SMALLHOLDER IRRIGATION TECHNOLOGY IN GHANA: ADOPTION AND PROFITABILITY ANALYSIS

BY

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DECLARATION

I, Alberta Vincentia Asante, do hereby declare that this submission is my own work towards the MPhil (Agricultural Economics) and that, to the best of my knowledge, it contains no material previously published by another person nor material which has been accepted for the award of any other degree of the University, except where due acknowledgement has been made in the text.

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DEDICATION

I dedicate this thesis to my Father, Dr. Stephen. K. Asante, my mentor, for seeing in me the potential to become a researcher just like him and giving me the chance to develop that potential.

ABSTRACT

Irrigation development is very critical to the development of the agricultural sector this is because it will ensure food security as farmers will be able to crop more than twice a year, which will improve yields and reduce rural poverty by creating rural employment which will help by ensuring yearlong agricultural production. This study examines the factors which influence the adoption of smallholder irrigation technologies in Ghana and their profitability. Data for the study was collected from January to March, 2011 in three well known irrigation districts namely the Keta municipality, Kasena Nankana East district and the Akuapem South municipality. The Probit model was employed to examine the probability of adopting either the ground water motor pump, ground water manual or the surface water motor pump irrigation systems.

Gross margin analysis was also performed to determine the most profitable of the systems practiced. From the results, ground water motor pump irrigation was found to be the most profitable of the systems. The implicit wages of family labour for the smallholders under the different irrigation systems were derived so production functions were estimated. The empirical results show that surface water motor pump irrigators earn the highest implicit wages for family labour. Empirical results for the Probit model indicate that household size and association with farmer-based organization have significant impacts on the probability of adopting groundwater manual pump irrigation whilst farm size and extension contact had negative impacts. The probability to adopt groundwater motor pump irrigation is positively influenced by education farm size, land tenure, household size and gender whilst extension contact, experience and association have a negative effect. For surface water motor pump irrigators, farm size and extension had a positive and significant influence on adoption while land tenure and association negatively influenced adoption. In order to promote smallholder irrigation in Ghana the knowledge of farmers in the existing irrigation technologies must be facilitated through frequent participation in workshops, training programs. Farmers must also be helped to get the best out of their pumps by being trained on pump selection and maintenance, crop selection and agronomic practices, the handling of crops after harvest and marketing of produce. Financial institutions should also provide access to affordable loans on reasonable terms to farmers to enable them improve their operations

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CHAPTER ONE

INTRODUCTION

1.1 Background

Approximately 80 percent of poor people in sub Saharan Africa continue to depend on the agricultural sector for their livelihoods. But unlike other regions of the world, agriculture in sub Saharan Africa is characterized by very low yields due to agro ecological features, poor access to services, lack of knowledge and inputs and low levels of investment in infrastructure and irrigation (Calzadilla et al., 2009). Improvements to agricultural productivity often involve irrigation development, promote economic growth and provide a pathway out of poverty. The average rate of irrigation development for the countries of sub Saharan Africa from 1988 – 2000 was 43,600 ha/yr (FAO, 2001). However if these rates continue then an additional 1 million hectares of land will be irrigated by the year 2025 (FAO, 2001).

Agriculture has a central socio economic position in Ghana (Namara et al., 2011). Ghana's agriculture is dominated by approximately 2.74 million small scale producers with average farm size of about 1.2 hectares and low use of improved technology. Small farmers account for about 80 percent of domestic production (MoFA, 2010). This sector accounts for about 65 percent of the work force, about 40 percent of the GDP and about 40 percent of foreign exchange earnings through exports (Namara et al., 2011). Ghana's economy has been largely dependent on agriculture and its growth is key to overall economic growth and development (MoFA, 2010). However, the sector is vulnerable since it relies on rainfall during a roughly six month rainy season. In situations such as these, irrigation development offers the promise of greater food security and the rural area development by ensuring yearlong agricultural production (Namara et al., 2011).

According to the Ghana Shared Growth Development Agenda 2010-2013, for Ghana to become a middle income country by 2015 it has to modernize agriculture by a dynamic and competitive private sector. That should lead to accelerated growth (www.gtz.com). Growth in agriculture may be achieved both through extensification (putting more land under cultivation) and intensification (increasing the productivity of existing land). In most cases, irrigation is central to increasing productivity of existing agricultural land (Namara et al., 2011). The Millennium Challenge Account (MCA) has 'poverty reduction through agricultural transformation' as its main goal. This transformation often termed modernization can be achieved by utilizing the country's significant irrigation potential, mechanization, improving farmer's access to improved technologies such as high- yielding varieties, improved agronomic practices and crop protection techniques (Namara et al., 2010).

According to Namara et al. (2011), Ghana's irrigation sector has often been equated to public / communal service, an irrigation scheme which comprises the 22 irrigation schemes managed by GIDA and ICOUR. However, Ghana's irrigation systems can be broadly classified into two groups based on their current levels of formalization. These are the conventional systems mainly surface irrigation schemes initiated and developed by the government or NGO's and the emerging irrigation systems, which are initiated and developed by private entrepreneurs and farmers either autonomously or with limited support from government or NGO's (www.awm-solutions.iwmi.org).

1.2 Problem Statement

Sub Saharan Africa is blessed with significant land and water resources and diverse agro ecosystems but agricultural productivity is low and hunger and malnutrition persist, particularly in rural areas (Giordano et al., 2012). The occurrence of erratic rainfall have created uncertainty for agricultural production and emphasized the need for irrigation in Africa (Adetola, 2009). Irrigation development has been recognized globally as an important means of overcoming climate uncertainty with regards to agricultural production and productivity (MoFA, 2010). Irrigation is a key input to agricultural growth. It plays a pivotal role in increasing crop productivity. Over the last decades availability of water for irrigation has been declining rapidly. On the contrary, the demand for access to irrigation water has been growing faster (Upadhyay, 2004). Although irrigation systems have been promoted in the region, irrigation infrastructure has not expanded mainly due to lack of demand for irrigated products, lack of access to complementary inputs, poor market access, unfavorable topography, low-quality soils and low incentives for agricultural intensification.

In Ghana, weather uncertainties have had adverse impact on the nation's agriculture, over the years, even though irrigated agriculture is well known it is yet to be significant in Ghana (MoFA, 2010). The dependence on rain fed agriculture, particularly in northern Ghana, means that even though production of the major staple food crops is adequate in most years, seasonal food insecurity is widespread (www.awm-solutions.iwmi.org). Ghana is endowed with a lot of untapped water resources. Only 38 percent of agricultural land in Ghana is cultivated and productivity is generally low (www.awm-solutions.iwmi.org). Out of the identifiable 500,000 hectares of irrigable land only about 11,000 hectares are under formal cultivation (MoFA, 2010). On the other hand, 17,636 hectares are under informal irrigation which means that irrigation contributes only about 0.5 percent of the country's agricultural production (Breisinger et al, 2008).

