of the world (e.g. India) have emphatically endorsed the need for water conservation and rainwater harvesting in both their national water and agricultural policies. Appropriate water harvesting structures, including farm ponds, check dams, harvesting bunds and percolation tanks are provided at various places to check flooding and make water available for irrigation (Singh *et al.*, 2009).

According to Yuan *et al.* (2003), harvesting rainwater for agricultural purpose involves three systems. These systems include; rainwater conserved agriculture where by the received rainfall is stored directly in the soil profile. The next system is the runoff agriculture, this system allows rainwater to be stored in a catchment area and applied to fields for irrigation. Rainwater harvesting and supplemental irrigated agriculture is the third system in which rainwater is

stored in a reservoir or more reservoirs within a command area. Yuan *et al.* (2003) add that an effective rainwater harvesting technology must be characterized by three features including; the catchment area, water storage (reservoirs, wells or cellars) and irrigation methods (manual watering or drip system). Despite the discovery of these systems, smallholder farmers still lack access to irrigation technology in different parts of the world. This suggests that each one of these systems may be associated with some constraints that limit effective adoption by the smallholder farmers.

Also, rainwater harvesting irrigation systems have been categorized into micro-catchment and macro-catchment systems (Oweis & Hachum, 2006). Micro-catchment systems are less costly and simple to construct, they are usually found on individual farms. On the other hand, macro-catchment systems are large systems and usually require some high level of investment. The sustainability and efficient utilization of the macro-catchment systems requires an understanding of existing water use regulations and rights to help avoid conflict of interest, and smallholder farmers should be involved in their planning and management. The authors also maintained that alternative management arrangements for these systems include; community-based management, farmer cooperatives, and cost sharing. The findings of these studies suggest that irrigation systems that are acquired and managed by individual farmers may be under the micro-category while those that can be utilised by several farmers or groups of farmers fall under the macro-system.

Hatibu *et al.* (2006) indicate that smallholder farmers have considered macro-catchment systems as an opportunity for poverty reduction since they provide reliable water for the growing of high valued crops in the lean season. Most of these systems are started, funded and

established by smallholder farmers themselves, with no support from government and NGOs. As a result ownership and management is farmer led.

Besides, Samuel & Mathew (2008), maintain that storage of rainwater can be done in two main ways; artificial storage (roof water harvesting) and storing in the soil (groundwater). The former is a temporary storage arrangement, which focuses on providing immediate relief from water scarcity, while the latter focuses on providing substantial and sustainable relief from water scarcity. The authors added that groundwater can be recharged by diverting excess runoff into the ground through percolation pits and trenches, this will there by contribute significantly to reviving groundwater reserves.

Notwithstanding these categorizations of rainwater harvesting for irrigation and their limitations, the bottom line is to make water available for irrigation and also reduce the stress on groundwater. This, therefore, justifies the promotion of the PAVE Irrigation Technology, which happens to satisfy all the requirements outlined in the above categorization. Also, it is noteworthy to state that, the types of irrigation water capture and storage systems may differ from one geographical area to another.

2.3 Types of Irrigation Systems in Ghana

MoFA (2011) has categorised the irrigation sector in Ghana into informal or smallholder, formal and large scale commercial irrigation sub sectors. The informal irrigation subsector covers irrigation systems that require little capital investment and are mostly farmer owned, usually with a land size of about 0.5ha. Informal irrigators require simple water capture, water storage, and application systems. Investment in this subsector is very low due to the lack of recognition, limited credit access, and high land tenure insecurity.

Formal irrigation sub sector involves irrigation schemes that rely on irrigation structures that are funded and developed by the government or donors. Most of these schemes are underutilized due to poor operation and maintenance. Lastly, large scale commercial irrigation subsector usually refers to irrigation schemes that are co-funded by both the private and public sectors.

The above categorization of the irrigation sector in Ghana has placed much emphasis on the source of funding. Moreover, Namara, *et al.* (2010) has provided a broad categorization of the irrigation systems depending on the type of water capture systems, the storage systems, the application and the management of the systems. These categories are the conventional systems and emerging systems.

2.3.1 Conventional Irrigation Systems

2.3.1.1 Public Surface Irrigation Systems

These systems cover all public irrigation schemes in Ghana such as Botanga, Golinga, Tano and Veia irrigation schemes among others. Depending on the type of water capture, storage and application, Namara, *et al.* (2010), have further categorized these systems into seven groups including; firstly, run-of-river diversion-based gravity-fed irrigation systems: here a weir is constructed to divert excess water in a canal and to the field under gravity. Secondly, reservoir or storage-based gravity-fed irrigation systems: with this, water is stored in a reservoir and applied to the field by gravity. Thirdly, lake-pumping-based sprinkler irrigation systems: here water is pumped from a lake into an open canal to feed a reservoir, and subsequently pumped into sprinklers to be applied on the field. The fourth system is the run-of-the-river-pumping-based sprinkler irrigation systems, whereby water stored in concrete weirs are pumped into sprinkler systems to irrigate fields. The rest of the systems are reservoir-pumping-based

sprinkler irrigation systems, reservoir-pumping-based gravity-fed irrigation systems, and river-pumping-based gravity-fed irrigation systems.

2.3.1.2 Small Reservoir-based Communal Irrigation Systems

Namara, *et al.* (2010), indicated that Small reservoir-based Communal Irrigation Systems are donor led systems, community participation is usually a key in their design and construction. Their management, operations, and maintenance are usually vested in Water User Associations (WUAs) comprising of community appointed members. Depending on the size, priority of water use, structure and management systems small reservoirs can be classified as small dams and dugouts. Regarding the distinction between these classifications, the authors indicated that the surface area of small dams are bigger than dugouts. Also, small dams have intake structures such as canal and laterals, whiles dugouts have no intake structures.

2.3.2 Emerging Irrigation Systems

2.3.2.1 Groundwater Irrigation Systems

The challenges associated with surface water irrigation systems in Ghana has paved the way for groundwater irrigation systems. Kortatsi (1994), indicated that, need to increase agricultural productivity coupled with erratic rainfall patterns in Ghana, has made the use of groundwater for irrigation a necessity. Adding to that, Namara *et al.* (2010), recognized that, there is an increase in the usage of groundwater in Ghanaian Agriculture, and indicated that groundwater irrigation can further be categorized into seasonal shallow wells, permanent shallow wells, shallow-tube wells and communal borehole systems.

Critical among the groundwater irrigation systems is the borehole irrigation system. These systems utilize water from deep aquifers. Namara *et al.* (2010), stated that boreholes rely on

aquifers for their recharge, suggesting that the deeper the aquifer the higher the cost of construction. According to the authors, this among other factors has made the use of groundwater for irrigation unsuccessful in Ghana, especially at places where the aquifers are deep.

The PAVE irrigation technology is a typical example of the borehole irrigation system; however, its uniqueness in harvesting run off to recharge aquifer water levels tips it as a viable and a successful irrigation technology in Ghana, and especially in the north where infiltration rates are poor.

2.4 Irrigation Water Control and Management

The control and management of irrigation water invariably determine the sustainability of the system. The management types in irrigation management can be understood well if we are able to determine who has authority. The way an irrigation system operates relies solely on the person or group of persons with the charter of control, they have the responsibility to shape the management style (Hunt, 1989).

Yoder (1994), identified two main management systems, which include; agency managed and locally managed (fanner managed). According to him, the agency managed system refers to a system whereby authority is given to agency of government to develop, operate, maintain and regulate all irrigation related activities. The operation and maintenance of the irrigation systems become a sole responsibility of the authorized agency's staff. Irrigation systems (Vea, Tano, Boltanga, and Golinga irrigation systems) under the management of Ghana Irrigation Development Authority (GIDA) can be seen as a typical example of agency managed systems.

However, Yoder (1994) indicated that in some cases irrigators are allowed to control irrigation delivery in their canals.

On the other hand, Yoder (1994) referred to the locally managed systems as those systems where by access and control of the facility are entirely the responsibility of the irrigators. Here, the charter of authority is given to the local community. Usually, leaders of these systems are members of the local community, tasked to coordinate the use of available resources to yield a higher level of irrigation delivery that cannot be attained individually.

Over the years, the locally managed systems have attracted the attention of government, NGOs and other partners. This without a vestige of doubt is attributable to the fact that, they require few public resources to operate and also ensures continuous operation of irrigation facilities (Yoder, 1994). Most Governments and NGOs have therefore taken significant steps to improve the performance of irrigation facilities by transferring the operation and maintenance cost to the irrigators. Yoder (1994) indicated that many countries have initiated programs to ensure that agency managed systems are turned over to the locally managed system due to their success stories.

Although the success of locally managed irrigation systems depends largely on the ability of group members to contribute labour and other necessary resources to keep the system functional and durable, inadequate resource mobilization has been identified as a major constraint in locally managed system (Yoder, 1994). As a locally managed system, promoters of the PAVE Irrigation Technology (PIT) are considering to charge smallholder vegetable farmers a fee for irrigation water usage. This is expected to enhance resource mobilization and for that matter continual operation of the technology.

A key success indicator of locally managed irrigation systems is cooperation among group members. Dayton-Johnson (2000), develops a model to determine the factors that affect cooperation in smallholder locally managed irrigation systems. The results revealed that heterogeneity of group members affects the performance of irrigation management groups negatively. Also, the findings revealed that higher wages increase the cost of cooperation and hence negatively affect cooperative performance. The author computed the direct and indirect effects of social heterogeneity, economic inequality and group size on cooperative efforts and the results pointed out that, economic inequality and group size largely affect cooperative efforts indirectly than directly, and both variables negatively affect group cooperation.

By the same token, Fujiie *et al.* (2005) in examining the conditions that affect the success or otherwise of collective action in managing irrigation in the Philippines demonstrated that it will be very difficult for group managed irrigators to cooperate under the following conditions:

- 1) When irrigation water is highly abundant, in other words when irrigators do not experience water shortages.
- 2) When there is a huge difference between farmers located up and down stream of the water source.
- 3) When group members (Irrigator Associations) are many in terms of the number of beneficiary farmers and the service area.
- 4) When farmers have an option to engage in non-farm economic activities.
- 5) When the population of the local community is high with little social interaction among the people.
- 6) When the people have no prior experience in locally managed irrigation systems.

Fujiie *et al.* (2005) noted that even though the moves by most governments to shift from agency managed irrigation systems to locally managed systems have a higher potential of

enhancing efficiency and equity, there is the need to acknowledge the difficulties in organising rural farmer groups and the need for incentivizing group leaders. Cooperation among farmers is therefore considered as a key indicator of successful use of the PAVE Irrigation Technology (PIT).

2.5 Viability of irrigation Systems and Technologies

The development of new irrigation systems and technologies in the past few decades has placed importance on the need to understand the economic and financial viability of agricultural production under these systems. Both producers and consumers of these technologies are interested in knowing how profitable or otherwise these technologies may be. To this end, several empirical studies have been conducted to ascertain the profitability of some of these systems.

Notably, Hagos *et al.* (2013), in assessing the economics of some selected water control technologies in Ethiopia, reported positive Net Present Values (NPVs) for all selected water control technologies including Shallow wells, small dams, river diversions and deep wells at 8%, 10% and 15% discount rates. This suggests that crop production under any of these water control technologies will be financially feasible, hence farmers can comfortably adopt and use the technologies. They recommended improvement of market infrastructure and the promotion of education to ensure sustainability and profitability of the technologies.

Equally, Baranchuluun *et al.* (2014) in determining the viability of drip and sprinkler irrigation systems compared to furrow irrigation in the production of potatoes, radish, headed cabbage and tomatoes revealed that potatoes, radish, and headed cabbage have NPVs of 117.3, 137.1 and 200 respectively under the drip irrigation systems. Also, the crops have Benefit Cost Ratios (BCRs) of 3.6, 3.2 and 9.2 for potatoes, radish and headed cabbage respectively. The sprinkler

irrigation system also indicated positive NPVs of 76.5, 93.3 and 112.3 for potatoes, radish and cabbage with respective BCRs of 2.7, 2.7 and 2.3. The furrow irrigation system had the least NPVs although positives. The NPVs were estimated at 41.46 for potatoes, 53.68 and 52.60 for radish and headed cabbage respectively. Also, BCRs estimated were 2.12, 2.21 and 1.78 for the respective crops. Baranchuluun *et al.* (2014), therefore concluded that crop production under the drip irrigation system will be more efficient compared to the sprinkler and the furrow irrigation systems.

Besides, Senkondo *et al.* (2004) performed an investment analysis in Tanzania to on the viability of Rainwater Harvesting for agricultural production in some selected semi-arid areas. The results revealed positive Net Present Values (NPVs) for the production of maize, rice and onions under rainwater harvesting for production. This indicates that discounted present value of the cash inflows exceeds the discounted present values of the cash outflows. Also, the Benefit Cost Ratios (BCRs) from the analysis were greater than one for all the three crops under rainwater harvesting production systems. The Internal Rate of Returns (IRR) was also found to be higher than the opportunity cost of capital. They concluded that investment in rainwater harvesting for crop production is viable.

Also, in Zimbabwe, Mupaso *et al.* (2014) assessed the impact of irrigation technology on the financial and economic performance of smallholder irrigation. The results revealed positive NPVs for all the technologies, namely the sprinkler, drip and flood irrigation technologies. The flood irrigation technology had the highest NPV of US\$ 13,758, the drip system followed with an NPV of US\$ 10,507 and then the sprinkler with an NPV of US\$ 7,718. The flood irrigation technology also had the highest IRR and BCR values of 27% and 2.10 respectively. The sprinkler system had an IRR of 17% and a BCR of 1, where as the drip technology had an IRR

of 13% and BCR of 2. The authors also revealed that flood irrigation technology could be viable because of its low operational cost. In addition, Kumar *et al.* (2009) used Cost- Benefit Analysis to evaluate the viability of check basin irrigation system and gravity-fes micro-irrigation system in vegetable production. The study revealed NPVs of INR 65,223 and INR 160,523 for the check basin and micro-irrigation systems respectively. Also, an IRR of 12.2% and a BCR of 1.78 were reported for micro-irrigation system where as the check basin irrigation system had an IRR of 6.4% and a BCR of 1.38. The indicated that financially the Micro-irrigation system was financially viable than the check basin irrigation system.

The indicators of investment worth (Net Present Value and Benefit Cost Ratio) employed in these studies were used to determine the financial viability of the PAVE Irrigation Technology in smallholder vegetable farming in the Northern and Upper East Regions, Ghana. This is because the establishment of the technology requires a huge initial cost and the benefits are spread over time.

2.6 Theories of Technology Adoption

The literature on adoption theories provide the fundamentals for understanding the adoption decisions of both individuals and groups. Straub (2009), stated that the theory of adoption examines the decision of an individual whether to adopt or not to adopt an innovation. Several adoption theories have emerged over time. Notably, is the Rogers theory of innovation difusion, this theory, draws its strength from its ability to provide a general understanding of the factors influencing an individual's decision to adopt an innovation or not. Rogers identified five stages of adoption which include; the awareness stage, the persuasion stage, decision stage, the implementation stage and the confirmation stage (Rogers, 1995). The characteristics of the new technology in question also influence its adoption. These attributes were identified by

Roger to include; relative advantage, compatibility, complexity, trialability, and observability of the technology (Rogers, 1995).

Another theory that tries to explain adoption behavior is the Technology Acceptance Model (TAM). The model was developed by Davis (1989) taking into consideration the social cognitive theory and the decision-making theory. The model is based on the assumption that, an individual's decision to adopt an innovation depends on their perception of the technology. Davis identified two perceived characteristics that are likely to influence adoption of an innovation to include; perceived ease of use and perceived usefulness. He added that perceived ease, entails potential adopters believe that the use of the new technology would not require more effort. Whereas, perceived usefulness entails, an individual's believe that, that new technology will improve performance (Davis, 1989).

In economic theory, the expected utility theory is identified as the most prominent theory in adoption studies. Caswell *et al.* (2001), indicated that, in economics, the adoption of a new technology is based on the assumption that the individual is a utility maximizer, and makes a choice based on maximizing his/her expected utility subject to policies, natural resource assets, personal characteristics and prices. The authors linked smallholder farmers adopting decisions to the decision to invest in a business, indicating that it may come with a huge initial cost and a pool of benefits over time. Hence, an individual's decision to adopt a new technology may change over time as they get in contact with those that have adopted the technology already. Assessing the adoption behavior of smallholder vegetable farmers is therefore grounded on the above theories. Specifically, this current study guided by the expected utility theory.

2.7 Empirical Studies on Agricultural Technology Adoption

To ensure that appropriate technologies are developed and promoted to improve agriculture productivity, technology developers as well as promoters have over the years prompted researchers to identify the factors that influence or are likely to influence the adoption behaviour of potential adopters of these technologies.

Mariano *et al.* (2012) employed a logit model to determine the factors that influences farmer's decision to adopt modern rice technologies and good management practices in the Philippines. The result of the study indicated a significant and positive relationship between formal education and technology adoption. The findings also revealed that farm size was a significant determinant of technology adoption with a positive influence. Access to credit was not left out, it also turned out to have a direct relation to technology adoption, suggesting that as farmers receive more credit they are more likely to adopt new technologies. The results also indicated that access to extension service as well as farmers household size were significant factors in technology adoption with positive and negative relations respectively.

Moreover, Uaiene *et al.* (2009) employed a probit model in determining the factors that influence agricultural technology adoption in Mozambique. Their findings revealed that access to credit, membership to an association, formal education and access to extension were significant and positive factors in agricultural technology adoption. Furthermore, Nathanel *et al.* (2015) in estimating the socio- economic factors influencing small scale farmers in Katsina State decisions to adopt early maturing maize varieties, employed the probit model. With a sample size of about 300 small scale maize farmers, the results revealed a negative but significant relation between the age of farmer and the probability of adopting a new technology. Other variables such as income of the farmer, membership in an association and farm size were

found to be positive and significant. In other words, they have a high probability in influencing farmers decisions to adopt a new technology.