The country has sufficient water resources and estimates of Ghana's irrigation potential range from 0.36 to 2.9 million hectares depending on the degree of water control. (www.awm- solutions.iwmi.org). Ghana's water sources are mainly groundwater and surface water. Irrigation may take many different forms, from large schemes to small systems of shallow tube wells from surface irrigation to small sprinkle or drip systems (Lipton et al., 2003). Traditionally, ropes and buckets have been used by farmers to lift and distribute water from shallow open wells or watering cans have been used to lift water from streams (Adeoti et al., 2007). This system, as Adeoti et al. (2007) note, is less capital intensive and advantageous to farmers with the only problem being the highly labour intensive nature and low delivery capacity. Improved water lifting technologies with relatively higher efficiencies like the motorized pumps are also used to lift irrigation water from either surface or groundwater sources but these are capital intensive lifting devices. The adoption of some of these capital intensive micro-irrigation schemes has however been difficult for smallholder farmers who usually operate small farms and run on relatively small capital (Hyman et al. 1995; Brabben et al., 2000). The lack of simple, affordable and well adapted water development technologies suitable for irrigation agriculture is a serious handicap to the efforts of achieving food security in sub-Saharan Africa (Hyman et al., 1995; Brabben et al., 2000; Adeoti et al., 2007).

Over the years, governments have tended to focus on the construction of large scale irrigation systems with the majority of the systems established in the Northern and the Upper East Regions of Ghana. The performance of these large scale irrigation systems have not however been optimal in terms of anticipated benefits (Korrtenhorst et al., 1989; Alam, 1991; Adams, 1992). As a result of these shortcomings, various authors (Adams, 1992; Turner, 1994; Namara et al., 2011) and other stakeholders have advocated for the promotion of small scale and affordable irrigation schemes to boost food production in the country. According to the World Bank (1985), the budgetary expenditures on irrigation are substantial compared to its limited role in overall agriculture. Less than a third of the estimated total irrigated land in Ghana lies within 22 well-known public schemes, and not enough is known of the location, development and management of the informal irrigation schemes that account for the remaining two-thirds of total irrigated land (Namara et al.,2011). Many of the farmers operating under small scale irrigation schemes have established under their own initiates. Very little attention and assistance has been given to promote their operations. Moreover, even within this small area, researchers lack a clear understanding of where in Ghana different types of irrigation infrastructure are used and to what effect. This makes it difficult to actually know the number of small holder farmers under informal schemes, the various types of technologies they are practicing and whether they are actually making any profit. The study seeks to find out the factors that affect the adoption of small scale irrigation technologies in Ghana. The following research questions are raised: What are the smallholder irrigation technologies adopted by smallholder farmers? What are the determinants influencing the adoption of the smallholder irrigation technologies? What are the constraints affecting their expansion? Which of the smallholder irrigation technologies is the most profitable one being practiced by the farmers? How much would it cost if family labour was to be paid for amongst the various technologies?

1.3 Objectives of the Study

The main objective of the study is to examine factors which influence the adoption of small scale irrigation technologies in Ghana and their profitability levels.

The specific objectives are:

1. Identify the various smallholder irrigation technologies adopted by small holder farmers.
2. To identify the determinants of smallholder irrigation technology adoption and the constraints to adoption.
3. To determine the most profitable irrigation technology amongst the smallholder farmers.
4. To calculate the shadow wages for family labour amongst the various smallholder irrigation systems identified.
5. Make policy recommendations based on the empirical results.

1.4 Justification of the Study

Based on Ghana's unsuccessful experience with public irrigation, there is a strong argument for the country to encourage private sector investment rather than continuing to sink public funds in poorly operated and maintained public irrigation schemes (Namara *et al.,* 2011). Despite considerable potential for development and the emphasis placed on irrigation development in many plans, less than two percent of the total cultivatable area in Ghana is irrigated.

Although donors and policymakers express interest in providing new funds for irrigation development, the lack of reliable data on where irrigation currently exists, trends in its development, and opportunities and constraints within formal and informal schemes undermines consensus about how to build on what already exists in the sector (Namara et al.,2011). Little is officially known about smallholder irrigation systems, but they are expanding at a rapid rate, mainly fuelled by access to relatively affordable pumping technologies and to export markets for horticultural crops. There is very limited reliable information on the relative importance of various irrigation systems in West Africa, thus, making it difficult to argue for or against any particular irrigation system based on already available information (Dittoh et al., 2010)

Previous studies have investigated the adoption of crop specific technologies (new varieties) and studied the behavior over time of the growers of a specific crop in one or several regions; this study investigates the adoption of technologies that are non-crop specific in several regions. A number of potential barriers to the adoption of a technology such as micro irrigation have been identified (e.g., Zilberman et al., 1985). Inadequate information, education, and training are significant barriers to the adoption of new agricultural technology (He et al., 2007). Uncertainty and risk, also associated with information about the technology, discourages adoption (Foltz 2003). Lack of access to credit, especially when a significant expenditure is required to purchase equipment, prevents adoption (He et al., 2007). Absent or unreliable supply of equipment, and insufficient transportation or infrastructure can also be major barriers to adoption of a new technology. The results should provide an insight into circumstances that limit the practice of irrigation in Ghana. The irrigation projects implemented in developing countries provide a wide variety of information, services, and financial assistance; however, very little rigorous evaluation has been conducted on the actual impact of these programs on participating households. While the role of irrigation in poverty reduction has been studied more extensively in Asia, relatively little research has been done in Sub-Saharan Africa (e.g., Hussain *et al*, 2004).

1.5 Organization of the Study

The thesis is organized into five main chapters. Chapter 1 has presented an introduction to the study. Chapter 2 provides a review of the relevant literature relating to agricultural technology adoption, implicit wages of family labour and the profitability of smallholder irrigation technologies. Chapter 3 presents the methods of data collection and data sources; a description of the study area, the sampling and analytical techniques and gives an outline of the empirical methods used in the analysis. Chapter 4 provides the descriptive statistics from the survey and discusses the empirical results. Chapter 5 provides a summary and the conclusions of the study as well as some suggestions for further research.

CHAPTER TWO

LITERATURE REVIEW

This chapter examines relevant literature on technology adoption: the process of adoption, measurement of adoption, and factors affecting adoption. It also reviews existing literature on shadow wages and gross profits.

2.1 Definition of Irrigation

Irrigation technology is a system of improving natural production by increasing the productivity and expanding the total area under agricultural production especially in the arid and semi-arid regions of the world (Bhattarai *et al*., 2002).

According to Averbeke *et al*. (2011) irrigation is the artificial application of water to land for the purpose of enhancing plant production. It reduces or removes water deficits as a limiting factor in plant growth and makes it possible to grow crops where the climate is too dry for this purpose and to increase crop yields where plant-available soil water is a yield-limiting factor during parts or all of the growing season

2.2 Types of Irrigation Systems

Irrigation water can be applied to a crop by several different means which include surface irrigation, sprinkler irrigation and micro irrigation.

Surface irrigation methods use the soil surface to spread water across a field or orchard to the plant. This includes furrow irrigation, border/ flood irrigation and basin irrigation. In furrow irrigation, small channels or furrows are used to convey water across a field. The water infiltrates through the bottom and the sides of the furrows thereby getting to the plant roots for uptake by the plant and wetting the nearby soil. In border irrigation, the field is divided into strips which are separated by border ridges running down the slope of the field. The widths of the strips usually range between 20- 100 feet. The area between the ridges is flooded during irrigation. This system is used for tree crops and for leafy crops such as alfalfa and small grains. In basin irrigation, a field is divided into sub-units or basins which are separated by border ridges with the ground of each basin being level. During irrigation the basins are filled with the desired amount of water and the water remains ponded within the basin until infiltration gradually takes place (GWPC, 2005).

In sprinkler irrigation, water is applied throughout the field by means of rotating sprinklers/ mini sprinklers. These sprinklers are connected to a pressurized pipe system. Sprinklers usually spread water over a radius of 5 feet to 300 feet (depending on the design). The pipe system that supplies the water to the sprinklers can be permanent, moveable or a combination. These systems are operated automatically and by use of electricity (GWPC, 2005). Micro-irrigation is the system where water is applied to the plant through emitters so that water leaves the emitter as a droplet. The water is supplied to the emitters through a network of mainline and lateral pipelines that are usually made of plastic. A head unit is used to regulate pressure (GWPC, 2005).

2.3 Irrigation Policy in Ghana

The irrigation policy goal is, to achieve sustainable growth and enhanced performance of irrigation contributing fully to the goals of the Ghanaian agricultural sector as outlined in the Growth and Poverty Reduction Strategy (GPRS I & II). The policy beneficiary is the Ghanaian economy as a whole, but more specifically, the Policy is designed to improve the livelihood of all existing and potential part- and full-time irrigators and related farmer and farmer-based organizations, ensuring that private sector service providers will be given new opportunities to perform.

The specific targets of the policy are: National food security; intensified and diversified production of agricultural commodities; increased livelihood options; optimum natural resource use; reduced negative environmental impacts and expanded investment space for irrigated production. Ghana's irrigation policy has been designed to open up the investment space for intensified and diversified irrigated crop production in Ghana. The policy is designed to accomplish this by addressing four main problem areas which include: the low agricultural productivity and slow rates of growth, the constrained socio-economic engagements with land and water resources, environmental degradation associated with irrigation production and the lack of irrigation support. In the quest of solving these four problem areas, the policy comes out with "thrust" which is aimed at achieving accelerated and sustained irrigation development in Ghana. Thrust A; performance and growth realizes the productive capacity of the existing irrigation systems and responds to the new demands for irrigated production through the mix of well-coordinated public and private initiatives. The socio-economic inclusion is the Thrust B which is aimed at removing constraints to enhance a balanced socio- economic engagement with land and water resources. The environmental performance of the various irrigation systems and their related practices are taken care of in Thrust C and finally. Thrust D involves extending cost effective, demand driven irrigation services to both the public and private irrigators.

2.4 Irrigation Development in Ghana

Records date irrigation to have begun about a century ago, even though serious irrigation efforts date back to the past fifty years (Namara *et al*, 2011). Between 1960 and 1980 approximately 19,000 ha of irrigated land have been developed. By 2007 the area under irrigation had expanded to 33,800ha. Namara *et al*. (2011) in their study on irrigation development in Ghana observed that irrigation systems can be classified into two types. Conventional systems which are mainly initiated and developed by the Ghanaian government or various NGO's and emerging systems, which are initiated and developed by private entrepreneurs and farmers. Though little is officially known about emerging systems they are expanding at a rapid rate mainly fuelled by access to relatively affordable pumping technologies and export markets for horticultural crops (Namara *et al*, 2011). Of the irrigated land, slightly less than 9,000 ha were developed by the Government of Ghana with the remainder of the land having been developed by the private sector. Public irrigation schemes are scattered across Ghana and cover a total of 8800 ha. Approximately 11,000 farming families benefit from these systems and cultivate approximately 0.8 ha per household. Emerging systems are gradually eclipsing conventional systems in terms of area irrigated, yield obtained, production levels and value of production. These systems include tube well irrigation, small motor based irrigation, out-grower systems. Surface water pumping based private and communal irrigation systems are widely observed over all of Ghana's ten administrative regions though they are particularly abundant in the Eastern, Ashanti, Brong Ahafo and Volta regions. Sub- surface and groundwater based irrigation systems are not evenly distributed across the regions but are fast spreading beyond traditional enclaves such as the Volta region's Keta strip (Namara *et al*, 2011).

2.5 Smallholder Irrigation Technologies

Smallholder irrigation technologies are generally divided into groups based on the source of water and the lift system (Dittoh *et al.*, 2010).

According to Dittoh *et al*. (2010) in a study on Sustainable Micro-Irrigation Systems for Poverty Alleviation in the Sahel, broadly classified smallholder micro irrigators into four categories namely: bucket/calabash/watering can system, manual (pedal/hand) pump system, motorized pump system and gravity/canal system. The study notes that the traditional bucket/ calabash/ watering can technology plays a dominant role in irrigated agriculture in the communities. Van Averbeke *et al*. (2011) on Smallholder irrigation schemes in South Africa indicate that as at 2010 there were 302 smallholder irrigation schemes which made up a total area of 47,667 ha. Out of this the principal source of water was the river or diversions by means of weirs or through dam storage. The study classified the schemes into gravity-fed surface, pumped surface, overhead and micro irrigation. Namara *et al.* (2010) in their study on the typology of irrigation classified Ghana's irrigation systems into two broad categories namely the conventional systems and the emerging systems. The conventional systems are those developed with the initiative of the government and by various NGO's. However the study defines emerging systems as those that are initiated and developed by farmers with little or no support from government. These systems include groundwater irrigation systems based on motorized pumps, river/stream lifting/pumping based irrigation systems, public/ private partnership-based systems, out-grower systems, lowland / inland valley rice water capture systems and private small-reservoir systems. Owusu et al. (2011) also classified smallholder irrigators into gravity flow, bucket/treadle pump on surface water, bucket/treadle pump on groundwater, motor pump on surface water and motor pump on groundwater. The study was conducted on 135 farmers in the Upper East, Northern, Eastern and Volta regions of Ghana on the livelihood impacts of improved on-farm water control in sub-Saharan Africa.

2.6 Gross Margin Analysis

Dittoh et al. (2010) in their study on the sustainable micro-irrigation systems for poverty alleviation systems in the Sahel, the gross margin analysis was calculated for the categories of systems identified. The systems included the permanent well, motorized pump concrete reservoir system; permanent well, bucket fetch to- barrel system; permanent well motorized pump basin system and the permanent well bucket fetch to watering can system. The results indicated that the permanent well motorized pump method was the most profitable of the systems followed by the permanent well bucket motorized pump basin system and finally the permanent well bucket fetch to watering can system. Namara *et al.* (2011) estimated the profitability of rice production under different systems and found out that surface water pumping: private smallholder was the most profitable followed by the small reservoir/ dugout, then public systems (river pumping/gravity flow) and finally the public system run-off river diversion –gravity fed.