Besides, Muyanga (2009) estimated a probit model to ascertain the drivers of the adoption of tissue culture banana in Kenya. The findings identified smallholder farmers education and credit availability as key drivers of adoption with positive and significant impact. However, gender, household size, household income, marital status and land size were found to have no significant effect on adoption of tissue banana technology in their model. Also, in analysing the factors that influence the adoption of irrigation technology and its effects on household poverty in Ghana Adeoti (2009) found that number of extension visits has a significant and positive influence on adoption, whereas dependency ration and regional dummy (location) was found to be significant but negatively affects irrigation technology adoption.

Likewise, Zavale *et al.* (2005) in their study on the adoption of improved maize seeds by smallholder farmers in Mozambique found household size as a proxy of labour availability to be statistically significant and affects smallholder farmers adoption decisions positively. The age of a smallholder farmer was also found to be statistically significant but negatively affects the adoption of new agricultural technologies at the national level. Their findings also identified off farm income and formal education as significant and positive factors influencing the adoption of improved maize seeds. But institutional factors, such as access to extension service and access to credit were found to have a negative effect on the probability of adopting the technology, although both variables were found to be statistically significant. Notwithstanding, Nzomoi et al (2007) using a logit model to determine factors influencing technology adoption in the production of horticultural export produce in Kenya, found that education was a

significant and positive factor. This explains that farmers with higher levels of education are more likely to embrace new ways of doing things, hence are likely to adopt technologies.

Similarly, Shiferaw *et al.* (2008) employing the double hurdle (DH) model to assess technology adoption under seed constraints and its economic impacts on improved pigeon pea seed varieties in Tanzania found out that education, awareness of improved varieties and women participation in decision making were significant and positively affects adoption of new technologies. In the same vein, a study by Asfaw *et al.* (2011), on the drivers of agricultural technology adoption among cross-section of farmers in Ethiopia, using double hurdle (DH) model reveals that awareness of the technology (improved seed varieties) and the perceived attributes of the technology were positive and significantly affects technology adoption. Their study suggested the need for promoting and creating positive awareness about current chickpea technologies.

The above empirical works have pointed out some of the widely used methods in adoption literature and as well identified some of the factors that determine the adoption of agricultural technology. These studies point out that, socioeconomic factors of respondents such as (age education, household income, household size, technology awareness), Institutional factors such as (access to extension, access to market, access to credit) and technology characteristics such as (userfriendliness, reliability technology) among others are factors that significantly influence agricultural technology adoption.

2.8 Irrigation Water Pricing and Willingness to Pay (WTP)

The increasing scarcity of water for agriculture and irrigation for that matter has moved a motion for proper valuation of this non-market good. For this reason, Schoengold & Zilberman

(2007), pointed out two major water pricing systems namely; volumetric fee system and the per hectare fee system. The former is used to provide a limitation on the volume of water usage while the latter is used to encourage intensification of agricultural lands. However, the authors indicated the inability to measure adequately the amount of water an individual use's is enough a significant threat to the functionality of these water pricing systems.

Salman & Al-Karablieh (2004), indicated that even though water is a basic requirement for human survival, the lack of appropriate pricing has led to pollution, over usage of water and lack of sustainable water supply due to inadequate cost recovery. The authors argued that, without appropriate charges, water will be used carelessly. Salman & Al-Karablieh (2004) therefore suggested that, adoption of appropriate irrigation technologies should be complemented with participatory management to ensure efficient use and hence reduce water losses. Consequently, Salman & Al-Karablieh (2004) advised that water pricing and costing must take into consideration Willingness to Pay (WTP).

Willingness to Pay (WTP) is an economic concept that measures the monetary value that an individual will pay for improvement in quantity or quality of a particular good or service at a particular time (Young, 1996). Although not the only method used in assessing WTP for improving or otherwise the quality of a goods and services, literature has illustrated that Contingent Valuation Method (CVM) has been employed by many researchers in determining farmers WTP amount. Contingent Valuation Method (CVM) is a stated preference method of valuing non-market goods and services. Unlike the revealed preference (RP) methods which are indirect, Stated Preference methods and for that matter, CVM is a direct approach to estimating the value that consumers place on a particular non-market good or service. Over the years, CVM has been noticed as the most standard and widely used technique in eliciting information on the value people place on a non-market good. With CVM respondents are asked

directly to state the maximum amount they are WTP for the use of good and in this case irrigation water service.

A study conducted by Chandrasekaran, et al. (2009) on Farmers' Willingness to Pay (WTP) for irrigation water revealed that about 50% of the respondents were willing to pay with an average WTP value of INR 212.50/ha/year in the wet season. While about 66% respondents were willing to pay for irrigation water in the dry season, with an average WTP value of INR 224.50/ha/year. The findings indicated a significant and negative relationship between WTP value and family labour as a proxy for household size. Also, area under rice cultivation was found to be significant and negative and crop water requirement was found positive and significantly affects WTP. The study, therefore, recommends that the existing Water User Associations (WUAs) be strengthened and empowered to fix reasonable charges for irrigation water to cover operation and maintenance activities of irrigation systems.

Besides, Biswas & Venkatachlam (2015) estimated farmers WTP for improved irrigation water in India and found average WTP value to be INR 219/per acre. Employing a Contingent Valuation approach, the study revealed a negative relationship between the bid amount and WTP, which confirms the theory of demand. Age of respondent and the income from crops were found to be positive and significant whilst gender and level of education were identified as insignificant factors on WTP. Biswas & Venkatachlam (2015), argued that given a reliable irrigation water supply farmers will be able to increase production significantly and hence pay a fraction of their surplus for irrigation water. They further suggested that policy makers should shift from the conventional command and control systems of irrigation management to a system that will put into account the preferences of farmers in policy formulation.

In China, Tang *et al.* (2013), conducted a contingent valuation study to estimate farmers' willingness to pay for irrigation water. An estimated mean WTP value of 80.4 RMB/mu/yr was established. Farmers' household size was found to be negative and significant indicating that bigger families are likely to have lesser WTP on the average. Also, income, irrigated area and type or source of irrigation water were found to be positive and significant in determining farmers WTP. Moreover, it was revealed that, gender, education, and age were not having a significant effect on farmers WTP. Tang *et al.* (2013), concluded that farmers are willing to pay for irrigation water service if and only if they are duly recognized. The study suggests that farmers should be involved in all stages of irrigation development through their local WUAs to ensure better irrigation water management. This will make farmers feel that they are owners of the irrigation system and ensure that available water is used efficiently to increase crop production.

Furthermore, with 80% of respondents willing to pay for watershed services, Ndetewio *et al.* (2013), found the coefficient of farm size, household income, education and farm distance to be positive and significant factors in determining farmers WTP in Tanzania. On the other hand, the coefficient of gender and land tenure were found positive but not significant. Ndetewio *et al.* (2013), recommended that policy makers should promote environmental education and develop a participatory management approach, this to them will help improve farmers WTP for watershed and irrigation services.

Moreover, Alemayehu (2014), employed the Contingent Valuation Method (CVM) with double bounded dichotomous questions in estimating smallholder farmers' WTP for improved irrigation water in Ethiopia. The findings pointed out that, 60.71% of the respondents were willing to pay and 39.29% were not willing to pay the initial bids offered (12, 26 and 36

Birr/0.25/ha/year). The study results identified educational level, gender, household size, cultivated land size, family income and as the factors having significant effect on WTP for improved irrigation water. Alemayehu (2014) estimated a mean WTP amount of 128.88 Birr(\$6.7)/ha/year and 162.72 Birr(\$8.56)/ha/year using a double bounded Probit. This suggests that WTP value changes from 128.88 to 162.72 Birr/ha/year. The study suggests the need for the development of proper irrigation water pricing systems by appropriate policy makers.

Also, using CVM and the bidding game elicitation criteria, Angella *et al.* (2014) found that, farmers were willing to pay an average of Ush 20,000/acre/season as user fees as against the Ush 15,000/acre/Season requirement by the Doho Rice Irrigation Scheme (DRIS) to cover its operations and maintenance cost. The regression result of the study using Ordinary Least Squares (OLS), revealed that the relationships between formal education, farm size, practical experience, training, access to credit and farmers WTP user fees were positive and statistically significant. However, it was found that distance to the nearest market was significant but affects farmers WTP negatively.

Similarly, Baidoo *et al.* (2013) revealed that an over whelming percentage of about 79.50% of their respondents indicated they were willing to pay for improved irrigation systems and the remaining 20.50% of the respondents indicated they were not willing to pay. The findings revealed that soil type was statistically significant and affects farmers WTP negatively. On the other hand, crop type was found to be significant and positive. The coefficient of education turns out to be negative although it was not found to be significant. Hence, they recommended the cultivation of water- loving crops such as tomatoes, onions, and garden in the study area. In addition, Basarir *et al.* (2009), in analysing farmers willingness to pay (WTP) for high-quality irrigation water used the Tobit and the Heckman sample selection models. The results

from the Tobit model revealed that gender has a positive and significant effect on producers willingness to pay (WTP). On the other hand, none of the independent variables were significant in the Heckman sample selection model.

Also, a study on the willingness to pay for irrigation water by Gautam *et al.* (2017) found age of farmer and farm revenue to be significant factors but affects farmers' willingness to pay for irrigation water negatively. Similarly, Mallios & Latinopoulos (2001) in their study on the willingness to pay for irrigation water in Chalkida in Greece found out age has a negative relationship with the amount farmers are willingness to pay.

Conversely, a CVM study conducted by Alhassan *et al.* (2013) using the Payment Card Elicitation format to estimate farmers WTP for improved irrigation under the Bontanga Irrigation Scheme (BIS) in Ghana, found a mean WTP value of GHS 16.32/ha/year and median of GHS 14/ha/year as premium. Location of farm, off scheme income and Land lease post significant negative effect on farmers' WTP for improved irrigation under the BIS (Alhassan *et al.*, 2013). Alhassan *et al.* (2013) further revealed that land ownership and scheme income significantly and positively affect the amount smallholder farmers' are willing to pay for improved irrigation under the Bontanga Irrigation Scheme (BIS) in Ghana. Based on these findings, it was recommended that there was the need for cost benefit analysis to ascertain whether the needed expansions in the scheme would be beneficial (Alhassan *et al.*, 2013).

Notwithstanding its' wide recognition, CVM has its own shortcomings, which include, format bias, ordering problem, starting bids effect, strategic bias, free rider problem among others. However, studies including Ndetewio *et al.* (2013), Alhassan *et al.* (2013), Baidoo *et al.* (2013) and Angella *et al.* (2014) adopted the approach in estimating WTP to aid the designing of

irrigation water pricing policies and for conducting cost benefit analysis in developing countries. Contingent Valuation Method (CVM) practitioners have adopted elicitation approaches such as the bidding game, payment card method, open ended and the dichotomous choice approaches.

The bidding game approach involves asking a respondent of his/her WTP a certain amount of money (Cedi) and then keep increasing (or decreasing) this amount until the respondents accept (or decline) to pay. This elicitation approach has received less patronage over the past years because the repetition of questions may cause respondents to end the interview by saying a “yes” or “no” at the mention of some amount.

The dichotomous choice approach is an elicitation format, whereby the respondent is asked whether he/she is willing to pay a particular amount of money for a specific good or improvement. Here the respondent only says either a “yes” or a “no”. The limitation of this approach is that it is not able to observe the true WTP amount of the respondent. It can be argued that respondent that says “yes” may have a WTP greater than the bid amount, and the respondent with a “no” may have a WTP less than the initial bid amount.

Alternatively, the Payment Card (PC) approach can be employed to elicit respondents WTP amount. It involves a list of possible WTP values on a card, given to a respondent to circle or tick the maximum amount he/she is willing to pay. According to Boyle *et al.* (1996), PC is an array of prices given to the respondents to indicate their choice of WTP. The choice of a respondent in PC format questions is considered the lowest amount they are willing to pay. Hence, their true WTP lies between the value chosen and the next highest value (Cameron & Huppert, 1989). Notwithstanding the fact that some respondents may be restricted to only the

values on the payment card, Rowe *et al.* (1996), indicated that while the displayed amount are not truncated from above, there is no problem of restricted choices. Also, Reaves *et al.* (1999), recommended that the Payment Card elicitation approach for CVM studies due to the likelihood of recording zero bids in such studies. Hence, this study adopted the Payment Card (PC) approach in eliciting respondents' maximum WTP value.

The above empirical works have pointed out some of the methods that are widely used in estimating WTP amount as well as determining the factors that influence WTP. Therefore, this study employed the CVM in estimating smallholder vegetable farmers are willing to pay for irrigation water under PAVE Irrigation Technology (PIT) in the Upper East and Northern Regions.

2.9 Constraints of irrigation technology adoption

It is obvious that smallholder vegetable farmers are constrained in their bid to adopt agricultural technologies, of which irrigation technologies are key. Oweis & Hachum (2006), identified some socio-economic factors that are likely to limit the adoption of water harvesting irrigation technologies to include; land tenure issues, unclear water rights systems, and technology familiarity and compatibility challenges. Moreover, Nzomoi *et al* (2007), identified inappropriate technologies, inadequate technical knowledge, poor infrastructure and limited access to information as constraints of technology adoption. Besides, Brant (2007) reported that the promotion of new technologies and programs aimed at improving crop production and reducing vulnerability is hindered by the limited knowledge on the use of the technologies and the lack of technical assistance.

Also, Tun Oo, et al. (2015) identified the shortage of farm lands, lack of credit, high input prices and poor management as the factors that are militating against smallholder farmers adoption decisions. Akinnagbe & Irohibe (2014), added that the major issues confronting the adoption of agricultural technologies and adaptation strategies in Africa are inadequate knowledge and the lack of proper institutions to provide necessary support to smallholder farmers.

Generally, these studies have identified limited access to information, lack of credit, inadequate technical knowledge and lack of proper institutions as likely barriers to agricultural technology adoption.

2.10 Summary of Literature Review

The increasing water scarcity for agricultural and domestic needs has led to the development of rainwater harvesting systems to help improve agricultural productivity. These systems need to be adopted and managed properly to achieve their establishment goal. Also, there is the need to place an economic value on the usage of water of this systems to avoid over use.

The empirical studies show that elsewhere, farmers are willing to adopt and pay a fee for irrigation water usage towards operations and maintenance of irrigation systems. Furthermore, some constraints that are likely to limit the adoption of agricultural technologies were also brought to light. Some methods of analysis employed by these studies in determining the factors that influence willingness to agricultural technologies and in estimating WTP include Probit, Logit, OLS, Tobit, double hurdle and interval regression models. Also, the studies indicated that socioeconomic characteristics, institutional factors, and technology characteristics largely affects farmers willingness to adopt and pay for irrigation services.

CHAPTER THREE

METHODOLOGY

3.1 Introduction

This chapter presents the theoretical framework, the sources of data collection, the methods of data analysis, the definition of variables and the measurements variable included in the analysis and the study area.

3.2 Theoretical Framework

The economic literature on technology adoption is largely grounded in expected utility theory. According to Caswell *et al.*, (2001) the adoption of a new technology is based on the assumption that the individual is a utility maximiser and therefore makes a decision based on maximizing his/her expected utility subject to policies, personal characteristics, natural resource assets, and prices. The theory encapsulates the behaviour of smallholder vegetable farmers in adopting the PAVE Irrigation Technology. Thus, smallholder vegetable farmers are concerned with maximization their utility (farm profits) subject to their demographic characteristics, institutional factors, and characteristics of the technology itself. Therefore, the choice to adopt or not to adopt the technology depends on the technology's its ability to meet farmer's expected outcomes. Discrete choice econometric models such as multi-nomial logit, Logit and Probit among other methods as indicated by Guerre and Moon (2006) are mostly used in determining the factors that influence technology adoption. According to Kebede *et al.* (1989), smallholder vegetable farmers will only adopt a new technology if the utility or farm profits (U) of adopting the technology are higher than utility of not adopting it. Given that $U_1(X)$ represents a smallholder farmers' utility if they adopt a new technology subject to socio-economic and physical factors (X) and $U_0(X)$ represents the utility they derive for not adopting the new technology. Therefore, the utility functions of adopting and not adopting can be written as;

$$U_1(X) = XB_1 + E_1 \dots\dots\dots (1)$$

$$U_0(X) = XB_0 + E_0 \dots\dots\dots (2)$$

Where B_1 , B_0 and E_1 E_0 are the estimated coefficients and error terms of adopting or not adopting the new technology respectively. The probability of adopting the new technology can, therefore, be expressed as;

$$P(Y = 1) = P(U_1 > U_0) \dots\dots\dots (3)$$

$$= P(XB_1 + E_1 > XB_0 + E_0)$$

$$= P\{X(B_1 - B_0) > E_0 - E_1\}$$

$$= P(XB > E)$$

$$= F(XB)$$

Where $F(XB)$ is the cumulative density function of F evaluated at XB

3.3 Methods of Data Analysis

3.3.1 Cost Benefit Analysis (CBA)

The first objective of determining the financial viability of smallholder vegetable farming under the PAVE Irrigation Technology (PIT) in the Upper East and Northern Regions was achieved using the Cost Benefit Analysis (CBA) approach to estimate Net Present Value (NPV) and Benefit Cost Ratio (BCR) of smallholder vegetable farming under the PIT. These two profitability indicators are both discounted cash flow techniques, with basis from the concept of opportunity cost. The choice of these discounted cash flow measures of investment worth is critical since they consider the time value of the benefit streams. Gittinger (1982) indicated that undiscounted measures such as the payback period, proceeds per unit of outlay, average annual proceeds per unit of outlay and average income on book values of investment have all failed to take into consideration the time value of money. Also, these undiscounted measures sometimes makes it difficult to choose between different investment options. In this study, the analysis covers the two vegetables (Okro and Bra) that were cultivated under the technology

within the period. According to Gittinger (1982), Net Present Value (NPV) is the difference between the present value of the cash inflows and the present value of the cash outflows of a project. A positive NPV indicates that smallholder vegetable farming under the PIT is financially feasible. Also, Benefit Cost Ratio (BCR) is the ratio of the present value of the benefits to the present value of the cost discounted at a chosen interest rate. A BCR value greater than 1 indicates that smallholder vegetable farming under the PIT is financially viable

The NPV and BCR are specified as follows;

$$NPV = \sum_{t=1}^n \left(\frac{B_t - C_t}{(1+i)^t} \right) \dots\dots\dots (4)$$

Where;

N= Number of Years (t), B_t = Benefit at time t, i = *interest rate* and C_t = Cost at time t

The BCR is specified as;

$$BCR = \sum_{t=1}^n \frac{\frac{B_t}{(1+i)^t}}{\frac{C_t}{(1+i)^t}} \dots\dots\dots (5)$$

Generally, the cost elements considered for the study covers the installation cost of the technology (cost of the technology, pumps, drip kits, poly tanks) and operational cost including cost of seeds/seedlings, fertilizer, pesticides, fuel and cost of labour (sowing, weeding, spraying, harvesting).