2.7 Implicit Wage for Family Labour

The small size of farms is a persistent phenomenon in the organization of agriculture in developed countries (Schmitt, 1991; Picazo-tadeo et al., 2005). Family labour is usually the most important cost item for small farms without taking transaction costs into account, the farmer will allocate optimally his own and his family labour when marginal labour product equals the wage rate that represents opportunity cost of farm labour (Picazo-tadeo et al.,2005). Menon et al. (2005) estimated the shadow wages of adults and children directly from the marginal agricultural productivity for the shadow wages of child labour in Nepal. The study estimated a cost function, enabling each component of the household labour to be measured. An estimate of the size of the children's shadow economy as compared to the adult contribution is also calculated based on the estimation of a production function. Generally, shadow wages calculated from the primal side showed wages to be much higher than the dual estimations. The study also found out that shadow wages for adults were lower in households that employed children on their farms. However, on farms with school aged children in non-working condition adult shadow wages was found to be higher. Menon et al. (2005) concluded that results from the dual approach i.e. using the Trans log cost function represented the Nepalese shadow economy more closely than the primal approach. Owusu et al. (2011) using a Cobb-Douglas production function estimated the shadow wages of family labour for 135 smallholder irrigation farmers in Ghana. The study found motor pump irrigators to generate the highest wage rate for family labour followed by gravity flow, rain fed and manual pump irrigators. This empirical finding concurred with the hypothesis that amongst all the WCC smallholders farmers, motor pump irrigators are able to generate the highest wage rate for family labour which is the key ingredient in the decision making process of small holder farmers in sub-Saharan Africa.

2.8 Importance of Irrigation to Agriculture

Increased supplies of irrigation water have been instrumental in feeding the populations of developing countries in the last 50 years. Irrigation water has increased food security and improved living standards in many parts of the world. With a rapidly growing world population and a limited food supply, fifty years ago it was common to hear concerns of food shortages and mass starvation. This was particularly true for the populations of developing countries. While malnutrition is still a concern in many countries, the reason is not a lack of a sufficient global food supply. There are a number of reasons for this increase in food production, including high yield varieties of seed and increased use of fertilizers. However, the role of water development in providing irrigation water to cropland has also been significant. Water projects are generally composed of a system of reservoirs designed for storing water and canals designed for transporting water. Projects that provide water for irrigation have benefited developing countries in many ways. Benefits include the expansion of food supply, stabilization of water supply, the improved welfare of some native populations, and a relative decrease in deforestation of land for agriculture.

Irrigation and Agricultural Land Expansion: One clear benefit of water projects is an expansion in the feasible land base for agricultural production. A region might have high quality soil for growing crops, but if it doesn't receive enough rainfall at the right times of the year, it can't be used for crop production. For areas that receive rainfall during the wrong season, the development of reservoirs allows water to be stored during the rainy time of the year, and then used for farming during a dry part of the year. For those areas that don't receive enough water for growing crops, canals allow water to be transported from a water-rich area to an arid area (Schoengold *et al*., 2007).

Irrigation and Increased Crop Yields: There is indisputable evidence that irrigating land leads to increased productivity. Irrigation is a necessary input into the high yield varieties developed during the Green Revolution. One acre of irrigated cropland is worth multiple acres of rain-fed cropland. Globally, 40% of food is produced on irrigated land, which makes up only 17% of the land being cultivated. Irrigation allows farmers to apply water at the most beneficial times for the crop, instead of being subject to the timing of rainfall. (Schoengold *et al.*, 2007)

Irrigation and Double Cropping of Land: Another benefit of reservoirs is that stored water can be used for double cropping of fields. There are many tropical areas that are warm throughout the year, but have seasonal rains for a portion of the year while remaining dry and arid for the other part. The ability to store water during the rainy season for use in the dry season could allow a farmer to move from one annual crop to two or three (Schoengold *et al.*, 2007).

Irrigation and Employment and Income: There is evidence in many regions that employment opportunities have increased after the development of irrigation systems. This can occur either because labour is needed for new land brought into production, or for land that is being double cropped and therefore requires additional labour in planting and harvesting. (Schoengold *et al.*, 2007)

Irrigation Supply Stabilization

The construction of a water storage and conveyance system decreases the risk associated with stochastic rainfall. Farmers are better able to plan their cropping patterns when they can predict the supply of water available. The planting of certain crops, such as tree crops, requires the assurance of a sufficient water supply. Irrigation also allows farmers to apply water at the times that are most beneficial for the crop, instead of being subject to the variation in rainfall.

Irrigation and Deforestation: The expansion of agriculture is a primary cause of deforestation in developing countries (Schoengold *et al.*, 2007). Increasing food production in a region requires either more intensive use of existing cropland or an expansion of agriculture onto new cropland. Irrigation is a necessary input into many high-yield varieties of crops in production. One major outcome is that irrigation can reduce the need for new agricultural land development. This could lead to a decrease in deforestation, and the resulting environmental problems such as soil erosion. This relies on the two benefits of irrigation mentioned earlier – higher yields and double cropping. If an area lacks irrigation systems, then as increasing yields become necessary, they can be achieved either through the use of more land or the development of irrigation. Over time, yield increases are essential because of larger populations, higher standards of living, and increased meat consumption. (Schoengold *et al.*, 2007)

2.9 Groundwater Irrigation Potential in Ghana

Agricultural use of groundwater, once mainly in domestic use, is rising due to access to pumping technologies. Groundwater irrigation provides potential employment opportunities, particularly during the long dry season in the Northern Savannah Zones of Ghana. The groundwater resources of the country are found in two main rock formations: 1) the sedimentary formation made up of mainly Voltarian origin, which occupies about 43 percent of non-sedimentary formation made up mainly of the crystalline basement complex of pre-cambrian origin, which occupies 57 percent of the total area of the country with yields of 1.5 to 32.0 m3/ha at depths of 20 to 100 m (Odame-Ababio, 2002). The quality of groundwater resources in Ghana is generally good except for some cases of localized pollution with high levels of iron and fluoride, as well as high mineralization with total dissolved solids, especially in some coastal aquifers (Water Resources Commission, 2000). It is also already one of the major livelihood strategies in the coastal zones of Volta region, particularly for those with access to electricity. However, full realization of the economic potential of groundwater faces numerous challenges including absence of explicit policy support, lack of access to affordable drilling technology, and cost of energy for abstracting water. Groundwater yield can be as high as 183m3/hr in limestone aquifers (Darko, 2005). Except for low pH (3.5-6.0), high iron values (1-64 mg l"1) in a few cases and high salinity values (5000-14 584 mg l"1) in some coastal aquifers, groundwater quality is generally considered good for domestic and agricultural purposes. Aquifers underlie almost all areas in the country. Occurrence of groundwater, however, is controlled principally by local geology and other factors, such as topography and climate (Namara *et al.*, 2011).

In Northern Ghana, aquifers have been located at between 10 and 60 meters deep with an average of 27meters. In southern Ghana, due to thicker soil cover, boreholes are deeper, ranging between 25 and 90 meters deep, with an average of 42 meters. Ghana has more than 56,000 groundwater abstraction systems, comprising boreholes, hand dug wells and dugouts (Kortatsi 1994). In the Volta basin, annual groundwater production through boreholes, hand dug wells, and piped systems has increased substantially over past decades, reaching an estimated 88 million m3/year, giving approximately 44 percent of the population improved access to groundwater (Nicola *et al.*, 2005). Despite the rapid development, groundwater production is still less than 5 percent of the average annual groundwater recharge in most of the basins, so that the present production should not be expected to have any significant impact on the water balance. Similarly, a study in Nabogo basin (a sub catchment of the White Volta river basin), showed that current well pumping rates yield significantly less water than annual groundwater recharge to the basin (Lutz *et al.*, 2007).

Model results for several scenarios, involving increased population, access to potable water for all citizens, and/or decreased rainfall indicate that extraction rates will still be less than groundwater input to the Nabogo basin (Lutz *et al.*, 2007). The assessment of groundwater recharge and development suggests that it would be sustainable from a geo-scientific point of view, at least in the foreseeable future (Nicola *et al.*, 2005).

2.10 Limitations and Opportunities for Further Expansion

According to a study by Barry *et al.* (2010) groundwater resources in the underlying aquifers of Ghana are capable of sustaining shallow groundwater irrigation. It also indicates that groundwater irrigation could be expanded if the appropriate drilling technologies are used. Groundwater irrigation provides employment opportunities and substantial income, particularly during the long dry season in the northern savannah zones of Ghana (Namara *et al.*, 2011). In terms of constraints in groundwater irrigation, Namara *et al.* (2011) outline that the full realization of the economic potential of shallow groundwater irrigation is faced with many challenges including land tenure insecurity, lack of access to the appropriate low-cost drilling technologies, lack of decision support for precise sitting of the wells, inefficiencies in the output markets, crop pests and diseases and the absence of explicit government support services (extension and credit etc.). The farmers also lack proper advice on the type, rate of application and the safety precautions required in calibrating and applying chemicals. Knowledge about Ghana's groundwater resources is scarce and much of the limited information paints a pessimistic view about the groundwater potential in agriculture. Groundwater use for agriculture is not sufficiently addressed in Ghana's water and irrigation policy

2.11 Factors Influencing Irrigation Technology Adoption

One important way to increase agricultural productivity is through the introduction of improved agricultural technologies and management systems (Doss, 2006). Technologies play an important role in economic development. Adoption and diffusion of technology are two interrelated concepts describing the decision to use or not to use and the spread of a given technology amongst economic units over a period of time. The duration of adoption of a technology vary among economic units, regions and attributes of the technology itself (Stevens, 2007). The rate of adoption is usually measured by the length of time required for a certain percentage of members of a system to adopt an innovation. Extent of adoption on the other hand is measured from the number of technologies being adopted and the number of producers adopting them (Banabana-wabbi, 2002). However, the current study focuses only on the factors affecting farmer's adoption of irrigation technologies. Depending on the technology being investigated, various parameters may be employed to measure adoption. Measurements also depend on whether they are qualitative or quantitative.

The most common variables used in modeling technology adoption processes are human capital variables, attributes of the technology, nature of the farming system, land tenure, resource endowment, risk and uncertainty, social capital and social psychological factors (Buttel *et al.*, 1990; Feder *et al.*, 1982; Leagans, 1979; Namara *et al.*, 2007; Rogers, 1995).

In this study the variables that are hypothesized to affect the adoption of irrigation technologies are discussed in this section. The empirical literatures of these factors are discussed below.

The household head's age influences the attitude he or she may have towards a new technology; however, there is not a consensus in the literature with regard to the direction of the influence of age on adoption (Knowler *et al.*, 2007). In addition, farmers" perception that technology development and the subsequent benefits, require a lot of time to realize, can reduce their interest in the new technology because of farmer's advanced age, and the possibility of not living long enough to enjoy it (Caswell *et al.*, 2001; Khanna, 2001). Furthermore, elderly farmers often have different goals other than income maximization, in which case, they will not be expected to adopt an income – enhancing technology. Namara *et al*., (2007), developed a logit model to estimate the determinants of micro irrigation technologies in their study on the adoption of micro-irrigation technologies in India. They found age to be positively related but not have any significant effect on the adoption of the micro irrigation technologies. Bhandari *et al*., (2006) found age to be positive and significant in the adoption of shallow tube wells in Nepal. DiGennaro, (2010) also found age to be positive and have a significant effect on the adoption of micro irrigation equipment.

Human capital is considered as one of the basic building blocks or means of achieving livelihood outcomes (Ellis, 2000). Human capital represents the skills, knowledge, ability to labour and good health that together enable people to pursue different livelihood strategies and achieve their livelihood objectives. At the household level human capital varies according to household size, educational level, skills and health status.

Rogers (1983), indicates that technology complexity has a negative effect on adoption. However, education is thought to reduce the amount of complexity perceived in a technology thereby increasing a technology's adoption. Education represents a human capital of the farmer and is hypothesized to have a positive effect on the adoption of new technologies. The reason being that education permits a more critical evaluation of the productive characteristics and costs of adopting innovations, enabling farmers to distinguish more easily those improvements whose adoption provides the opportunity for economic gains from those that do not (Owusu *et al*., 2010). Farmers who have invested in schooling and information will be better informed about the existence and general performance of different technologies, they will make more accurate assessments of differences in farm-level performance and will make more efficient adoption decisions(Owusu *et al*., 2010). Wang (2008) developed a multinomial logit model to estimate the determinants of farmers discrete choice of alternative land improvement strategies (i.e. use of borders, furrows, sprinkler irrigation and drip irrigation). They found out that education did not significantly influence the adoption of land improvements (drip or sprinkler irrigation). Schuck *et al*. (2005) found a positive relationship between the level of educational attainment and the adoption of sprinkler irrigation technology by

Colorado farmers. Karami (2006) found that there is a positive relationship between the education and the adoption of sprinkler irrigation by farmers in Iran.

Zhou *et al.* (2008) also found that educational level had a positive relationship with the adoption of water saving irrigation technologies in China. Bhandari *et al.* (2006) using a Probit model to analyze the factors determining tube well ownership found educational level to positively affect adoption in Nepal. Namara *et al*. (2007), in their study on the determinants of micro irrigation technologies in India found the level of education to be positive and significantly affect the adoption of micro irrigation technologies. This confirmed the fact that micro irrigation technologies need special technical and managerial skills for proper utilization. Foltz (2003), however, found out that educational level had a negative effect on adoption of drip irrigation systems in Tunisia.