The benefits considered for this study are the crop revenues generated from vegetable farming under the PIT.

3.3.2 The factors that Influence Smallholder Vegetable Farmers Willingness to Adopt the PIT

Potential adopters seek to maximize their utility by making a decision to adopt or not to adopt a particular technology. The choice is discrete, involving 1 for adopting the technology or 0 otherwise. Therefore the dependent variable (PITadopt) is dichotomous variable and cannot be

estimated using Ordinary Least Squares (OLS). Hence, estimating the adoption model, the study employed discrete choice econometrics model as indicated Guerre and Moon (2006).

Largely, the Probit and Logit models have been employed in most adoption studies including; Mariano *et al.* (2012); Uaiene *et al.* (2009) and Muyanga (2009) among others. A Probit model was employed in this study due to its dominance in the adoption literature, its normality assumption and its computational parsimony.

If a farmer's decision to adopt the PIT will yield some level of utility represented by y_i , then

y_i^* is an unobserved variable indicating the maximum utility level that informs a farmer to either adopt or not adopt the technology. Following Muyanga (2009), the Probit model can be expressed as follows, where y_i^* is the latent variable

$$y_i^* = \beta_0 + \beta_i X_i + \mu_i \dots\dots\dots (6)$$

$$y_i = \begin{cases} 1, & \text{if } y_i^* > 0 \\ 0, & \text{if } y_i^* \leq 0 \end{cases} \dots\dots\dots (7)$$

The empirical model of the factors that influence a smallholder vegetable farmer's decision to adopt or not adopt the PIT is specified as follows;

$$PIT_{adopt} = \beta_0 + \beta_1 Loc + \beta_2 Sex + \beta_3 Age + \beta_4 AgeCateg + \beta_5 Marital + \beta_6 Educ + \beta_7 Hsize + \beta_8 lnfarmInc + \beta_9 lnOtherInc + \beta_{10} Credit + \beta_{11} Ac_{mkt} + \beta_{12} Farmsize + \beta_{13} AC_{Extension} + \beta_{14} PIT_{Aware} + \beta_{15} PIT_{Reliable} + \beta_{16} PIT_{mgt} + \beta_{17} Gender_{ConMgt} + \beta_{18} PIT_{Training} + \beta_{19} PIT_{Userfriendly} + \mu_i \dots\dots\dots (8)$$

The study seeks to test the following null (H_0) and alternate (H_A) hypothesis:

H_0 : Farm Income has no effect on smallholder vegetable farmers' decision to adopt the PIT

H_A : Farm Income has a positive effect on smallholder vegetable farmers' decision to adopt the PIT

H_0 : Education has no effect on smallholder vegetable farmers' decision to adopt the PIT

H_A : Education has a positive effect on smallholder vegetable farmers' decision to adopt the PIT

Testing of the rest of the independent variables follows in the same way.

The hypotheses were validated using Z-Test.

Z- Calculated = $\beta_1/SE(\beta_1)$, where β_1 is the coefficient of particular variable and $SE(\beta_1)$ is the standard error of the variable. The calculated Z value is compared to the critical Z value on Z-distribution table. The null hypothesis (H_0) if Z-Calculated is greater than Z- Critical.

The P-values of the independent variables were reported. The P-value is the probability that the test statistic (Z-Test) equals the observed value or a value in the set of values that provides stronger evidence against H_0 . The smaller the P-Value the stronger the evidence against H_0 . A P-value of 0.1 or less suggests that we reject the H_0 and conclude that variable has no significant effect.

3.3.2.1 Variables Definition, Measurement and the Apriori Expectation

Dependent Variable (PITadopt) is a dummy variable taking the value of one (1) for adoption and Zero (0) otherwise.

Independent/ Explanatory variables

The independent variables included in the model were selected based on their relevance in the adoption literature, mainly socio-economic characteristics of the farmer institutional factors such as access to credit and extension services and the characteristics of the technology to be adopted.

Location of respondents (Loc): is a dummy variable coded 1 for Upper East 0 otherwise. It is expected to be positive ($\beta_1 > 0$).

Sex of Respondent (Sex): this variable is a dummy variable taking the value of 1 for female and 0 otherwise. It is expected to be positive, suggesting that women will be willing to adopt the PAVE Irrigation Technology in vegetable production compared to their male counterparts.

This is because women are mostly involved in vegetable production than men. Hence, they will want to embrace any improvement that will enhance their production. Thus, is hypothesised to be ($\beta_2 > 0$)

Age of respondent (Age): this variable is measured as the number of years of the smallholder farmer. It is expected to have a positive sign. Thus indicating that as a smallholder farmer's age increases his/her willingness to adopt increase. Hence, ($\beta_3 > 0$)

Age group of respondent (AgeGateg): it is a dummy variable coded 1 for adult (>35 years) and 0 otherwise. ($\beta_4 > 0$)

Marital status of respondent (Marital): it is a dummy variable coded 1 for married 0 otherwise. ($\beta_5 > 0$)

Education (Educ): it is a continuous variable measured by the number of years a smallholder vegetable farmer spent in school. It is hypothesised that education will have a positive effect on smallholder vegetable farmer's decision to adopt the PAVE Irrigation Technology. This explains that as a smallholder vegetable farmer increases his/her educational level by a year, his/her willingness to adopt the PAVE Irrigation Technology increase. Thus, $\beta_6 > 0$

Household size (H_size): this variable is also a continuous variable measured by the number of people in the smallholder farmer's household. It is also a proxy for family labour. It is hypothesised to take a positive sign, indicating that an increase in the number of people in the smallholder farmer's household will increase their decision to adopt the technology. This means that farmers with large family sizes will want to adopt new technology to increase production to feed the family. Therefore, ($\beta_7 > 0$)

Farm Income (LnFarmInc): it is continuous variable measured by the total income (GHC) generated from farming, it hypothesised to take a positive sign. Thus, as a farmer's income from farming activities increase their willingness to adopt a new technology increase. Therefore, ($\beta_8 > 0$)

Other sources of Income (lnOtherInc): this variable is also continuous measured in Ghana Cedis (GHC). It is expected to be positive, indicating that farmer with increasing income from other sources either than farming will be willing to adopt new technologies. ($\beta_9 > 0$)

Access to credit (Credit): credit is a fundamental requirement for the success of every entrepreneur, in this case, smallholder farmers. It is a dummy variable indicating 1 for yes and 0 otherwise. It hypothesised to take a positive sign, thus farmers that have access to credit are more willing to adopt new technologies compared to their counterparts. ($\beta_{10} > 0$)

Access to market (AC_Mkt): it is a dummy variable coded 1 for yes and 0 otherwise. It is expected to have a positive sign, suggesting that farmers that have access to market will be willing to adopt new technologies than those without access to the market. ($\beta_{11} > 0$)

Farm Size (F_size): This is a continuous variable measured in Hectares of land (Ha). It is expected to be positive. It suggests that farmers with large farm sizes are more likely to adopt new technologies. ($\beta_{12} > 0$)

Access to extension (Ac_extension): farmers that have contact with extension agents tend to have more information on new ways of doing things, hence they are likely to adopt new technologies. It is coded 1 for yes and 0 otherwise. ($\beta_{13} > 0$)

Awareness of the technology (PIT_aware): Farmers' level of awareness of a new technology also influences their decision to adopt. It is a dummy variable coded 1 for yes 0 otherwise. it is expected to have a positive sign, indicating that farmers with some knowledge about the technology are more likely to adopt it. ($\beta_{14} > 0$)

Perceived reliability of the technology (PIT_reliable): the way farmers perceive the technology also influences its adoption. The variable is dummy taking 1 yes it is reliable and 0 otherwise. It is expected to have a positive sign. Indicating that farmers that perceived the PAVE Irrigation Technology to be a reliable source of irrigation water are more likely to adopt it. ($\beta_{15} > 0$).

Community managed (Com_mgt): it is a dummy variable coded 1 for yes 0 otherwise.

$$(\beta_{16} > 0)$$

Gender Consideration in the Management (Gender_ConsMgt): women are noted for their involvement in vegetable production, hence considering them in decision making is expected to have an effect on the adoption of the technology. It is dummy variable coded 1= yes women should be part of the management 0 = otherwise. It is hypothesised to be positive indicating that, involving women in the management of the technology will increase its adoption.

Therefore, $(\beta_{17} > 0)$

Training (PIT_Training): it is dummy variable coded 1= yes 0= otherwise. it is hypothesised to be positive. Thus, farmers that have participated in any training about the technology are more likely to adopt it. $(\beta_{18} > 0)$

Perceived User friendliness (PIT_Usefriendly): it is a dummy variable taking 1= yes 0= otherwise. It is hypothesised that farmers that perceived the technology to be user-friendly are more likely to adopt it. Hence, it expected to have a positive sign. $(\beta_{19} > 0)$

3.3.3 The Amount Smallholder Vegetable Farmers are Willing to Pay

The third objective of the study is to estimate the amount that smallholder vegetable farmers are willing to pay for irrigation water under PAVE Irrigation Technology (PIT) in the Upper East and Northern Regions. The median and mean WTP values were estimated by first obtaining the values of β and σ , in order to construct the fitted values of $\log Y_i$, so that for any vector of x variable the conditional mean can be expressed as $(x_i^1 \beta)$. However, to retransform $\log Y_i$ into Y_i , the median was expressed as $\exp(x_i^1 \beta)$ and the mean was computed by multiplying the median by a scalar $\exp(\sigma^2/2)$. σ Denotes the standard error regression.

3.3.4 Factors that Influence Smallholder Vegetable Farmers WTP Amount

The Contingent Valuation Method (CVM), which is a stated preference method of valuing non-market goods and services was employed in this study. Unlike the Revealed Preference (RP) methods which are indirect, Stated Preference methods and for that matter, CVM is a direct approach to estimating the value that consumers place on a particular non-market good or service. The approach has gained noticeable grounds as the most standard and widely used technique in eliciting information on the value people place on a non-market good. With CVM respondents are asked directly to state the maximum amount they are WTP for the use of a good and in this case irrigation water service. Specifically, the Payment Card (PC) elicitation method was used to elicit the maximum amount smallholder farmers were WTP for irrigation water.

According to Cameron & Huppert (1989) with Payment Card elicitation the amount circled by the respondent on the Payment Card (PC) is only stated and not observed. Hence, its probability lies within an interval. There an interval regression model was estimated to determine the factors influence smallholder farmers WTP. The approach is specified as follows, if the respondent's true Willingness to Pay value, say, Y_i falls within an interval defined by the circled amount (WTP_L) and the next highest value (WTP_U), then $\log Y_i$ will fall between $(\log WTP_L)$ and $(\log WTP_U)$.

$$P_r(WTP_L < \log Y_i < WTP_U) \dots\dots\dots (9)$$

For computation parsimony, Cameron & Huppert (1989) presumed that $E(\log Y_i/x_i)$ is a function with a generic form of $g(x_i/\beta)$, hence linear in parameters. Therefore, we can have a function;

$$\log Y_i = x_i^1 \beta + U_i \dots\dots\dots (10)$$

Where $U_i \sim N(0, \sigma^2)$; has a constant variance, zero mean and normally distributed.

$$P_r(WTP_L \leq x_i^1 \beta + U_i < WTP_U) \dots\dots\dots (11)$$

Standardizing the lower and upper interval thresholds, the probability can be stated as;

$$P_r(Y_i \subseteq (WTP_L, WTP_U)) \\ = P_r((\log WTP_{Li} - x_i^1 \beta) / \sigma < Z_i < (\log WTP_{Ui} - x_i^1 \beta)) \dots\dots\dots (12)$$

Z_i Is the standard normal random variable. Letting Z_{Li}, Z_{Ui} represent the lower and upper intervals respectively, equation (4) can be expressed as a difference between two cumulative standard normal density functions. Hence, can be specified as $\Phi(Z_{Ui}) - \Phi(Z_{Li})$. Φ Is the cumulative standard normal density function.

Hence, for n independent observations the joint probability density function can be interpreted as likelihood function of defined over the unknown parameters β and σ .

The log-likelihood function can, therefore, be expressed as;

$$\text{Log}L = \sum_{i=1}^n \log [\Phi(Z_{Ui}) - \Phi(Z_{Li})] \dots\dots\dots (13)$$

The empirical model of the factors that influence smallholder vegetable farmers WTP amount is expressed as;

$$\begin{aligned}
 PIT_{WTP} = & \alpha_0 + \alpha_1 Loc + \alpha_2 sex + \alpha_3 Age + \alpha_4 AgeCateg + \alpha_5 Educ + \alpha_6 H_{Size} + \\
 & \alpha_7 lnfarmInc + \alpha_8 lnOtherInc + \alpha_9 Exp + \alpha_{10} Credit + \alpha_{11} Ac_{Mkt} + \alpha_{12} F_{Size} + \\
 & \alpha_{13} Ac_{Extension} + \alpha_{14} Food_{short} + \alpha_{15} Payment_{Struc} + U_i \dots\dots\dots (14)
 \end{aligned}$$

The study seeks to test the following null (H_0) and alternate (H_A) hypothesis:

H_0 : Farm Income has no effect on smallholder vegetable farmers' WTP amount

H_A : Farm Income has a positive effect on smallholder vegetable farmers' WTP amount

H_0 : Education has no effect on smallholder vegetable farmers' WTP amount

H_A : Education has a positive effect on smallholder vegetable farmers' WTP amount

Testing of the rest of the independent variables follows in the same way.

The hypotheses were validated using Z-Test.

Z- Calculated = $\beta_1 / SE(\beta_1)$, where β_1 is the coefficient of particular variable and $SE(\beta_1)$ is the standard error of the variable. The calculated Z value is compared to the critical Z value on Z-distribution table. The null hypothesis (H_0) if Z-Calculated is greater than Z- Critical.

The P-values of the independent variables were reported. The P-value is the probability that the test statistic (Z-Test) equals the observed value or a value in the set of values that provides stronger evidence against H_0 . The smaller the P-Value the stronger the evidence against H_0 . A P-value of 0.1 or less suggests that we reject the H_0 and conclude that variable has no significant effect.

3.3.4.1 Variables definition and Measurement

Dependent Variables (lnWPTlo and lnWTPup) to dependent variables are considered, thus taking the lower and upper intervals of smallholder vegetable farmers bid amount.

Independent/ Explanatory variables

The independent variables included in the model were selected based on their relevance in the adoption literature, mainly socio-economic characteristics of the farmer institutional factors such as access to credit and extension services and the characteristics of the technology to be adopted.

Location of respondents (Loc): is a dummy variable coded 1 for Upper East 0 otherwise. It is expected to be positive ($\alpha_1 < 0$)

Sex of Respondent (Sex): this variable is a dummy variable taking the value of 1 for female and 0 otherwise. It is expected to be positive, suggesting that women will be willing to pay more than their male counterparts. It is hypothesised to be ($\alpha_2 > 0$)

Age of respondent (Age): this variable is continuous measured in the number of years of the smallholder farmer. It is expected to affect WTP positively, indicating that as a smallholder farmer's age increases his/her WTP also increases. It is hypothesised to be ($\alpha_3 > 0$).

Age group of respondent (AgeGateg): it is a dummy variable coded 1 for adult (>35 years) and otherwise. ($\alpha_4 > 0$).

Education (Educ): it is a continuous variable measured by the number of years a smallholder vegetable farmer spent in school. It is expected that education will have a positive effect on smallholder vegetable farmer's WTP for irrigation water under the PAVE Irrigation Technology. ($\alpha_5 > 0$).

Household size (H_size): this variable is also a continuous variable measured by the number of people in the smallholder farmer's household. It is expected to take a negative sign, indicating that an increase in the number of people in a smallholder farmer's household will decrease his/her WTP amount. ($\alpha_6 < 0$).

Farm Income (LnFarmInc): it is continuous variable measured by the total income (GHC) generated from farming, it hypothesised to take a positive sign. Thus, as a farmer's income from farming activities increases he/she is likely to pay more for irrigation. ($\alpha_7 > 0$)

Other sources of Income (lnOtherInc): this variable is also continuous measured in Ghana cedi (GHC). It is expected to be positive, suggesting that farmers with increasing income from other sources either than farming are likely to pay more for irrigation. ($\alpha_8 > 0$)

Experience (Exp): it is measured by the number years a smallholder farmer has been cultivating vegetables. It expected that farmers with more experience will be WTP more for irrigation water. ($\alpha_9 > 0$)

Access to credit (Credit): It is a dummy variable indicating 1 for yes and 0 otherwise. It expected to take a positive sign, thus farmers that have access to credit will be WTP to pay for irrigation water. ($\alpha_{10} > 0$).

Access to market (AC_Mkt): it is a dummy variable coded 1 for yes and 0 otherwise. It is expected to have a positive sign, suggesting that farmers that have access to market are more likely to pay for irrigation water. ($\alpha_{11} > 0$).

Farm Size (F_size): This is a continuous variable measured in Hectares of land (Ha). It is expected to be positive. It suggests that farmers with large farm sizes will be WTP to more for irrigation water. ($\alpha_{12} > 0$).

Access to extension (Ac_extension): farmers that have contact with extension agents are likely to understand the benefits of the technology better, and hence will be WTP for irrigation water under the technology to enhance it sustainability. It is expected to take a positive sign meaning that farmers have access to extension services are likely to pay more for irrigation water. ($\alpha_{13} > 0$).

Experience of food shortages (Food_short): this variable is dummy variable coded 1= Yes I do sometimes experience food shortages and 0= otherwise. It hypothesised to positively affect WTP, thus smallholder vegetable farmers that sometimes experience food shortage are more likely to pay for irrigation than those that are somehow food secured. This is because their demand for irrigation is high. ($\alpha_{14} > 0$)

Mode of payment (Mode_payment): how the payment for irrigation water is made, is expected to also influence smallholder vegetable farmers WTP amount. The variable is dummy taking 1= monthly payment 0= otherwise. It is hypothesised to take a positive sign, suggesting that smallholder vegetable farmers will be WTP more under a monthly payment arrangement than an annual (seasonal) payment arrangement. ($\alpha_{15} > 0$)

3.3.5 Constraints of Adopting the PIT

The Kendall's coefficient of concordance was used to achieve the fourth objective; to analyse the constraints that Smallholder vegetable farmers likely to face in adopting the PAVE Irrigation Technology (PIT) in the Upper East and Northern Regions. Smallholder vegetable farmers under PIT were asked to list the major constraints they face in adopting the PAVE irrigation technology in vegetable production. These constraints were ranked by the smallholder vegetable farmers and analysed to obtain the mean score of each constraint. Using the mean scores the constraints were ranked in an ascending order. Kendall's coefficient of concordance (W) was estimated to know the level of agreement among the respondents on their major constraints of using PIT in smallholder vegetable farming. The value of Kendall's coefficient of concordance lies between 0 and 1, it indicates the degree of agreement among the respondent on their most pressing constraints. The following hypothesis were tested and validated using the Chi-Square test.

H₀: There is no agreement among respondents on the constraints that they face in using the PIT in vegetable production.

H₁: There is agreement among respondents on the constraints that they face in using the PIT in vegetable production.

The Kendall's coefficient of concordance (W) is specified as;

$$W = \frac{12[\sum T^2 - (\sum T)^2/n]}{nm^2(n^2-1)} \dots\dots\dots (15)$$

Where W = Kendall's coefficient

T = total rank score for each constraint

n = number of constraints and m = total of number of respondents

SPSS version 20, STATA version 12 and Microsoft excel were used for the analysis.

3.4 Data Collection

3.4.1 Types and Sources of Data

The study employed data from both primary and secondary sources. Primary data were collected using focus group discussions and interviews in each of the communities. Semi-structured questionnaires were designed and pre-tested to ensure that they were relevant in addressing the major issues of this study. The survey questionnaire captures the socio-economic characteristics of the respondents, questions on willingness to adopt and pay for irrigation water under the technology. It also presents an introduction (Contingent Valuation Scenario) explaining what the technology is, how it operates, who is providing it and why farmers should pay as recommended by (Bateman & Turner, 1992). Rowe *et al.* (1996) suggested that values on the PC can progress by either increasing values at a uniform rate or at an exponential scale. This study considers increasing values on a uniform scale, where the values listed on the PC and the intervals between them increase at a uniform rate. This is because increasing values exponentially would not present realistic values for smallholder farmers to choose. See appendix 1 for the survey questionnaire.

Data on the operational cost was collected for the whole production period (3 months) of the cultivated vegetables (Okro and Bra). Records on production cost were taken as and when the cost was incurred. Also, data on revenues (benefits) were obtained by multiplying the yield (Groupings for Okro and Bundles for Bra) by the market price of the vegetable as at the time of the analysis. This was done community by community.

Also, secondary data was collected using desk reviews (reports from Conservation Alliance) to ascertain the cost of putting up a unit of PAVE irrigation technology.

3.4.2 Sampling Procedure and Sample Size

A multi-stage sampling technique was used in the primary data generation. In the first stage, three (3) districts and 3 communities in the Northern and Upper East Regions were purposively selected because the “PAVE Project” is being implemented in these districts. Based on the population of the various communities, in the second stage 80, 160 and 140 smallholder vegetable farmers were randomly selected from Bingo, Jeing and Nyong Gumah respectively. This included both non- beneficiary and beneficiary smallholder vegetable farmers in the selected communities

3.4.3 Sample Size Determination

The sample size for the study was determined using the formula below as specified by Agresti & Finlay (2009) in their book Statistical Methods for the Social Sciences.

$$n = \frac{Z^2 * P(1 - P)}{M^2}$$

Where;

n = Required Sample Size

Z = Confidence level at 95% (standard value of 1.96)

P = Estimated prevalence of farm attribute in the project area

M = Margin of error at 5% (standard value of 0.05)

The value of P is an unknown value that falls between 0 and 1. To solve for n we used $P = 0.5$, as this is expected to give us the largest possible variance value of 0.25 for $P(1 - P)$ on the assumption of homogeneity among the farmers.

$$n = \frac{1.96^2 * 0.5(1 - 0.5)}{0.05^2}$$

$$n = \frac{3.8416 * 0.25}{0.0025}$$

$$n = \frac{0.9604}{0.0025}$$

$$n = 384.16$$

Hence, the study used a sample size of 380, which was distributed among the communities based on their populations. Thus, relatively, the population of Ziong and Nyong Gumah was as twice as the population of Bingo. Hence, I adopted a ratio of 2:2:1 arrive at the sample sizes for the communities.

Table 3.1: District, Community and Sample Size

District	Community	Beneficiary	Non-Beneficiary	Total
Karaga	Nyong Gumah	40	100	140
Savelugu	Ziong	40	120	160
Talensi	Bingo	40	40	80
Grand Total		120	260	380

3.4.4 Study Area

The study was conducted in two of the ten administrative regions of Ghana, namely the Northern and Upper East regions. The Northern Region is the largest region in Ghana, it covers about 70,384 sq km. It is bordered to the north by the Upper East and Upper West Regions, to the south by the Brong Ahafo and (Gautam, Paudel, & Guidry, 2017, February) the Volta Regions. It also shares boundaries with Togo and Cote d'Ivoire to the East and West respectively. It has a single rainy season and long dry season. Vegetation is that of a grassland with a guinea savannah woodland. Drainage is mainly by the Black and White Volta Rivers. The Northern Region has 26 administrative districts. This study concentrates on two of them, namely; Savelugu-Nanton, and Karaga districts.

The Upper East Region is located in the north-eastern corner of Ghana, it is within longitude 00 and 10 West and latitudes 10° 30' N and 11° N. It is bordered to the north, east and west by Burkina Faso, West Mamprusi District in Northern Region and Sissala District in the Upper West Region respectively. It has a total land area of about 8,842 sq km, representing about 2.7 percent of the total land area in the country. The soil and drainage features of the Region are inadequate compared to other parts of the country. Its soil is characterised by low fertility with low organic matter content and high erosion problems. Also, the Region is prone to seasonal water logging and floods. Drainage is mainly by the white and Red Volta and Sissili Rivers. The Region is characterised by one rainy, which is erratic both in duration and spatially. It experiences a long dry spell November to Mid-February. It has 13 administrative districts. This study focuses on interested in one of them, thus the Talensi District.

In general, the project area is characterised by one season rainfall with an average of 1320mm and a mean run off of 1480 (million cubic litres). The area also falls within the White Volta basin as shown in the figures below (Conservation Alliance, 2016)

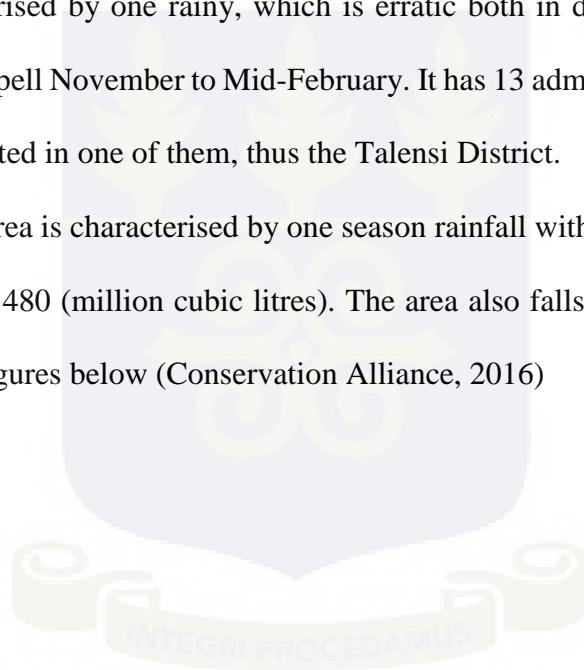
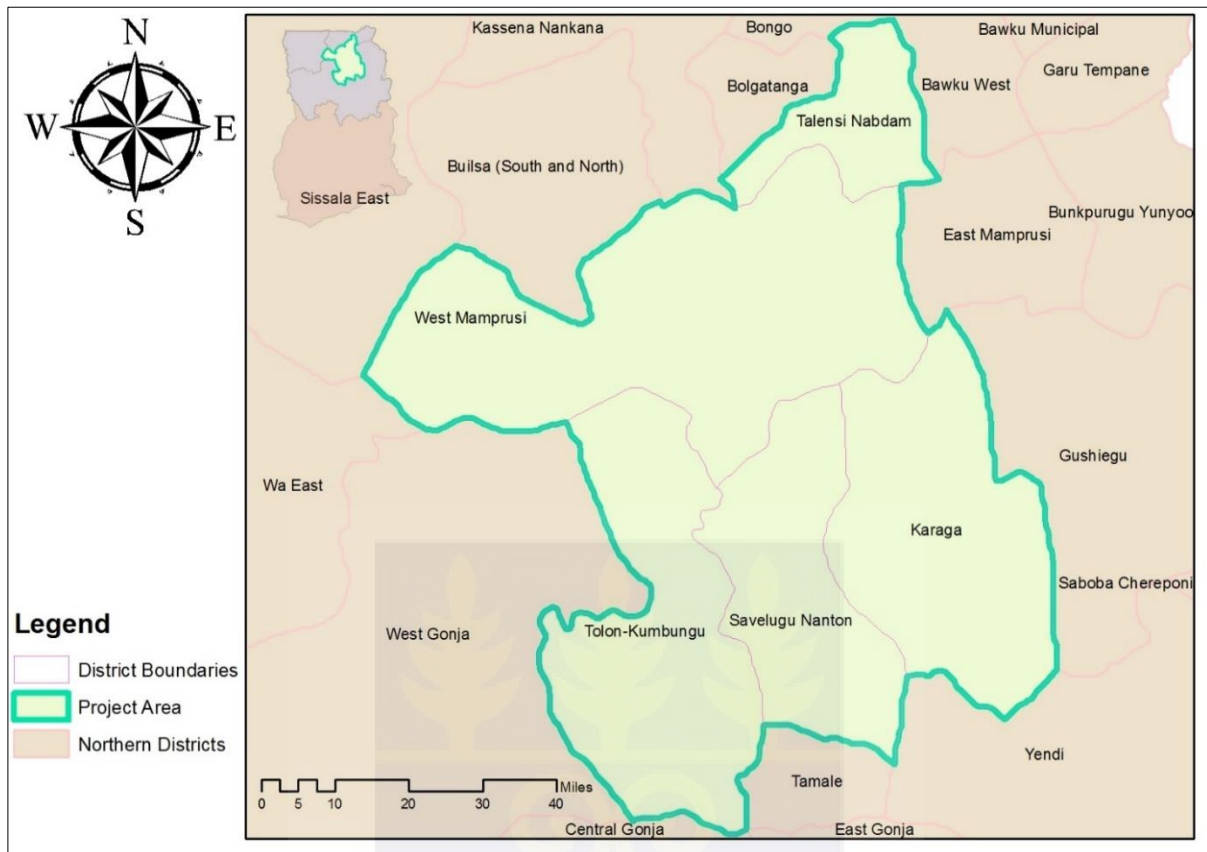
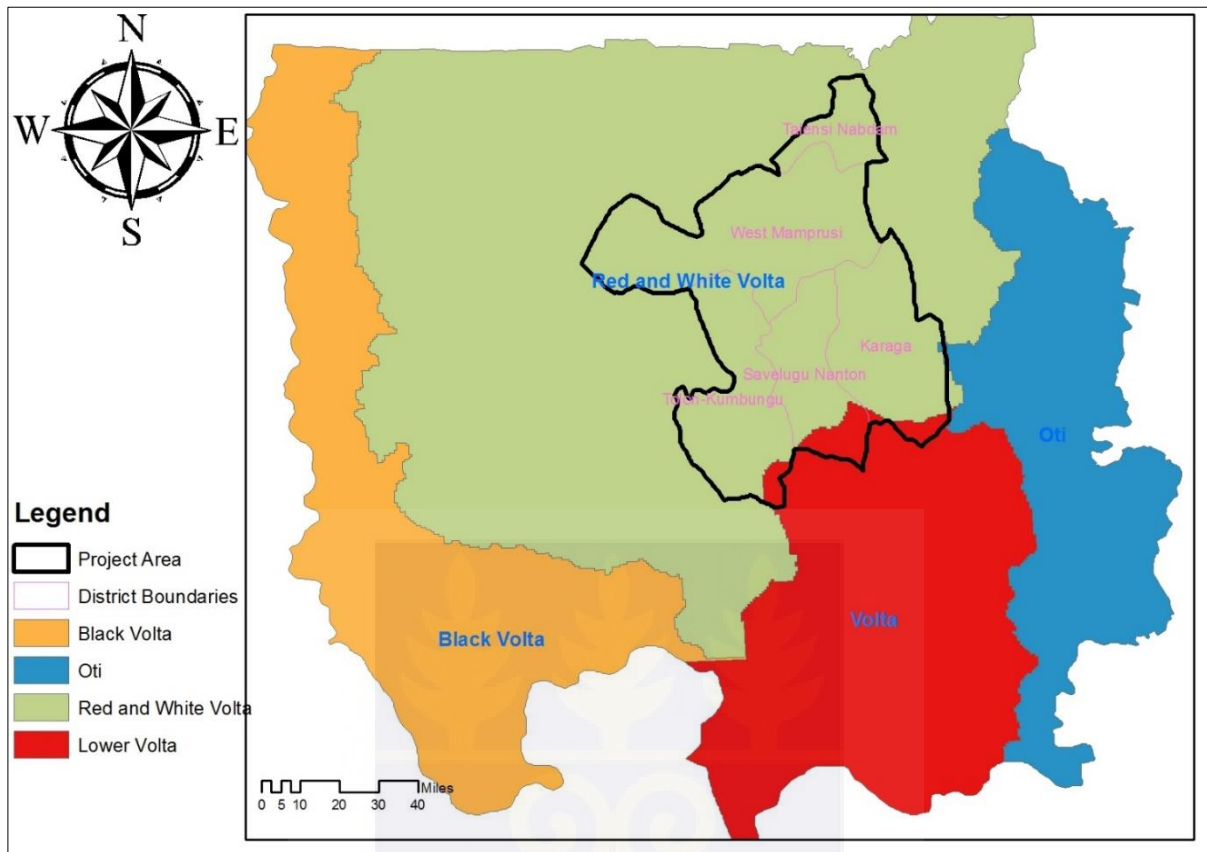


Figure 3. 1: Map of Study Area



Source: Adapted from Conservation Alliance site selection report (April, 2016)

Figure 3. 1: Map of Study Area with Major Rivers



Source: Adapted from Conservation Alliance site selection report (April, 2016)

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.0 Introduction

This chapter presents the results and discussions of the study. It covers the socio-economic characteristics of the respondents in the study. Then it presents the indicators of the financial viability of the PAVE Irrigation Technology in smallholder vegetable farming. Furthermore, results on the determinants of smallholder vegetable farmers willingness to adopt the PAVE Irrigation Technology, estimates of the amount that smallholder vegetable farmers are willing to pay (WTP) and the factors that influence the willingness to pay amount are presented and discussed. Finally, the factors that are likely to inhibit the adoption of the PAVE Irrigation Technology among smallholder vegetable farmers' in the study area are presented and discussed.

4.1 Socio-Economic Characteristics of Respondents

4.1.0 Gender of Respondents

Out of the total sample of 380 respondents (see table 4.1) 246 were males representing 64.7% of the sample while 134 were representing 35.3% of the sampled respondent. There are more males into the production of vegetables in the study area than females.

Table 4. 1: Gender of Respondents by Community

Variables	Zieng	Nyong gumah	Bingo	Total
Male	102 (26.8%)	98 (25.8%)	46 (12.1%)	246 (64.7%)
Female	58 (15.3%)	42 (11.1%)	34 (8.9%)	134 (35.3%)
Total	160 (42.1%)	140 (36.8%)	80 (21.1%)	380 (100%)

Source: Field Survey (2017)

4.1.1 Age Distribution of Respondents

The minimum and maximum ages of the sampled respondents are 18 years and 92 years respectively while the mean age was found to be 36.07 years. Furthermore, it was found that majority of the respondents (55%) were between the ages of 18 and 35 (Table 4.2). This implies that significant number of the population were of the youthful age (≤ 35 years) and about 45% of the respondents were adults (> 35 years).

Table 4. 2: Age Categories of Respondents

Age Categories	Frequency	Percentage (%)
≤ 35 years	209	55
> 35 years	171	45
Total	380	100

Source: Field Survey (2017)

Out of the 55% of youth in vegetable production, Zieng has the majority (25%) whereas Nyong gumah and Bingo has 19.7% and 10.3% respectively. (Table 4.3)

Table 4. 3: Age Categories by Community

	Zieng	Nyong gumah	Bingo	Total
≤ 35 years	95 (25.0%)	75 (19.7%)	39 (10.3%)	201 (55.0%)
> 35 years	65 (17.1%)	65 (17.1%)	41 (10.8%)	171 (45.0%)
Total	160 (42.1%)	140 (36.8%)	80 (21.1%)	380 (100%)

Source: Field Survey (2017)

4.1.3 Religion of Respondents

The religious distribution of the three communities (Table 4.4) indicates that majority (78.4%) are Muslims, while 7.1% and 14.5% represents Christians and Traditionalists respectively.