Gender is an important determinant in technology adoption (Knowler *et al.,* 2007). Gender issues in agricultural production and technology adoption have been investigated for a long time. The gender of the household head is hypothesized to impact the adoption decision but the effect could be either positive or negative. Most show mixed evidence regarding the different roles men and women play in technology adoption. Since adoption of a practice is guided by the utility expected from it, the effort put into adopting it is reflective of this anticipated utility. It might then be expected that the relative roles women and men play in both ‘effort’ and ‘adoption’ are similar, hence suggesting that males and females adopt practices equally.

Traditionally, men and women play different roles when it comes to agricultural activities. Men are often the bread winners and are usually in control of finances and decisions regarding the purchases of agricultural technology and inputs. This social aspect may make men more likely to adopt new technology. Whilst women on the other hand are recognized to be more particular about the food requirements of the family (DiGennaro, 2010). Women may therefore be more likely to recognize the advantage of irrigation equipment for increasing household food security and be more likely to adopt irrigation technologies (DiGennaro, 2010). Using a logit model in the study on the adoption of micro irrigation technologies amongst 101 farmers in the Zambia, DiGennaro, (2010) found out that female headed households were more likely to adopt micro irrigation technologies than male headed households.

Farm characteristics including farm size, labour availability and land tenure affect the adoption of irrigation technologies. Farm size is considered by most studies as the first and usually the most important determinant. Some technologies are termed as scale-dependent because of the great importance of farm size in their adoption. Farmers who have more land are usually in a better position to adopt new strategies/technologies. This is not only because they have the tendency to diversify but also because they have larger lands to operate their returns on their investments are much more. The effect of farm size has been variously found to be positive or even neutral to adoption (Mugisa- Mutetikka *et al.,* 2000). Farm size affects adoption costs, risk perceptions, human capital, credit constraints, labour requirements, tenure arrangements and more. With some technologies, the speed of adoption is different for small- and large- scale farmers. Shretha *et al*. (1993) in a study on the choice of drip irrigation in Hawaii's sugar industry found that farm size was positively correlated with drip irrigation. Green *et al*. (1996) in a study on California's farmers choices amongst traditional irrigation technologies indicated that farm size was positively related to the adoption of drip irrigation since farmers with larger fields were more likely to adopt drip irrigation. Bhandari *et al.* (2006) in their study on the economics of groundwater irrigation found farm size to positively affect the adoption of shallow tube wells in Nepal.

Labor availability is another often-mentioned variable which affects farmers' decisions regarding adoption of new agricultural practices or inputs. Some new technologies are relatively labour saving, and others are labour using. For example, ox cultivation technology is labour saving, and its adoption might be encouraged by labour shortage. The operative constraint in African farming systems is the peak-season labour scarcity. One of the major purposes of farm mechanization is to alleviate labour bottlenecks. For example, ox power and tractor power can make possible more timely farming operations and allow increased production and reduced labour demand and, sometimes, more double and multiple cropping. Feder *et al.* (1985), labour availability may affect a farmer's decision to adopt technology. A labour shortage promotes the adoption of labour-saving practices, but hinders the implementation of technologies that require more labour input. A greater labour force was hypothesized to increase the adoption of labour demanding conservation practices such as waste management, nutrient management and pesticide management. Adeoti, (2009) in the study of the adoption of treadle pumps in Ghana concluded that increase in labour availability had a positive effect on the adoption of the treadle pump technology since the technology required labor for operation.

Tenant's lack of motivation to adopt would be due to the perception of benefits accruing to the landowner, and not to the renter. Land tenure is hypothesized to have a positive effect on adoption. Land ownership which was proxied by the ownership of wells had a positive effect on the adoption of micro irrigation in India, Namara *et al*. (2007) this is because well owners have a high degree of control on the water source and have the motivation to effectively use the available water. Schuck *et al.* (2005) in the study on the adoption of sprinkler irrigation technology by Colorado farmers found land tenure to exhibit a negative effect on adoption of the sprinkler technology. From the study it was observed that the greater the proportion of land rented the lower the proportion of sprinkler irrigation. This is because land owners incentive to invest in capital equipment will diminish if benefits are to be shared with tenants.

Financial capital at the household level refers to savings held in the bank, access to credit in the form of loans and stocks. They are only useful to the household when they can be converted into a form of capital (e.g. irrigation equipment) or used directly for the purchase of food. Access to credit is also an important factor in new technology adoption. Access to capital in the form of either accumulated savings or capital markets is necessary in financing the adoption of many of the new agricultural technologies.

Information is acquired through informal sources like the media, extension personnel, visits, meetings, and farm organizations and through formal education. It is important that this information be reliable, consistent and accurate. Thus, the right mix of information properties for a particular technology is needed for effectiveness in its impact on adoption. Acquisition of information about a new technology demystifies it and makes it more available to farmers. Information reduces the uncertainty about a technology's performance hence may change individual's assessment from purely subjective to objective over time (Caswell *et al.*, 2001). Exposure to information about new technologies as such significantly affects farmer's choices about it. Adeoti, (2009) also found out that extension contact had a positive influence on the adoption of the treadle pump technology in Ghana. Abdulai *et al*. (2005) on the study in china found that the involvement of extension services had a positive and significant impact on the adoption of water saving irrigation technologies for rice production. Adeoti *et al.* (2007), using a sample of 108 farmers in Ghana to estimate the adoption of treadle pump irrigation found the number of extension visits per year to have a positive impact on the probability of adoption. Similar results were obtained by Karami (2006) in their study on the choices of irrigation methods in Iran and Wang (2008) on the adoption of water saving irrigation technologies in Northern China.

CHAPTER THREE

METHODOLOGY

In this chapter, the concept of irrigation as an adopted technology is outlined as well as the concepts for shadow wages of family labour and gross margin analysis. Hypotheses are formulated about factors influencing irrigation adoption, implicit wages and gross margin analysis. Finally, the data collection process is illustrated; the study area and household survey procedure are explained.

3.1 Conceptual Framework

The conceptual framework on the adoption of irrigation technology is discussed in this section.

3.1.1 Adoption of Irrigation Technology

Random utility theory allows the researcher to elicit preferences for complex multidimensional goods, from which models of preferences can be estimated (Hall *et al.,* 2003). These allow environmental goods to be valued in terms of their attributes by applying probabilistic choice models to choices between different combinations of attributes (Hanley *et al*., 2002).