Table 4. 4: Religious Distribution of respondents

Religion	Frequency	Percentage
Islam	298	78.4
Christianity	27	7.1
Traditional	55	14.5
Total	380	100.0

Source, Field Survey (2017)

4.1.4 Marital Status of Respondents

In table 4.5, majority (85.3%) of the respondents are married, this is followed by Single representing 10.8% and widowed representing 3.9% of the respondents in the study area.

Table 4. 5: Marital Status

Status	Frequency	Percentage (%)
Single	41	10.8
Married	324	85.3
Widowed	15	3.9
Total	380	100.0

Source: Field Survey (2017)

4.1.5 Respondents Education

In table 4.6, majority (75.3%) of respondents in the study area have no formal education, 9.5% of them have primary education while 7.6%, 6.1% and 1.6% of them have JHS, SHS and tertiary education respectively. Respondents spent a maximum of sixteen (16) years in school with a mean of 1.97 years.

Table 4. 6: Level of Education of Respondents

Level of Education	Frequency	Percentage (%)
No Education	286	75.3
Primary	36	9.5
JHS	29	7.6
SHS	23	6.1
Tertiary	6	1.6
Total	380	100

Source: Field Survey (2017)

4.2 Viability of the PAVE Irrigation Technology in Smallholder Vegetable farming.

The Net Present Value (NPV) and the Benefit Cost Ratio (BCR) specified in chapter three were computed for each of the project sites including Ziong, Nyong gumah and Bingo. To simplify the analysis some basic assumptions were made;

- 1) the cropping patterns will remain the same throughout the life span of the technology
- 2) Input and output prices are also constant, since it is believed that an increase in input prices will reflect in the output prices
- 3) The operational cost of cultivating the same type of crops on an additional plot of equal size (0.3 acres) is constant and the revenue generated too is constant. This is based on the assumption of homogeneity of production, which explains that doubling inputs will double output.
- 4) No replacement cost, thus the design of the technology requires no replacement cost.

These assumptions are justified since we are interested in knowing the viability of the PAVE irrigation technology in smallholder vegetable farming and not about predicting what will happen if any changes should occur as noted by Hagos et al. (2013), in their study on the economics of some selected water control technologies in Ethiopia. The life span of each unit

of the technology is 20-25 years, hence 20 years was used for the analysis and I considered a discount rate of 32.1% which is the rate of the central bank of Ghana.

4.2.2 Costs Identification

The cost considered in the analysis include the establishment cost and the operational cost. The establishment cost included the cost of the technology, drip kits, pumps, poly tanks and flow meters. On the other hand operational cost are the cost of inputs (seeds, fertilizer, compost, harvest booster), land preparation (Land clearing, ploughing, harrowing), fuel cost and the cost labour for sowing, weeding, fertilizer application and harvesting.

4.2.3 Benefits Identification

The analysis considered financial benefits of irrigation: increase in food production and household revenues. The benefit stream of an agricultural project is simply a build-up of the expected yield and the market price of the products cultivated. Hence, in this study benefits generated from each community was computed considering the yield per plot (0.3 acres) and the market price of the cultivated vegetables Roselle/Bra (*Hibiscus Sabdariffa*) and Okro (*Abelmoschus Esculentus*).

4.2.4 Choice of Interest Rate

The interest for this study was selected following the rates proposed by Gittinger (1982) including: the opportunity cost of capital, borrowing rate and social time preference rate among others. The opportunity cost of capital can be seen as the return forgone for investing in project A and not in project B. Gittinger (1982) indicates that it is a rate that has the potential of using all available capital in the economy, if all investments are based on it gives more returns. The borrowing rate on the otherhand is the rate that an individual or a nation has to pay on borrowed funds. Lastly, the social time preference rate is the interest rate charged on societal projects, it is usually lower than the rate charged on individuals since society has a longer time space than individuals.

This study used the average industry rate for agriculture from both banks and non bank financial institutions in Ghana. Thus the Annual Percentage Rates (APRs) as at 30th June, 2017. (See Appendix for rates).

The table 4.7 shows the financial viability indicators considered in this study (see appendix 3 for details). The results from the 20 year period cost-benefit analysis of producing Okro and Bra under the PAVE irrigation technology revealed that, Ziong has a Net Present Value (NPV) of GHC 3,637.61 and Benefit Cost Ratio (BCR) of 2.74. The analysis for Nyong Gumah and Bongo also revealed positive Net Present Values (NPVs) of GHC 1,544.21 and GHC 1,723.87 and Benefit Cost Ratios (BCRs) of 2.74 and 2.75 respectively.

This indicates that from the private investor’s point of view investing in the PAVE irrigation technology to enhance vegetable production in the dry season is financially viable, since the NPVs from all the communities turned out to be positive with their respective BCRs being greater than one. This suggest that promoting the PAVE Irrigation Technology for vegetable farming in the Northern and Upper East Regions has the potential of enhancing the livelihoods of smallholder vegetable farmers in the beneficiary communities.

Table 4. 7: Results of Financial Cost-Benefit Analysis by Community

Community	NPV (GHC)	BCR
Ziong	3,637.61	2.74
Nyong Gumah	1,544.21	2.74
Bongo	1,723.87	2.75

Source: Field survey (2017)

4.3 Factors Influencing Smallholder Vegetable Farmers' Willingness to Adopt the PAVE Irrigation Technology (PIT)

4.3.1 Willingness to Adopt the PAVE Irrigation Technology (PIT)

Majority (88.4%) of respondents in the study area are willing to adopt the PAVE Irrigation Technology (PIT) in dry season vegetable farming. (Table 4.8)

Table 4. 8: Willingness to Adopt

Willingness to Adopt	Frequency	Percentage (%)
Yes	336	88.4%
No	44	11.6%
Total	380	100%

Source, Field Survey (2017)

The results from the Probit model presented in Table 4.9 shows the factors that influence smallholder farmers' willingness to adopt the PAVE Irrigation Technology (PIT). The Pseudo R² value is 21.27% and the model provides a Wald Chi² (19) value of 62.47 which is significant at 1% level. This means that the model's predictive power is good and that the independent variables have a joint effect on the dependent variable. The significance of the estimated variables in the model are evaluated at 1%, 5%, 10% respectively. The marginal effect measures the effect that a change in an explanatory variable has on the dependent variable holding other variables fixed.

Table 4. 9: Result of Probit Model

Variables	Coef.	Robust Std.Err	P>Z	Marginal Effects
Constant	0.282	1.115	0.800	
Location (Reg)	-0.316	0.251	0.207	-0.052
Sex	0.201	0.205	0.328	0.030
	-			
Age	0.034***	0.011	0.003	-0.005
Age group (AgeCateg)	-0.528*	0.312	0.091	-0.074
Marital status (Marital)	-0.353	0.272	0.195	-0.043
Education (Educ)	-0.051*	0.028	0.064	-0.007
Household size (H_size)	0.020	0.014	0.156	0.003
Farm income (LnFarmInc)	-0.071	0.122	0.563	-0.010
Other income (LnOtherInc)	0.022	0.033	0.509	0.003
Credit	-0.029	0.190	0.879	-0.004
Access to market (Ac_Mkt)	-0.193	0.245	0.432	-0.026
Farm size (F_sizeha)	0.021	0.053	0.698	0.003
Access to extension (Ac_Extension)	0.363*	0.204	0.075	0.060
Awareness (PIT_Aware)	0.613**	0.290	0.035	0.124
Reliability (PIT_Reliable)	0.684**	0.291	0.019	0.146
Community managed (Com_Manag)	-0.346	0.484	0.474	-0.040
Gender in Mgt (GenderCons_Mgt)	1.375***	0.397	0.001	0.394
Training (PIT_Training)	0.542**	0.247	0.028	0.070
Userfriendliness (PIT_UserFriendly)	0.644***	0.226	0.004	0.126
Number of obs =	380			
Wald chi ² (19) =	62.47			
Prob > chi ² =	0.0000			
Log pseudolikelihood =	-107.24254			
Pseudo R ² =	0.2127			

***, **, * denotes significant levels of 1%, 5%, and 10% respectively

Out of the eighteen (19) variables hypothesised to have influence on the adoption of the PIT, nine (9) variables were found to be significant at 1%, 5% and 10% levels of significance. Seven (7) of the variables conform to their apriori expectations while two (2) of them do not.

The location variable (Reg) is negative but not significant, suggesting that there is no significant difference in the probability of adopting the PIT among smallholder vegetable farmers in the Northern and Upper East regions.

The variable age was found to be negative and significant at 1%. This indicates that a year increase in the age of a smallholder vegetable farmer will decrease his/her probability of adopting the PIT by (0.005) holding all other variables fixed. This is consistent with the findings of Nathanel *et al.* (2015) and Zavale *et al.* (2005) that age of farmers is negatively related to the probability of adopting a new technology. Also, further analysis on age categories (youth and adult) revealed a negative and significant parameter estimates at 10% probability level, indicating that younger farmers are more likely to adopt the PIT compared to older farmers. This could mean that younger farmers are more risk loving and adventurous than older farmers or that older farmers are relatively more resistant to change and hence will cling to their older ways of doing things.

Education of respondent measured in the number of years spent in school, was included in the model to find out whether an increase in smallholder farmers level of formal education will affect their willingness to adopt the PAVE irrigation technology. The results indicate that, smallholder vegetable farmers' level of education was significant at 10% probability level and negatively affects the probability of adopting the irrigation technology. This contradicts the expectation that formal education positively affects smallholder vegetable farmers' decision to adopt the technology. However, it suggests that education might serve as an exit option for smallholder vegetable farmers. Thus, smallholder vegetable farmers with higher education are open to alternative income generating activities, hence they may tend to seek formal employment opportunities than engage in irrigation farming. This finding contradicts the findings of Nzomoi *et al.* (2007) and Shiferaw *et al.* (2008) that education has a positive effect on technology adoption.

The parameter estimate for access to extension services was found to be significant at 10% probability level and also positive. This suggests that smallholder vegetable farmers who have contacts with extension officers are more likely to adopt the PIT compared to those that have no or less contacts with extension officers. This means that exposing farmers' to the benefits to the technology and providing them with the needed technical support will inspire them to use the technology in dry season vegetable production. The results confirm the findings of Uaiene *et al.* (2009) that access to extension has a positive effect on agricultural technology in Mozambique. Also, the result conforms to the findings of Mariano *et al.* (2012) which indicates that farmers' access to extension services increases their probability of adopting agricultural technology.

Also, the variable, awareness of the PAVE Irrigation Technology (PIT_Aware) is positive sign as expected and significant at 5% probability level. Awareness in this study was used as a proxy to the knowledge of the technology. The positive correlation shows that increasing awareness creation will have a positive effect on the adoption of the PAVE Irrigation Technology. Therefore, suggesting that interventions design to promote the adoption of the technology should include creating more awareness of the technology. This finding of technology awareness is in line with the findings of Shiferaw *et al.* (2008) and Asfaw *et al.* (2011) in their studies on the adoption of improved crop varieties in Tanzania and Ethiopia respectively.

Likewise, the variable on smallholder vegetable farmers' perception about the reliability of the PAVE Irrigation Technology (PIT_Reliable) in dry season farming took a positive sign as expected and also significant at a probability level of 5% level. This suggests that, smallholder vegetable farmers that perceived the PAVE Irrigation Technology to be a reliable source of irrigation water are likely to adopt it. This finding is in conformity with the findings of Asfaw

et al. (2011) that farmers adoption decisions are influenced by the perceived attributes of the available technology.

Gender consideration in the management (GenderCon_Mgt) also took a positive sign and significant at probability level of 1%. This implies that allowing women to take part in the decision making, such as decision on the type of crops to cultivate, how to market the products among others, is likely to enhance adoption of the technology. This could be attributed to the fact that vegetable production in northern Ghana is mostly done by women. This finding is consistent with the finding of Shiferaw *et al.* (2008), which reported a positive and significant influence of women participation in decision making on technology adoption. Also, van Koppen *et al.* (2001) reported that, although women contributes significantly to irrigation development they often neglected in the management of irrigation schemes, this study supports their argument that women should be included in the management of irrigation facilities.

The parameter estimate for the variable training (PIT_Training) is also positive sign and significant at 5% probability level. This indicates that taking part in any training activity on the PIT will have a positive effect on adopting the technology, signifying that farmers that smallholder vegetable farmers that have participated in any form of training about the PIT are more likely to adopt the technology than those that have not participated in any training. Training is expected to provide participants with a better understanding of the operations of the technology and therefore will enhance their probability of adoption.

Also, perceived user-friendliness of the technology (PIT_Userfriendly) was found to positive and significant at 1% probability level . This is consistent with the expectation, implying that smallholder vegetable farmers that perceive the PIT to be user friendly are more likely to adopt

the technology compared to those that consider using the PIT to be difficult. Thus smallholder farmers are more likely to adopt new technologies that are simple and easy to use, such as the PIT than new technologies with complex operations. This is also confirms the findings of Asfaw *et al.* (2011) that farmers adoption decisions are influenced by the perceived attributes of the available technology.

Other socio-economic factors such as farm income, other income farm size, gender, experience among others were found to have no significant effect on the adoption of the PIT in smallholder vegetable farming in the Northern and Upper East Regions of Ghana.

In conclusion, the null hypothesis that socio-economic characteristics of respondents, institutional factors, and technology characteristics have no significant effect on the adoption of the PIT is rejected since the probit model shows that about nine (9) of the variable would significantly influence the adoption of the technology.

4.3 Socio-Economic Distribution of WTP Bids

Table 4.10 shows the distribution of the willingness to pay bids among smallholder vegetable farmers. The response of the smallholder farmers indicates the interval in which his/her true WTP value lies. For instance, if a farmer chooses GHC 10 on the Payment Card, it is presumed that his/her true WTP value is greater than or equal to GHC 10, but less than GHC 20. This process is consistent with the recommendation of Cameron & Huppert (1989) and also follows the works of Alhassan *et al.* (2013) and Zakaria *et al.* (2014). See appendix 1 for the listed values on the Payment Card.

As shown in the table 4.10 about 66.1% of respondents indicated they were willing to pay GHC 10 per 0.3acres for irrigation water under the PAVE irrigation technology (this falls within the interval GHC 10 to GHC 20). Also, 18.4% indicated they were willing to pay GHC 20 per

month for irrigation water. In the same vein, 2.9% of smallholder vegetable farmers were willing to pay GHC 30. This makes economic sense, as the bid amount increases from GHC 10 to GHC 20 to GHC 30, proportion of farmers willingness to pay for irrigation water decreases.

Table 4. 10: Distribution of Willingness to Pay Bids per 0.3 Acres per Month

WTP Bids (GHC)	WTP Intervals (GHC)	Frequency	Percent
0	0-10	26	6.8
10	10-20	251	66.1
20	20-30	70	18.4
30	30-40	11	2.9
40	40-50	8	2.1
50	50-60	8	2.1
60	60-70	3	0.8
70	70-80	0	0
80	80-90	1	0.3
90	90-100	0	0
100	100-110	2	0.5
110	110+	0	0
	Total	380	100.0

Source: Field Survey (2017)

Table 4.11 presents the distribution of the willingness to pay amounts by community. Majority (28.2%) of smallholder vegetable farmers that are willing to pay at least GHC 10 for irrigation are from Zieng in the Northern Region. Also, 8.7 percent out of the 18.4 percent of smallholder vegetable farmers that are willing to pay at least GHC 20 for irrigation water usage under the PIT are from Nyong Gumah also in the Northern Region. Some vegetable farmers in the Northern Region are not willing to pay irrigation water usage (4.2% and 2.6% from Zieng and Nyong Gumah respectively). However, all smallholder vegetable farmers in Bingo (Upper East) are willing to pay at least GHC 10 for irrigation water usage. This suggests that smallholder vegetable farmers within the Northern and Upper Regions are prepared to pay at least GHC 10 monthly fees for irrigation water usage per 0.3 acres. Services that require higher fees of at least GHC 20 should target Nyong Gumah in the Northern.

Table 4. 11: Distribution of WTP Bids by Community

	GHC												Total
	0	10	20	30	40	50	60	70	80	90	100	110	
Zieng	16	107	20	5	4	4	1	0	1	0	2	0	160
(%)	4.2	28.2	5.3	1.3	1.1	1.1	.3	0	0.3	0	0.5	.0	42.1
Nyong	10	83	33	5	4	3	2	0	0	0	0	0	140
gumah													
(%)	2.6	21.8	8.7%	1.3	1.1	0.8	0.5	0.0	0.0	0.0	0.0	0.0	36.8
Bingo	0	61	17	1	0	1	0	0	0	0	0	0	80
(%)	0.0	16.1	4.5	0.3	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	21.1
Total	26	251	70	11	8	8	3	0	1	0	2	0	380
(%)	6.8	66.1	18.4	2.9	2.1	2.1	0.8	0.0	0.3	0.0	0.5	0.0	100.0

Source: Field Source (2017)

Out of the 251 farmers willing to pay at least GHC 10, 160 of them are males representing 42.1% whereas 91 representing 23.9% are females (see table 4.12). This implies that a pricing policy that requires smallholder vegetable farmers to pay at least GHC 10 per month should target more males than females. About 6.80% of the respondents indicated they were not willing to pay (WTP) for irrigation water under the technology. Majority of them (5.0%) were males and 1.8% were females.