Within the framework of random utility, an individual's indirect utility can take the following functional form (Louviere, 2001): Due to the influence of the random component, it is difficult to predict individual preferences. The random component allows one to model the choice of options in a probabilistic form, where the probability that an individual prefers option j in the choice set over other options n can be expressed as the probability that the utility associated with option j exceeds that associated with all other options. Let Y_m and Y_p represent the individual's utility to two choices, which we denote by U^a and U^b. U^a Denotes the utility to m and U^b the utility of p. The observed choice between the two reveals which one provides the greater utility, but not the unobservable utilities. the observed utilities indicator equals 1 if $U^a > U^b$ and 0 if $U^a \leq U^b$ (Greene, 2002)

The linear random utility model is formulated as:

$$U^a = \chi^1 \beta_a + \varepsilon_a \text{ And } U^b = \chi^1 \beta_b + \varepsilon_b \quad (3.1)$$

Then if we denote by $Y = 1$ the farmer's choice of alternative a we have:

$$\text{Prob}\left[Y = 1/\text{X}\right] = \text{Prob}\left[U^{a} > U^{b}\right]$$

$$= \text{Prob}\left[\chi^{1}\beta_{a} + \varepsilon_{a} - \chi^{1}\beta_{b} - \varepsilon_{b} > 0/\text{X}\right] \quad (3.2)$$

$$=\text{Prob}\left[\chi^{1}(\beta_{a} - \beta_{b}) + \varepsilon_{a} - \varepsilon_{b} > 0/\text{X}\right] \quad (3.3)$$

$$= \text{Prob}\left[\chi^{1}\beta + \varepsilon > 0/\text{X}\right] \quad (3.4)$$

Where,

β is the deterministic (observable or explainable) component of the utility that Y_m has for option U^a

ε denotes a stochastic element (random and unexplained) that represents unobservable influences on individual choice.

As indicated in equation (3.4), if the error term ε is assumed to be standard normally distributed, then the Probit model is appropriate.

The Probit model is one of the two basic binary choice models commonly used to analyze the choice behavior of an individual facing two alternatives. Irrigation technology adoption is a complex phenomenon and several economic and social factors contribute to the farm- level decisions of the farmer. Adoption studies in agriculture generally attempt to establish factors that influence the adoption of a technology in a specific locality (Adesina et al., 1995).

The Probit model was selected for the analysis of the adoption behavior. In this framework, the probability of a farmer (P) to adopt a new irrigation technology is a function of socio-economic, farm-level and institutional characteristics (χ_i).

The Probit model is specified as:

$$\text{P} = \beta^{'}\chi_{i} + \mu_{i} \quad (3.5)$$

Where,

P_i is the probability of adopting an irrigation technology and χ_i are the farmers characteristics (Davidson et al., 1995). The irrigation technologies are defined as the small scale irrigation systems that have been introduced to increase private irrigation. These systems include: small scale irrigation using motor pumps and manual pumps (i.e. treadle and bucket).

The behavioral model that is used to examine the adoption of small scale irrigation technologies is given by:

$$Y_i = g(\mathrm{I}_i) \quad (3.6)$$

$$I_i = b_o + b_j \chi_{ji} \quad (3.7)$$

Where,

Y_i Is the observed response for the i^{th} observation i.e. the binary variable, $Y_i = 1$ for an adopter, $Y_i = 0$ for a non-adopter.

I_i is an underlying stimulus index for the i^{th} observation (generally, there is a critical threshold for each farmer I_i^*. If $\mathrm{I}_i < \mathrm{I}_i^*$ the farmer is observed to be a non-adopter. If

$\mathrm{I}_i > \mathrm{I}_i^*$ the farmer is observed as an adopter. g is the functional relationship between the field observation and the stimulus (I_i) that determines the probability of adopting an irrigation technology. I =1,2…,m are observations on variables for the adoption model.

$m =$ the sample size

χ_{ij} is the j^{th} explanatory variable for the i^{th} observation.

$j = 1, 2, 3..., n$

b_j is an unknown parameter.

3.1.2 Empirical Model on Irrigation Technology Adoption

The Probit model assumes that the ownership is a function of a latent variable, and ownership is observed only when the latent variable exceeds the individual specific threshold value. The latent variable is assumed to be a function of a farm and household characteristics.

A farmer's decision to adopt or not to adopt a technology is assumed to be an outcome of a complex set of factors. These factors are related to the farmer's objectives and constraints. Now if farmers and their technologies can be classified according to a set of variables, then it is also possible that the probability that a farmer adopts a particular technology can also be estimated.

The empirical model employed in the study is specified as follows:

$$ADOPT = \beta_0 + \beta_1(AGE) + \beta_2(FMSZE) + \beta_3(EDU) + \beta_4(EXT) + \beta_5(\text{TEN}) + \beta_6(\text{GEN})$$

(+/-) (+) (+) (+) (+) (+/-)

$$+ \beta_7(XP) + \beta_8(HHSZ) + \beta_9(CREDIT) + \beta_{10}(ASSOC) + \mu_1$$

(+) (+) (+) (+)

Where,

$$ADOPT = \begin{pmatrix} 1 & \text{if farmer adopts an irrigation technology} \\ 0 & \text{otherwise} \end{pmatrix}$$

Where,

AGE denotes the age of the farmer in years

FMSZE is the size of the farmer's farm in Ha

EDU is the number of years of formal education

EXT denotes extension contact (dummy variable, 1 =yes, 0=no)

TEN is land tenure (dummy variable 1=owned, 0=rented)

HHSIZE household size (number of people in household)

GEN denotes the gender of the farmer (1=male, 0= female)

XP is the number of years of farming

CREDIT denotes access to credit facility (dummy variable, 1=yes, 0=no)

ASSOC denotes membership of farmer association (dummy variable, 1=yes, 0=no)

3.1.3 Production Technology of the Smallholder Farmers

The empirical approach adopted here involves estimating a production function in order to derive the shadow wages of family labor directly from marginal agricultural productivity (Jacoby, 1993; Picazo-Tadeo *et al*., 2005; Owusu *et al*., 2011).

The production function summarizes a technical relationship amongst the maximum outputs attainable for different combinations of all possible factors of production (Madueme, 2010)

The production function is thus written as:

$$Q = f(L, K, M) \quad (3.9)$$

Where, $Q = output$; $L = labour$ both hired and family labour; $K = capital$; M = variable inputs $f(.)$ Describes the functional relationship between farm output and different mixtures of labour, capital and variable inputs such as seed, chemicals, fertilizer etc. According to Madueme (2010) the Cobb Douglas function is given by

$$Q = AL^{\alpha 1} K^{\alpha 2} M^{\alpha 3} \quad (3.10)$$

Taking the logarithmic form, the equation is rewritten as:

$$InQ = In(A^{\alpha 1} K^{\alpha 2} M^{\alpha 3}) \quad (3.11)$$

And is estimated as

$$InQ = In \quad A + \alpha_1 InL + \alpha_2 InK + \alpha_3 InM \quad (3.12)$$

where,

α_1 , α_2 , α_3 are the parameters describing the combination of labour, capital and variable inputs. A is the constant term. The logarithmic form allows these parameters to be interpreted as elasticity's (Madueme, 2010).

3.1.4 Determination of Shadow Wages Of Family Labor

The following section involves the empirical determination, measuring the marginal product of family labour from the estimation of the primal side production. The empirical exercise consists of estimating a production function in order to derive shadow wages of family labour directly from the marginal productivity of labor. Treating the household as a profit maximizing firm, it will only employ an input if the added benefit provided is greater than the added cost of the input. This implies that the level of input use will occur where the marginal benefit is equal to the marginal cost. The household will use irrigation up to the point where the cost of an additional unit of irrigation equals the added value its use produces. However, since there are no water markets in rural regions, there is no explicit wage for irrigation water (DiGennaro, 2010). In this case, the cost of irrigation can be represented by the labour costs of irrigation. In the rural areas also, labour markets are usually missing or insufficient forcing households to be self-sufficient for their labour supply.