Table 4. 12: Distribution of WTP Bids by Gender

	GHC												Total
	0	10	20	30	40	50	60	70	80	90	100	11	
Female	7	91	24	4	3	3	1	0	0	0	1	0	134
(%)	1.8	23.9	6.3	1.1	0.8	0.8	0.3	0.0	0.0	0	0.3	.0	35.3
Male	19	160	46	7	5	5	2	0	1	0	1	0	246
(%)	5.0	42.1	12.1	1.8	1.3	1.3	.5	.0	.3	.0	.3	.0	64.7
Total	26	251	70	11	8	8	3	0	1	0	2	0	380
(%)	6.8	66.1	18.4	2.9	2.1	2.1	.8%	.0	.3	.0	.5	.0	100.

Source: Field Source (2017)

By age categorization, majority (35%) of smallholder vegetable farmers that are willing to pay a minimum of GHC 10 are within the youthful age group (≤ 35 years) see table 4.13. Similarly, among smallholder vegetable farmers that are willing to pay a minimum of GHC 20 monthly for irrigation, the youth are the majority (11.3%) out of (18.4%). Also, majority of the respondents that are not willing to pay are within the adult age group (> 35 years). This indicates that the private installed irrigation system such as the PIT should target the youth.

Table 4. 13: Distribution of WTP bids by Age

	GHC												Total
	0	10	20	30	40	50	60	70	80	90	100	110	
≤ 35	11	133	43	7	4	7	2	0	1	0	1	0	209
(%)	2.9	35.0	11.3	1.8	1.1	1.8	0.5	0.0	0.3	0.0	0.3	0.0	55.0
> 35	15	118	27	4	4	1	1	0	0	0	1	0	171
(%)	3.9	31.1	7.1	1.1	1.1	0.3	0.3	0.0	0.0	0.0	0.3	0.0	45.0
Total	26	251	70	11	8	8	3	0	1	0	2	0	380
(%)	6.8	66.1	18.4	2.9	2.1	2.1	0.8	0.0	0.3	0.0	0.5	0.0	100.0

Source: Field Source (2017)

Most of the smallholder vegetable farmers that are willing to pay at least GHC 10 per month for irrigation water usage have no formal education (see table 4.14). The percentages of smallholder vegetable farmers that indicated they were willing to pay GHC 10 keeps decreasing as you move from primary education to tertiary education. Thus from 7.1% to 5.5% to 4.7% and to 0.8. This suggests that smallholder vegetable farmers that have formal education are inclined to other income generating activities than irrigated farming, hence will want to pay less for irrigation water usage.

Table 4. 14: Distribution of WTP Bids by Educational Level

	GHC												Total
	0	10	20	30	40	50	60	70	80	90	100	110	
No.Edu	19	183	57	7	7	8	3	0	0	0	2	0	286
(%)	5.0	48.2	15.0	1.8	1.8	2.1	0.8	0.0	0.0	0.0	0.5	0.0	55.0
Prim	2	27	4	2	1	0	0	0	0	0	0	0	36
(%)	0.5	7.1	1.1	0.5	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.5
JHS	0	21	7	0	0	0	0	0	1	0	0	0	29
(%)	0.0	5.5	1.8	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	7.6
SHS	2	18	1	2	0	0	0	0	0	0	0	0	23
(%)	0.5	4.7	0.3	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.1
Tertiary	3	2	1	0	0	0	0	0	0	0	0	0	6
(%)	0.8	0.5	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.6
Total	26	251	70	11	8	8	3	0	1	0	2	0	380
(%)	6.8	66.1	18.4	2.9	2.1	2.1	0.8	0.0	0.3	0.0	0.5	0.0	100.0

Source: Field Source (2017)

4.4. Estimating the Amount Smallholder Farmers are Willing to Pay

The average median WTP amount is GHC 17.254 with a minimum amount of GHC 9.013 and a maximum amount of GHC 26.824 see table 4.15. Also, the average mean WTP amount is GHC 17.259 with a minimum amount of GHC 9.015 and a maximum amount of GHC 26.831.

Table 4. 15: Monthly Median and Mean WTP Amount

Variable	Obs	Mean	Std. Dev.	Min	Max
Medwtp	380	17.254	2.958632	9.012869	26.82357
Variable	Obs	Mean	Std. Dev.	Min	Max
MeanWTP	380	17.259	2.959448	9.015354	26.83097

The result indicates that on the average a smallholder vegetable farmer will be willing to pay an amount of GHC 17.259 (\$3.97)/month/0.3acre for irrigation water usage under the PIT. This suggests that smallholder vegetable farmers will be contributing at least GHC 4.315 (\$1) weekly and about GHC 103.554 (\$23.82) for the entire dry season (6 months). This WTP amount is higher than the GHC 90(\$20.70)/farmer/season proposed by the providers as service charge to cover the operations and maintenance cost of the technology.

4.6. Factors Influencing Smallholder Vegetable Farmers WTP Amount

The interval regression model result in table 4.16 shows a Wald Chi² (15) value of 58.14 which is significant at the 1% level. This means that the model's predictive power is good and that the independent variables have a joint effect on the dependent variable. The significance of the estimated variables in the model are evaluated at 1%, 5%, 10% respectively. From the analysis six (5) out of the fifteen (15) variables hypothesised in the model were found to have statistically significant influence on the smallholder vegetable farmers' willingness to pay for irrigation water under the PAVE irrigation technology.

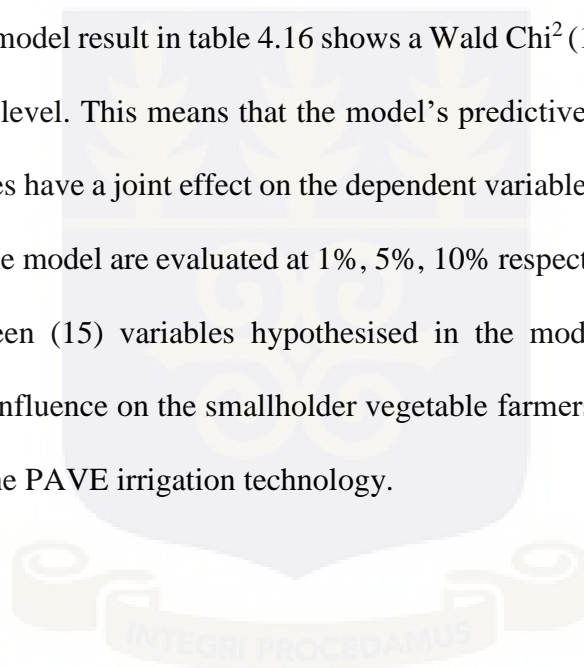


Table 4. 16: Interval Regression Result

Variables	Coef.	Robust Std.Err.	P>Z
Cons	2.985	0.262	0
Location (Reg)	-0.046	0.066	0.482
Sex	0.061	0.053	0.251
Age	-0.001	0.003	0.715
Age group (AgeCateg)	0.082	0.083	0.323
Education (Num_Sch)	-0.014**	0.007	0.037
Household size (H_size)	-0.008***	0.003	0.009
Farm income (LnFarmInc)	-0.044	0.034	0.198
Other income (LnOtherInc)	-0.017*	0.010	0.082
Experience (Exp)	0.000	0.003	0.937
Credit	-0.080	0.055	0.146
Access to market (Ac_Mkt)	0.043	0.065	0.508
Farm size (F_sizeha)	-0.014	0.011	0.225
Access to extension (Ac_Extension)	0.038	0.061	0.531
Food shortage (Food_Short)	0.153**	0.062	0.014
Mode of payment (Payment_Structure)	0.138**	0.060	0.022
σ		0.0234801	
Median WTP	GHC 17.254		
Mean WTP	GHC 17.259		
Number of obs =	380		
Wald chi ² (15) =	58.14		
Log pseudolikelihood =	-438.66344		
Prob > chi ² =	0.0000		

Source: Field Source (2017)

Education of smallholder vegetable farmer was hypothesized to have a positive influence on their willingness to pay amount, with the assumption that educated farmers will have a better understanding of the technologies potential in contributing to their livelihoods, hence will want to pay more for its sustainability. However, it was found to be negative and significant at 5% level. This suggests that as the number of years of education of a smallholder vegetable farmer increases, the amount she or he is willing to pay decreases. A likely explanation is that farmers with higher education are open to alternative income generating activities, hence they may prefer to pay less or quit irrigation and engage themselves in other activities. Baidoo *et al.* (2013) similarly reported results on the effect of education of farmers WTP for irrigation water in their study even though education was found to be insignificant.

Also, household size of the respondent took a negative sign and significant at the 1% level, indicating that smallholder vegetable farmers with larger family sizes are likely to pay less for irrigation water. This is consistent with our expectation and also makes sense in that, households with large families are expected to have higher consumption expenditures, making them less able to pay. This finding corroborates with the findings of Tang et al., (2013) that on the average bigger families are likely to have lesser WTP for irrigation water.

Furthermore, other sources of income (OtherInc) of the respondent took a negative sign but significant at 10% level, this is not in line with the expectation of this study. This finding suggests that smallholder vegetable farmers that engage in other income generating activities, especially in the dry season are likely to pay less for irrigation water. One possible explanation could be that these farmers may attach less value to irrigation compared to other activities. On the other hand those without other income generating activities will attach high value to irrigation and hence will be willing to pay more. This is in line with the view of Fujjie *et al.* (2005) that cooperation among a group of locally managed irrigators can be undermined, if some farmers have the option of engaging in non-farm income generating activities.

The variable indicating whether the respondents do experience food shortages (Food_Short) sometimes was included in the model to find out whether smallholder vegetable farmers experience of food shortages will affect their willingness to pay amount for irrigation water. It was hypothesised to take a positive sign. The variable took a positive sign as expected and was statistically significant at 5% level. This suggests that smallholder vegetable farmers that sometimes experience food shortages are likely to pay more for irrigation water under the PAVE irrigation technology. It further indicates that individuals that are less food secured will want to embrace reliable production ventures such as the PIT to enhance food productivity and

hence improve their livelihoods. This reinforces Conservation Alliance (CAs) vision of improving food security through its double cropping double income approach (Conservation Alliance, 2016).

The study also included the variable ‘mode of payment (Payment_Structure)’ in the model to ascertain whether a payment arrangement once adopted will have any influence on smallholder vegetable farmers’ willingness to pay for irrigation water. This is intended to help promoters develop a smooth and favourable payment system for irrigation water. Results indicate that the variable was a significant (5%) and positive, suggesting that smallholder vegetable farmers will be willing to pay more under a monthly payment arrangement compared to seasonal structure, where farmers are expected to pay after harvesting their crops.

Although age is not significant, it has a negative sign suggesting that the young are WTP more than older farmers. Also, the location variable (Reg) was insignificant, implying that there are no regional differences in determining smallholder vegetable farmers WTP amount for irrigation water. It can, therefore, be said that smallholder vegetable farmers in both the Northern and Upper East Regions have similar WTP amount perceptions.

The null hypothesis that socio-economic characteristics, institutional factors, and payment strategy are not significant factors in influencing the amount smallholder vegetable farmers are willing to pay is rejected since some of the variables were found to have significant effects on the WTP amount.

4.7 Constraints of Adopting the PIT in Smallholder Vegetable Farming

The analysis of the constraints that smallholder vegetable farmers are facing or are likely to face using the technology revealed that, there is some agreement among farmers on the

constraints. The Kendall's coefficient of concordance (W) was found to be 0.226, suggesting that there is about 22.6% agreement among the rankings of smallholder vegetable farmers on their most pressing constraints. However, it was found to be significant at 1% with a Chi Square value of 429.395. Financial constraint was ranked as the most pressing where as inadequate information was ranked as the least constraint. Also, poor management and land tenure issues as identified by Tun Oo et al. (2015) and Oweis & Hachum (2006) were ranked as the third (3rd) and fourth (4th) likely constraints of adoption respectively. The presence of these constraints suggests that smallholder vegetable farmer' are likely to operate below the maximum potential of the PIT. This further points out the sort of support services that smallholder vegetable farmers in the Northern and Upper East Regions need to improve upon the usage of the PIT in dry season farming.

Table 4. 17: Likely Constraints of PIT Adoption

Constraints	Mean Score	Rank
Financial Constraint	1.81	1 st
Inadequate Information	4.26	6 th
Poor management	3.70	3 rd
Land tenure issues	3.84	4 th
Inadequate technical knowledge	4.08	5 th
Market inaccessibility	3.30	2 nd
Number of Obs	380	
Kendall's W	0.226	
Chi ²	429.395	
df	5	
Asymp. Sig.	0.000***	

Source: Field Source (2017)

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This chapter provides a summary of the study and the main findings, it also presents the key conclusions and appropriate policy recommendations arising from the conclusions.

5.2 Summary of the Study

The prevalence of climatic events, such as drought and floods in northern Ghana has contributed significantly to food shortages in the area. This prompted the need for appropriate alternatives to enhance food production and improve rural livelihoods. Among the efforts made so far is the promotion of the PAVE Irrigation Technology by Conservation Alliance and its partners; PAVE Irrigation Systems Ltd (PIS) United States Agency for International Development (USAID) and International Fertilizer Development Centre (IFDC) under the PAVE project. The project is aimed at enhancing food security and improving the nutritional status of poor farming households in selected districts in the Northern and Upper East Regions through the adoption of the PAVE Irrigation Technology (PIT).

The study purposively selected three communities in the Northern and Upper East Regions where the PIT has been piloted and employed random sampling to select respondents in the communities. Data was collected from 380 smallholder vegetable farmers in the selected communities. The data collected covers the socio-economic characteristics of the respondents, their willingness to pay (WTP) information, the likely constraints of adopting the technology. Also, data on the financial cost and benefits of producing vegetables (Okro and Bra) under the technology were collected from three pilot sites in the selected communities.

The Net Present Values (NPV) and Benefit Cost Ratios (BCRs) from the three sites were estimated to ascertain the financial viability of the vegetable production under the technology, considering a period of 20 years and a discount rate of 32.1%. A Probit model was employed to analyse the factors that influence the adoption of the technology and the willingness to pay (WTP) amount was estimated using an interval regression model. Also, the constraints of adopting the PIT were analysed using Kendall's Coefficient of concordance. Finally, it is worthy of noting that, frequencies, tables and percentages and cross tabulations were also helpful in this study.

5.3 Major Findings and Conclusions

Firstly, the cost-benefit analysis revealed that vegetable production under the PAVE Irrigation Technology from all the three communities (Zieng, Nyong Gumah and Bingo) is financially viable. This suggests that smallholder vegetable farmers can sustainably adopt the technology for dry season farming. From the analysis, smallholder vegetable farmers can cover the establishment cost and the operational cost of production within a period of 20 years as used in the estimations (see appendix 3). Therefore, promoting the PAVE Irrigation Technology for dry season vegetable farming in the Northern and Upper East Regions can be seen as a major tool for reducing food insecurity, increasing incomes and enhancing the livelihoods of smallholder vegetable farmers in the beneficiary communities.

Also, it was found that majority of respondents in the study area were willing to adopt the PAVE Irrigation Technology (PIT) in dry season vegetable farming. From the Probit results smallholder vegetable farmer's decision to adopt the PAVE Irrigation Technology was influenced positively by technology awareness, perceived reliability of the technology, access to extension services, gender consideration in management, training and perceived user

friendliness and negatively by formal education and age of respondents. It can be concluded that smallholder vegetable farmers' willingness to adopt the PIT is largely influenced by farmer perception of the technology, demographic and institutional characteristics, and management strategy of the technology. It was also found that regional differences have no significant effect on the adoption PIT in smallholder vegetable farming. This implies that there are no spatial variations in willingness to adopt the PIT. It was also found that majority of the smallholder vegetable farmers in the two regions were males.

Furthermore, the descriptive statistics also revealed that majority of the respondents were willing to pay (WTP) for irrigation water under the technology to enhance its sustainability. Also, it was found that majority of smallholder vegetable farmers are willing to pay an amount within the interval GHC 10 to GHC 20, out of which majority are within the youthful age brackets. This implies that the youth are prepared to pay a maximum GHC 20 monthly for irrigation water usage.

It was found that on the average a smallholder vegetable farmer is willing to pay an amount of GHC 17.259 (\$3.97)/month/0.3ha for irrigation water usage under the PIT. This suggest that smallholder vegetable farmers can be contribute at least GHC 4.315 (\$1) weekly and about GHC 103.554 (\$23.82) for the entire dry season (6 months) as against the amount (GHC 90(\$20.70)/farmer/season) proposed by the providers of the technology to cover operation and maintenance cost per season. Therefore, it can be said that smallholder vegetable farmers in the Northern and Upper East Regions will be able to pay the proposed service charge of GHC 90(\$20.70) to cover the seasonal operations and maintenance cost of the technology to ensure the continuous and reliable operation.

The estimated interval regression model revealed that formal education, household size, and other income sources may have negative effect on the amount smallholder vegetable farmers are willing to pay (WTP) whereas the respondent experience of food shortage and mode of payment are likely to have positive effects on their willingness to pay (WTP) amount. It can be concluded that demographic characteristics of smallholder vegetable farmers, mode of payment and food security status of the farmer jointly influenced their willingness to pay (WTP) amount for irrigation water under the technology.

Finally, financial constraints and market inaccessibility were identified as the most pressing constraints that are likely to inhibit the adoption of the PAVE Irrigation Technology among smallholder vegetable farmers in the study area. The presence of these constraints suggests that smallholder vegetable farmers are still not operating on the frontier. Hence, there is still more room for improving the usage of the technology.

5.4 Policy Recommendations

From the findings, the following recommendations are made to assist policy makers and organisations that are interested in promoting irrigation development to enhance food security in the face of recurrent droughts and floods in the Northern and Upper East Regions of Ghana. Firstly, it was found that vegetable production under the PAVE Irrigation Technology from all the three pilot communities was financially viable. This means that efforts in installing more units of the technology will contribute significantly to improve the livelihoods of smallholder vegetable farmers. It is therefore recommended that, the government (MoFA and GIDA), Non-Governmental Organizations (NGOs) and all other parties interested in promoting food security and improving rural livelihoods to complement the efforts of Conservation Alliance (CA) and their partners to establish more units of the technology.

Secondly, majority of the respondents were willing to adopt the technology. This means that farmers' are prepared to use the technology in vegetable production to help improve their food security status. Therefore, farmers' should be given the required training that is needed to ensure sustainable use of the technology. Also, the relationship between age and willingness to adopt the PIT suggest that younger farmers are more likely to adopt the technology than older farmers. Therefore, government interventions such as Youth in Agriculture and Planting for Food and Jobs should be intensified to encourage the youth to take irrigation farming as a livelihood alternative. Also, there is the need to encourage more females to take up livelihood options in vegetable production. This can be done by getting more females on to current interventions such as the PAVE project, which seeks to ensure double cropping and double income. Above all, government should strengthen the necessary institutions to design and implement reliable irrigation technologies.

Also, extension agents should be trained and resourced to provide farmers' with information on new agricultural technologies such as the PIT. Also, a positive relationship between willingness to adopt and the awareness, training and perception variables point out that exposing farmers to the operations of the PIT is likely to increase adoption rates, hence the need for demonstration farms to enhance farmers' knowledge about the technology.

The structure of the technology management committee is critical to adoption, hence the composition of the committee should include both men and women to enhance adoption.

Thirdly, majority of the farmers are WTP to for irrigation water and therefore suggest the need for output markets. Public Private Partnership (PPP) arrangements are recommended to help link farmers' to output market as well as providing them with the needed physical and institutional supports services. Providers of the technology should set up workable Water User Associations (WUAs) to ensure proper water management practices are implemented for

constant water supply. Even though proposed service fee is less than smallholder vegetable farmers WTP amount, a flexible payment system and good supervision are recommended to get it enforced. Also, privately installed irrigation technologies should target more youth than adults.

In addition, in choosing beneficiaries of the technology, it is recommended that communities that sometimes experience food shortages should be given priority. This means that the beneficiaries of the technology should include people that are in search for alternatives to supplement their food production since they tend to have a high demand for the technology and hence higher willingness to pay (WTP) for irrigation water under the technology.

In reducing the constraints, smallholder vegetable farmers should be linked to credit institutions to acquire financial resources. They should be provided with the needed guidance to ensure that credit received is put to a productive use. Production without market will hinder the adoption of the technology, therefore the study recommends that farmers should be linked to output market and that the government should put the needed infrastructure in place to facilitate the linkage between producers and traders.

5.5 Limitations of the Study and Opportunities for Further Research

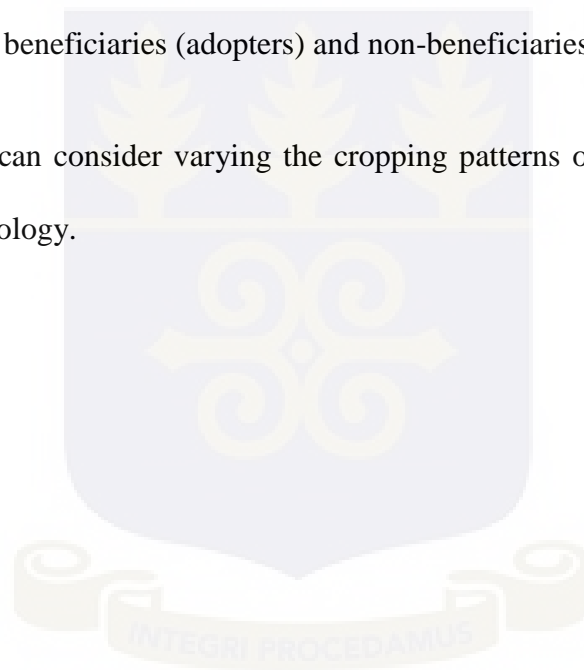
The limitation to this study include:

1. The study is only focused on the viability and the adoption of the PAVE Irrigation Technology without comparisons with other technologies.

3. It was difficult to convert the output of the cultivated crops (Okro and Bra) into standard units of measurements. Hence, in this study, I resorted to the conventional way of marketing such vegetables in Ghana (groupings for Okro and bundles for Bra).

Some opportunities for further research include:

1. Future research should focus on comparing the viability of the PAVE Irrigation Technology and alternative irrigation technologies.
2. Also, next study should concentrate on measuring the impact of the technology by comparing the production levels of beneficiaries (adopters) and non-beneficiaries of the technology.
3. Also, future studies can consider varying the cropping patterns of smallholder vegetable farmers under the technology.



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APPENDICES

Appendix 1, the Study questionnaire

University of Ghana
College of Basic and Applied Science
Department of Agricultural Economics and Agribusiness

Survey Questionnaire on the topic; **the profitability of the PAVE Irrigation Technology (PIT) in smallholder vegetable farming in the Northern Region.**

Introduction

The purpose of this questionnaire is to assess the profitability of the PAVE irrigation technology in vegetable production in your community. This is to help enhance adoption and sustainability of the Technology, we will therefore want information on your current production levels, the cost of production and revenue from production. We also want information on the maximum amount you will be WTP for irrigation water as well as the constraints you face using the technology. This information will assist Conservation Alliance, the government, other stakeholders to design appropriate interventions towards the promotion and sustainability of the PAVE irrigation technology and others.

The interview will take about 20 minutes of your time, please your inputs are very important and will be treated confidentially. Thank you.

Please am I permitted to continue? 1. Yes [] 2. No []

Questionnaire No. {.....} Name of Enumerator

District: Community:

Certified by

Section A

Socio-Economic characteristics of Respondent

1. Sex 1. Male [] 2. Female []
2. Age
3. Religion 1. Islam [] 2. Christianity [] 3. Traditional []
4. Marital status 1. Married [] 2. Single [] 3. Widowed []
5. Level of education 1. No education [] 2. Primary [] 3. JHS [] 4. SHS [] 5. Tertiary []
 e. others (*please specify*).....
6. Number of years spent in School
7. What is the size of your Household

Household composition	Number of people
Male adults (eighteen years and above)	
Female adults (eighteen years and above)	
Children between 6 years and 18 years	
Children under 6 years	
Total	

8. How much do you earn yearly from farming GHC
9. Do you have any other sources of income? 1. Yes [] 2. No []
10. If yes, please indicate the regularity and the amount you earn from these sources

Source	Regularity 1- Daily 2- Weekly 3- Monthly 4- Quarterly 5- Yearly	Income
Animal Sales		
Petty trading		
Artisan (Handicraft, Mason)		
Salaried worker/Pension/Social Security Fund		
Fishing/Hunting		
Remittances		
Others		

11. How many years have you been into vegetable farming?
12. Do you have any Farmer Based Organization (FBO) in your community? 1. Yes 2. No
13. If yes, are you member of the Farmer Based Organization (FBO)? 1. Yes [] 2. No []
14. If No, why 1. No interested 2. Strict requirements 3. Others (*Specify*).....
15. Did you receive any form of credit for production last year? 1. Yes [] 2. No []
16. If yes, what was the source of the credit? 1. Formal 2. Informal
17. How much credit did you receive? *Specify* in GHC
18. Was the facility easily accessible? 1. Yes 2. No
19. If no to [question 15] why? 1. No need 2. Lack of collateral 3. Not available 4. High interest rates
20. Did you have a market for your produce last year? 1. Yes [] 2. No []
21. If yes, where did you sell your produce? 1. Local Market [] 2. Regional Market [] 3. Other (*please specify*)
22. What is the Size of your farm land?
23. What is the nature of the soil in your area? 1. Waterlogged [] 2. Well drained [] 3. Other
24. What is the soil type of your farm? 1. Sandy 2. Loamy 3. Clayey
25. Which of the following vegetables do you produce? 1. Bra [] 2. Pepper [] 3. Okro [] 4. Other (*please specify*)
26. How frequent do you water your crops? 1. Once a day [] 2. Twice a day [] 3. More than twice a day
27. Do you have access to extension services? 1. Yes [] 2. No []
28. If yes, from which institution? 1. An NGO 2. MoFA 3. Other; specify
29. How frequent are extension visits? 1. Monthly [] 2. Bi-Monthly [] 3. Seasonally []
30. If no, why? 1. No need 2. Service very expensive 3. Others [to question 25]

Section B

The PAVE Irrigation Technology

PAVE Irrigation technology (PIT) is a rain water harvesting, aquifer recharge irrigation technology that injects excess water underground during period of rainy days and floods. Water captured can be stored in the soil for up to 180 days, and thus assure farmers of at least 6 months of irrigation. In essence the PIT ensures that water is available all year round for a dual season cropping in a year.

- 31. Are you aware of the PAVE irrigation technology in this community? 1. Yes [] 2. No []
- 32. Are you convinced that the PIT can be a reliable source of irrigation water in your community?
1. Yes [] 2. No []
- 33. Are you currently a beneficiary of the PAVE irrigation Technology? 1. Yes [] 2. No []
- 34. Do you sometimes experience food shortages? 1. Yes [] 2. No []
- 35. If yes, in which months do you normally experience food shortages?

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec

- 36. Given the availability of irrigation water all year, are you convinced that there will be an improvement in your food situation? 1. Yes [] 2. No []
- 37. Do you agree that the PIT should be managed by the community members? 1. Yes [] 2. No []
- 38. If yes, how should it be managed? 1. A committee of beneficiary farmers 2. Existing Water User Association (WUA) *if any* 3. Providers of the technology
- 39. If no, why?
- 40. Do you think there should be gender considerations in the management of the technology?
1. Yes [] 2. No []

- 41. If yes, please indicate the percentage of male and female representation

Gender	Percentage of representation
Male	
Female	

- 42. If no, please give reasons
- 43. Have you participated in any training program on the PAVE irrigation Technology?
1. Yes [] 2. No []
- 44. Do you perceive the PAVE irrigation technology as a user friendly technology in vegetable farming?
1. Yes [] 2. No []
- 45. Are you willing to adopt the PAVE Irrigation Technology in vegetable farming? 1. Yes [] 2. No []

Contingent Valuation Scenario (Read to Respondents)

Recognizing the impact of serious climatic events such as Drought and Flooding on the livelihoods and food security status of your community. Conservation Alliance (CA) in partnership with the PAVE Irrigation Systems Limited (PIS) is promoting the usage of the PAVE Irrigation Technology (PIT) in your community to help reduce the adverse climatic impacts.

The PIT is Water Conservation technology that captures, Filters and Inject Flood water underground, avails it for dry season farming. It guarantees at least 2 season farming, ensuring CA’s double cropping double income vision.

Even though the technology has a great potential of improving your livelihoods through all year round farming, you will agree with us that lack of proper management, operation and maintenance will undermined the success of the project.

Hence, implementers of the technology are interested in knowing the maximum amount that you are willing to pay towards the sustainable management and operation of the technology to ensure an all year round farming. So please answer the following question for us.

Note: The technology is for your community and will be managed by yourselves. So please tell us the truth the amount you are WTP for the smooth operation of the technology.

46. What is the highest amount you will like to pay per plot per month for irrigation water under the PAVE Irrigation Technology?

Please circle one of the amounts below

0 GHC	10 GHC	20 GHC	30 GHC	40 GHC	50 GHC
60 GHC	70 GHC	80 GHC	90 GHC	100 GHC	110 GHC

47. In your view, how should the payment be done?

1. Monthly user fees [] 2. Pay with part of crop harvested (Seasonally) []

48. If your response is zero (0), please indicate the reason (s) why you are not willing to contribute towards the maintenance of the facility

Land Size are too small	
Water is not well distributed	
Crop yields are too low	
Cost of production is too high	
Management will misappropriate the money	

Section C

Constraints of smallholder vegetable farmers in adopting/using the PAVE irrigation technology.

We are just about ending this interview, but before that, I would like to know some of the constraints you are facing or likely to face in adopting/using the PAVE irrigation technology for vegetable production.

49. Below are some factors that are likely to inhibit irrigation technology adoption. Please indicate and rank those that are applicable to you or those that you are likely to face.

Constraints	Tick	Rank
1. Financial Constraint		
2. Inadequate Information		
3. Poor management		
4. Land tenure issues		
5. Inadequate technical knowledge		
6. Market inaccessibility		
7.		
8.		



Appendix 2, Probit and Interval Regression Results

```
_____ (R)
/___ / ___/ / ___/
___/ / /___/ / /___/ 12.0 Copyright 1985-2011 StataCorp LP
Statistics/Data Analysis StataCorp
4905 Lakeway Drive
Special Edition College Station, Texas 77845 USA
800-STATA-PC http://www.stata.com
979-696-4600 stata@stata.com
979-696-4601 (fax)
```

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Serial number: 93611859953
Licensed to: Mohammed
University of Ghana

Notes:

```
1. (/v# option or -set maxvar-) 5000 maximum variables

. use "C:\Users\Mohammed\Desktop\My DataFullnew1.dta"

. probit PIT_Adopt Reg Sex Age AgeCateg_D Marit_D Num_Sch H_size LnFarmInc LnOtherInc
Credit Ac_Mkt F_sizeha Ac_Extension PIT_Aware PIT_Relia
> ble PIT_Manage GenderCons_Mgt PIT_Training PIT_UserFriendly
```

```
Iteration 0: log likelihood = -136.21138
Iteration 1: log likelihood = -108.05985
Iteration 2: log likelihood = -107.24398
Iteration 3: log likelihood = -107.24254
Iteration 4: log likelihood = -107.24254
```

```

Probit regression                               Number of obs   =       380
                                                Wald chi2(19)   =       62.47
                                                Prob > chi2     =       0.0000
Log pseudolikelihood = -107.24254             Pseudo R2      =       0.2127
    
```

	Robust					
PIT_Adopt	Coef.	Std. Err.	z	P> z	[95% Conf. Interval]	
Reg	-.3163697	.2507215	-1.26	0.207	-.8077747	.1750354
Sex	.2005368	.205005	0.98	0.328	-.2012656	.6023392
Age	-.0335354	.0113082	-2.97	0.003	-.0556991	-.0113717
AgeCateg_D	-.5277627	.3123747	-1.69	0.091	-1.140006	.0844805
Marit_D	-.3531402	.2723129	-1.30	0.195	-.8868636	.1805832
Num_Sch	-.0514133	.027766	-1.85	0.064	-.1058337	.0030072
H_size	.0203098	.0143302	1.42	0.156	-.0077768	.0483964
LnFarmInc	-.0705903	.1221412	-0.58	0.563	-.3099827	.168802
LnOtherInc	.0218346	.0330302	0.66	0.509	-.0429034	.0865725
Credit	-.0288658	.1900321	-0.15	0.879	-.4013219	.3435903
Ac_Mkt	-.1929031	.2452789	-0.79	0.432	-.6736408	.2878347
F_sizeha	.0206099	.0531924	0.39	0.698	-.0836454	.1248651
Ac_Extension	.3634317	.204249	1.78	0.075	-.0368889	.7637522
PIT_Aware	.6130242	.2904596	2.11	0.035	.0437338	1.182315
PIT_Reliable	.6838327	.2908062	2.35	0.019	.113863	1.253802
PIT_Manage	-.346161	.4839627	-0.72	0.474	-1.29471	.6023885
GenderCons_Mgt	1.37511	.396581	3.47	0.001	.5978253	2.152394
PIT_Training	.5422106	.2466162	2.20	0.028	.0588518	1.025569
PIT_UserFriendly	.6442566	.2264332	2.85	0.004	.2004557	1.088058
_cons	.2823068	1.11497	0.25	0.800	-1.902994	2.467607

. mfx

Marginal effects after probit

$$y = \text{Pr}(\text{PIT_Adopt}) \text{ (predict)}$$

$$= .92301459$$

variable	dy/dx	Std. Err.	z	P> z	[95% C.I.]	X
Reg*	-.0520046	.04506	-1.15	0.248	-.140311	.036302	.210526	
Sex*	.0302382	.03261	0.93	0.354	-.033675	.094152	.647368	
Age	-.0048425	.00169	-2.87	0.004	-.008153	-.001532	36.0684	
AgeCat~D*	-.0742979	.04447	-1.67	0.095	-.161456	.01286	.55	
Marit_D*	-.0426756	.02712	-1.57	0.116	-.095823	.010472	.852632	
Num_Sch	-.0074241	.00397	-1.87	0.062	-.015211	.000363	1.97105	
H_size	.0029327	.00209	1.40	0.160	-.001159	.007024	11.9079	
LnFarm~c	-.0101932	.01786	-0.57	0.568	-.045202	.024815	6.7298	
LnOthe~c	.0031529	.0048	0.66	0.511	-.006253	.012559	4.76735	
Credit*	-.0041661	.02745	-0.15	0.879	-.05796	.049628	.513158	
Ac_Mkt*	-.0255577	.02978	-0.86	0.391	-.083928	.032813	.813158	
F_sizeha	.0029761	.0077	0.39	0.699	-.012124	.018076	2.7945	
Ac_Ext~n*	.0599709	.03905	1.54	0.125	-.016558	.1365	.757895	
PIT_Aw~e*	.1239251	.0751	1.65	0.099	-.023276	.271126	.915789	
PIT_Re~e*	.1458545	.08143	1.79	0.073	-.013745	.305454	.942105	
PIT_Ma~e*	-.0400707	.04318	-0.93	0.353	-.124706	.044565	.939474	
Gender~t*	.3935525	.15242	2.58	0.010	.094813	.692292	.973684	
PIT_Tr~g*	.0695256	.02721	2.56	0.011	.016205	.122847	.331579	
PIT_Us~y*	.1264912	.05502	2.30	0.021	.018661	.234321	.855263	

(*) dy/dx is for discrete change of dummy variable from 0 to 1

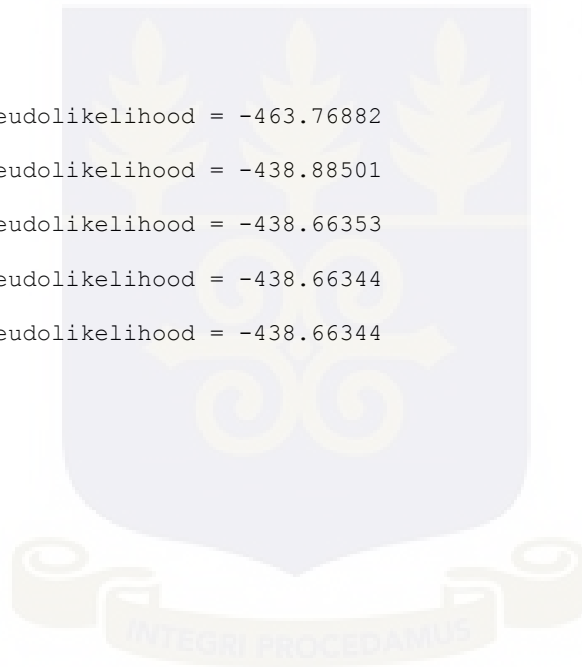
```
intreg LnWTPlo LnWTPup Reg Sex Age AgeCateg_D Num_Sch H_size LnFarmInc LnOtherInc  
Exp Credit Ac_Mkt F_sizeha Ac_Extension Food_Short Paymen  
> t_Structure, vce(robust)
```

Fitting constant-only model:

```
Iteration 0: log pseudolikelihood = -483.7393  
Iteration 1: log pseudolikelihood = -464.08608  
Iteration 2: log pseudolikelihood = -464.00444  
Iteration 3: log pseudolikelihood = -464.00444
```

Fitting full model:

```
Iteration 0: log pseudolikelihood = -463.76882  
Iteration 1: log pseudolikelihood = -438.88501  
Iteration 2: log pseudolikelihood = -438.66353  
Iteration 3: log pseudolikelihood = -438.66344  
Iteration 4: log pseudolikelihood = -438.66344
```



```
Interval regression                               Number of obs   =       380
                                                Wald chi2(15)   =       58.14
Log pseudolikelihood = -438.66344              Prob > chi2     =       0.0000
```

```
-----+-----
```

		Robust				
	Coef.	Std. Err.	z	P> z	[95% Conf. Interval]	
Reg	-.0462368	.0658189	-0.70	0.482	-.1752394	.0827659
Sex	.0610328	.0531715	1.15	0.251	-.0431814	.1652471
Age	-.0010656	.0029169	-0.37	0.715	-.0067826	.0046515
AgeCateg_D	.081948	.0829144	0.99	0.323	-.0805613	.2444573
Num_Sch	-.0137092	.0065869	-2.08	0.037	-.0266192	-.0007992
H_size	-.0076584	.0029482	-2.60	0.009	-.0134367	-.0018801
LnFarmInc	-.0444462	.0344977	-1.29	0.198	-.1120605	.0231681
LnOtherInc	-.0170992	.0098398	-1.74	0.082	-.0363849	.0021865
Exp	.0002039	.0025953	0.08	0.937	-.0048828	.0052905
Credit	-.0803079	.0552736	-1.45	0.146	-.1886422	.0280265
Ac_Mkt	.0432613	.0652785	0.66	0.508	-.0846822	.1712048
F_sizeha	-.0139306	.0114833	-1.21	0.225	-.0364374	.0085762
Ac_Extension	.0384955	.0614373	0.63	0.531	-.0819194	.1589104
Food_Short	.1527024	.0622077	2.45	0.014	.0307776	.2746272
Payment_Structure	.1379098	.0603583	2.28	0.022	.0196098	.2562098
_cons	2.985204	.2617063	11.41	0.000	2.472269	3.498139
-----+-----						
/lnsigma	-.8753266	.0563443	-15.54	0.000	-.9857594	-.7648938
-----+-----						
sigma	.4167259	.0234801			.3731557	.4653834
-----+-----						

```
Observation summary:      0 left-censored observations
                          0 uncensored observations
                          0 right-censored observations
                          380 interval observations
```

```
. **Predict wtp**
. capture drop wtp
. predict wtp
(option xb assumed; fitted values)
. **Calculate median wtp**
. capture drop medwtp
. gen medwtp = exp(wtp)
. sum medwtp
```

Variable	Obs	Mean	Std. Dev.	Min	Max
medwtp	380	17.25375	2.958632	9.012869	26.82357

```
. generate expsigmasq = exp((.0234801*.0234801)/2)
```

```
. generate MeanWTP = medwtp * expsigmasq
```

```
. sum MeanWTP
```

Variable	Obs	Mean	Std. Dev.	Min	Max
MeanWTP	380	17.25851	2.959448	9.015354	26.83097

Appendix 3, Cost-Benefit Analysis of vegetable farming under the PAVE Irrigation Technology.

COST-BENEFIT ANALYSIS OF THE PAVE IRRIGATION TECHNOLOGY IN VEGETABLE FARMING (BRA AND OKRO) AT ZIONG IN THE NORTHERN REGION

Cost Benefit Analysis for Ziong									
Year	Installation cost	Operational cost	Total Cost	Benefits	Discount factor	Discounted Cost	Discounted Benefits	Discounted NCF	Accumulated
0	60000	0.00	60,000.00	0.00	1.00	60,000.00	0.00	-60,000.00	-60,000.00
1	0	1,870.00	1,870.00	5,128.80	0.76	1,415.59	3,882.51	2,466.92	-57,533.08
2	0	14,960.00	14,960.00	41,030.40	0.57	8,572.86	23,512.57	14,939.71	-42,593.37
3	0	14,960.00	14,960.00	41,030.40	0.43	6,489.68	17,799.07	11,309.39	-31,283.98
4	0	14,960.00	14,960.00	41,030.40	0.33	4,912.70	13,473.94	8,561.24	-22,722.75
5	0	14,960.00	14,960.00	41,030.40	0.25	3,718.93	10,199.80	6,480.87	-16,241.87
6	0	14,960.00	14,960.00	41,030.40	0.19	2,815.24	7,721.27	4,906.04	-11,335.84
7	0	14,960.00	14,960.00	41,030.40	0.14	2,131.14	5,845.02	3,713.88	-7,621.96
8	0	14,960.00	14,960.00	41,030.40	0.11	1,613.28	4,424.69	2,811.42	-4,810.54
9	0	14,960.00	14,960.00	41,030.40	0.08	1,221.25	3,349.50	2,128.25	-2,682.29
10	0	14,960.00	14,960.00	41,030.40	0.06	924.49	2,535.58	1,611.09	-1,071.20
11	0	14,960.00	14,960.00	41,030.40	0.05	699.84	1,919.44	1,219.60	148.40
12	0	14,960.00	14,960.00	41,030.40	0.04	529.78	1,453.02	923.24	1,071.63
13	0	14,960.00	14,960.00	41,030.40	0.03	401.05	1,099.94	698.89	1,770.53
14	0	14,960.00	14,960.00	41,030.40	0.02	303.59	832.66	529.06	2,299.59
15	0	14,960.00	14,960.00	41,030.40	0.02	229.82	630.32	400.50	2,700.09
16	0	14,960.00	14,960.00	41,030.40	0.01	173.97	477.16	303.18	3,003.28
17	0	14,960.00	14,960.00	41,030.40	0.01	131.70	361.21	229.51	3,232.78
18	0	14,960.00	14,960.00	41,030.40	0.01	99.70	273.44	173.74	3,406.52
19	0	14,960.00	14,960.00	41,030.40	0.01	75.47	206.99	131.52	3,538.04
20	0	14,960.00	14,960.00	41,030.40	0.00	57.13	156.69	99.56	3,637.61
							2.74	BCR= 2.74	

								NPV= 3,637.61	
--	--	--	--	--	--	--	--	------------------	--

**COST-BENEFIT ANALYSIS OF THE PAVE IRRIGATION TECHNOLOGY IN VEGETABLE FARMING (BRA AND OKRO) AT
NYONG GUMAH IN THE NORTHERN REGION**

Cost Benefit Analysis for Nyong gumah									
Year	Installation cost	Operational cost	Total Cost	Benefits	Discount factor	Discounted Cost	Discounted Benefits	Discounted NCF	Accumulated
0	60000	0.00	60,000.00	0.00	1.00	60,000.00	0.00	-60,000.00	-60,000.00
1	0	1,810.00	1,810.00	4,961.60	0.76	1,370.17	3,755.94	2,385.77	-57,614.23
2	0	14,480.00	14,480.00	39,692.80	0.57	8,297.80	22,746.06	14,448.26	-43,165.98
3	0	14,480.00	14,480.00	39,692.80	0.43	6,281.45	17,218.82	10,937.36	-32,228.61
4	0	14,480.00	14,480.00	39,692.80	0.33	4,755.07	13,034.68	8,279.61	-23,949.00
5	0	14,480.00	14,480.00	39,692.80	0.25	3,599.60	9,867.28	6,267.68	-17,681.32
6	0	14,480.00	14,480.00	39,692.80	0.19	2,724.91	7,469.56	4,744.65	-12,936.67
7	0	14,480.00	14,480.00	39,692.80	0.14	2,062.76	5,654.47	3,591.71	-9,344.96
8	0	14,480.00	14,480.00	39,692.80	0.11	1,561.51	4,280.45	2,718.93	-6,626.03
9	0	14,480.00	14,480.00	39,692.80	0.08	1,182.07	3,240.31	2,058.24	-4,567.79
10	0	14,480.00	14,480.00	39,692.80	0.06	894.83	2,452.92	1,558.09	-3,009.70
11	0	14,840.00	14,480.00	39,692.80	0.05	677.39	1,856.87	1,179.48	-1,830.22
12	0	14,480.00	14,480.00	39,692.80	0.04	512.78	1,405.65	892.87	-937.35
13	0	14,480.00	14,480.00	39,692.80	0.03	388.18	1,064.08	675.90	-261.45
14	0	14,480.00	14,480.00	39,692.80	0.02	293.85	805.51	511.66	250.21
15	0	14,480.00	14,480.00	39,692.80	0.02	222.45	609.77	387.33	637.54
16	0	14,480.00	14,480.00	39,692.80	0.01	168.39	461.60	293.21	930.75
17	0	14,480.00	14,480.00	39,692.80	0.01	127.47	349.43	221.96	1,152.71
18	0	14,480.00	14,480.00	39,692.80	0.01	96.50	264.52	168.02	1,320.73

19	0	14,480.00	14,480.00	39,692.80	0.01	73.05	200.24	127.19	1,447.93
20	0	14,480.00	14,480.00	39,692.80	0.00	55.30	151.58	96.29	1,544.21
							2.74	BCR = 2.74	
								NPV = 1,544.21	

COST-BENEFIT ANALYSIS OF THE PAVE IRRIGATION TECHNOLOGY IN VEGETABLE FARMING (BRA AND OKRO) AT BINGO IN THE UPPER EAST REGION

Cost Benefit Analysis for Bingo									
Year	Installation cost	Operational cost	Total Cost	Benefits	Discount factor	Discounted Cost	Discounted Benefits	Discounted NCF	Accumulated
0	60000	0.00	60,000.00	0.00	1.00	60,000.00	0.00	-60,000.00	-60000.00
1	0	1,810.00	1,810.00	4,970.80	0.76	1,370.17	3,762.91	2,392.73	-57607.27
2	0	14,480.00	14,480.00	39,766.40	0.57	8,297.80	22,788.23	14,490.43	-43116.83
3	0	14,480.00	14,480.00	39,766.40	0.43	6,281.45	17,250.74	10,969.29	-32147.54
4	0	14,480.00	14,480.00	39,766.40	0.33	4,755.07	13,058.85	8,303.78	-23843.77
5	0	14,480.00	14,480.00	39,766.40	0.25	3,599.60	9,885.58	6,285.98	-17557.79
6	0	14,480.00	14,480.00	39,766.40	0.19	2,724.91	7,483.41	4,758.50	-12799.29
7	0	14,480.00	14,480.00	39,766.40	0.14	2,062.76	5,664.96	3,602.20	-9197.09
8	0	14,480.00	14,480.00	39,766.40	0.11	1,561.51	4,288.38	2,726.87	-6470.22
9	0	14,480.00	14,480.00	39,766.40	0.08	1,182.07	3,246.32	2,064.25	-4405.97
10	0	14,480.00	14,480.00	39,766.40	0.06	894.83	2,457.47	1,562.64	-2843.33
11	0	14,480.00	14,480.00	39,766.40	0.05	677.39	1,860.31	1,182.92	-1660.41
12	0	14,480.00	14,480.00	39,766.40	0.04	512.78	1,408.26	895.47	-764.94
13	0	14,480.00	14,480.00	39,766.40	0.03	388.18	1,066.06	677.88	-87.06
14	0	14,480.00	14,480.00	39,766.40	0.02	293.85	807.01	513.15	426.09
15	0	14,480.00	14,480.00	39,766.40	0.02	222.45	610.91	388.46	814.55

16	0	14,480.00	14,480.00	39,766.40	0.01	168.39	462.46	294.06	1108.61
17	0	14,480.00	14,480.00	39,766.40	0.01	127.47	350.08	222.61	1331.22
18	0	14,480.00	14,480.00	39,766.40	0.01	96.50	265.01	168.51	1499.74
19	0	14,480.00	14,480.00	39,766.40	0.01	73.05	200.61	127.57	1627.30
20	0	14,480.00	14,480.00	39,766.40	0.00	55.30	151.87	96.57	1723.87
							2.75	BCR= 2.75	
								NPV = 1,723.87	

A group of Okro (10 big pods) was sold at GHC 4

A bundle of Bar was also sold at GHC 4



Appendix 4. Bank Interest Rates

BANK OF GHANA
NOTICE TO FINANCIAL INSTITUTIONS AND THE PUBLIC
NOTICE NO. BG/GOV/SEC/2017/14

ANNUAL PERCENTAGE RATES (APR) AND AVERAGE INTEREST (AI) PAID ON DEPOSITS AS AT 30TH JUNE, 2017

The Bank of Ghana publishes the following financial institutions' Annual Percentage Rates (APR) and Average Interest (AI) paid on deposits for the information of the public. The publication of these rates is to promote transparency in the pricing and provision of banking services

	Deposits	Base Rate	Vehicle Loans	Mortgage	Other Consumer Credit	Agriculture	Manufacturing	Commerce	Construction
<i>Banks</i>	Average Interest Rate	Percent	Annual Percentage Rate	Annual Percentage Rate	Annual Percentage Rate	Annual Percentage Rate	Annual Percentage Rate	Annual Percentage Rate	Annual Percentage Rate
Access Bank	9.8	26.6	N/A	N/A	30.0	30.0	26.6	28.5	30.7
ADB Bank	9.1	22.9	31.8	N/A	29.2	27.8	29.8	29.8	29.2
Bank of Africa	13.0	27.2	35.6	36.6	N/A	35.6	35.6	36.6	35.6
Bank of Baroda	15.4	16.2	22.0-28.0	22.0-28.0	25.0-30.0	22.0-28.0	22.0-28.0	22.0-28.0	22.0-28.0
BSIC	9.0	29.6	29.6	29.6	29.6	29.6	29.6	29.6	29.6
Barclays Bank	10.4	18.9	34.2 - 38.5	34.2 - 38.5	34.2 - 38.5	26.2-35.9	26.2-35.9	26.2-35.9	26.2-35.9
CAL Bank	9.0	27.5	34.1	31.1	34.1	N/A	32.8	32.8	32.8
Capital Bank	12.6	32.3	N/A	N/A	36.4	N/A	38.1	39.4	N/A
Ecobank	9.2	25.9	34.1	34.1	N/A	26.5	26.5	28.7	26.5
Energy Bank	5.7	28.9	33.9	33.9	33.9	33.9	33.9	33.9	33.9
First Atlantic Bank	13.8	25.4	N/A	N/A	41.2	37.8	37.6	37.8	37.6
FBN Bank Ghana	10.9	28.6	N/A	N/A	32.8	N/A	31.7	31.7	31.7
Fidelity Bank	10.0	21.9	N/A	N/A	31.9	32.3	32.3	32.3	32.3
First National Bank	11.1	23.5	N/A	N/A	N/A	N/A	N/A	29.1	N/A
GCB Bank	8.7	25.0	30.7	30.7	30.7	26.4	26.4	26.4	26.4
GN Bank	13.3	21.8	32.0	N/A	32.0	26-32	26-32	22.6-27	26-32
Guaranty Trust Bank	7.4	24.8	N/A	N/A	33.3	N/A	29.9	31.5	31.0
Heritage Bank	9.6	25.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A
HFC Bank	11.4	29.0	34.4	31.9	39.5	38.7	34.5	36.4	35.6
National Investment Bank	11.4	29.7	N/A	N/A	N/A	37.2	37.2	37.2	38.2
OmniBank	17.3	29.5	38.4	N/A	37.9	38.4	38.4	37.9	38.9
Prudential Bank	10.9	26.7	33.6	33.6	33.4	33.3	34.5	33.6	34.5
Sovereign bank	10.5	34.9	N/A	N/A	N/A	N/A	32.0	30.0 – 39.0	N/A
Standard Chartered Bank	5.9	17.7	N/A	N/A	25 - 34	25 - 34	25 - 34	25 - 34	N/A
Societe Generale Bank	9.7	19.4	N/A	N/A	N/A	27.7	28.7	28.2	29.7
Stanbic bank	14.1	19.8	26.3	26.3	26.3	26.3	26.3	26.3	26.3

The Royal Bank	14.7	35.0	35.5-40.5	35.5-40.5	35.5-40.5	35.5-40.5	35.5-40.5	35.5-40.5	35.5-40.5
United Bank for Africa	13.6	27.7	33.1	N/A	31.0	32.9	30.4	32.6	31.7
Universal Merchant Bank	7.6	26.5	N/A	N/A	35.5	N/A	35.9	33.7	31.0
Unibank	12.6	40.9*	39.8	N/A	32.8	N/A	37.9	36.9	37.9
UT Bank	11.6	30.1	33.1	33.1	33.1	33.1	33.1	33.1	33.1
Zenith Bank	11.5	23.4	29.6	N/A	29.6	29.6	29.0	31.1	29.6
INDUSTRY AVERAGE	10.9	26.3	33.1	32.1	33.0	32.1	32.3	32.6	32.3

Source: www.bog.gov.gh



Appendix 5. Plagiarism Report



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