In a context where no well-functioning labour market exists, the shadow wage determines the household supply and demand of labour rather than a market wage (Skoufias, 1994; Le, 2009). The shadow wage is how much the household values its labour. Assuming that the household labour supply has a balance between irrigating crops and leisure time. The household will irrigate up to the point where marginal cost of irrigation (labour cost) is equal to the marginal revenue product of labour (shadow wages). Figure 3.1 illustrates how the adoption of a small scale irrigation technology affects supply and demand of labour for irrigation. The supply curve of labour for irrigation (S_L) is upward slopping. The household will choose to shift labour away from leisure to irrigation as the implicit wage increases. The demand for irrigation labour is represented by the marginal revenue product of labour (MRP_L). The MRP_L is downward sloping because of the law of diminishing returns assuming capital is fixed (DiGennaro, 2010). At equilibrium, the household supplies labour irrigation up to the point where shadow wages is equal to marginal revenue product for irrigation. In figure 1 where the labour supply curve (S_L) intersects with the marginal revenue product of labour (MRP_L). For a household using the traditional rope and bucket system for irrigation, the level of irrigation will be relatively low as a result of the low productivity of labour. With the introduction of the motor pump irrigation system which, though is less tedious requires more technical know-how in operation, increases the productivity of labour there will be an outward shift in the marginal revenue product of labour curve causing a higher demand for irrigation labour. This will mean a shift in MRP_L curve from MRP_L resulting in the household supplying more labour from q to q^1. It is therefore hypothesized that amongst the smallholder farmers motor pump irrigators are able to generate the highest implicit wage rates for family labour (DiGennaro, 2010).

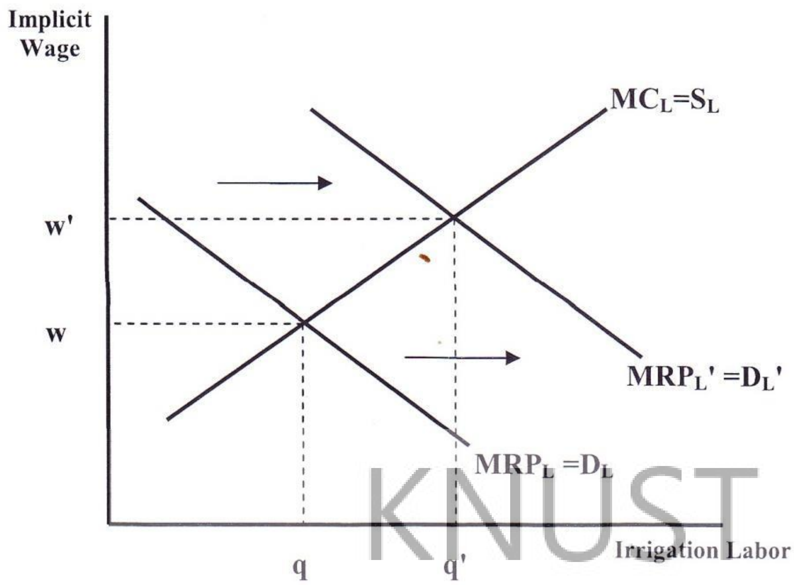


Figure 3.1 Demand for irrigation

Source: DiGennaro (2010)

The shadow wage is estimated using a cost function that treats household labour as a quasi-fixed factor. This approach allows a measure of the shadow wages for the component of the household labour force to be obtained. The production technology is described as a restricted cost function with two allocable quasi-fixed factors. By specifying family labour as a quasi-fixed factor it is not necessary to impute a market wage for family labour, but a shadow wage is estimated to correspond to the value of the marginal product.

The production function is assumed to have a Cobb-Douglas functional form (Jacoby, 1993; Picazo-Tadeo *et al*., 2005; Owusu *et al*., 2011). The model is specified as

$$InI_{ij} = \phi_{ij} + \sum_{i=1}^{2} \alpha In\mathrm{B}_{ij} + \tau_j \mathrm{E}_{ij} + \sum_{i=1}^{5} \lambda In_{ij} T + \mu_j$$

Where

InI_{ij} is the log of the value of output for smallholder farmer i under jth irrigation system and μ_j is the spherical error term. B_{ij} is the vector of demographic characteristics of the smallholder irrigation farmers i.e. age and education. E_{ij} denotes the family labor input of smallholder farmers under the different irrigation systems. T_{ij} denotes the quasi-fixed factors, land (i.e. farm size) and capital and the four variable inputs hired labour, seeds, chemicals and fertilizer. As noted by Menon, (2005); Owusu *et al*., (2011), the shadow wages associated with the Cobb-Douglas specification of the production function is evaluated as

$$w_i^* = \hat{\tau}_j \frac{\overline{I_{ij}}}{\overline{\mathrm{E}_{ij}}}$$

Where $\hat{\tau}_j$ is the coefficient of E_{ij}, $\overline{I}_{ij}$ and $\overline{\mathrm{E}}_{ij}$ are the values of the output and family labour respectively evaluated at the mean.

3.1.5 Gross Margin Analysis

Farm Gross Margins provide a simple method for comparing the performance of enterprises that have similar requirements for capital and labor.

Gross Margin = Gross Income- Total Variable Cost, (Jamala *et al*., 2011)

Where,

GM=Gross Margin;

GI= Gross Income; calculated as gross output $\times$ unit price of each commodity

TVC= Total Variable Cost; all variable inputs in irrigation production. This includes; family labour, hired labour, seed, chemicals and fertilizer.

3.2 Hypotheses of the study

The following hypotheses are tested:

1. Adoption is negatively influenced by farmer's age and gender.
2. Education level, extension contact, land tenure, farm size, household size, farming experience, credit availability and membership with farmer association positively influences the adoption of smallholder irrigation.
3. Amongst the smallholder irrigation farmers, motor pump irrigators are able to generate the highest implicit wage rate for family labour than manual pump irrigators.
4. Amongst the smallholder irrigation farmers, motor pump irrigators make the most profit.

3.3 Data Collection

In this section, the study area is described followed by the sampling techniques adopted in the data collection.

3.3.1 Study Area

The Study Area

The study was carried out in three districts in three different regions of Ghana. The districts are Kasena-Nankana East in the Upper East Region, Akuapem South Municipality in the Eastern Region and Keta Municipality in the Volta Region. These districts were purposively selected because of the prevailing small holder irrigation schemes in the farming communities of the districts. Notably, surface-water-pumping-based private and communal irrigation systems are located in most of the ten administrative regions of Ghana, particularly in the Eastern, Ashanti, Brong-Ahafo, and the Volta Regions of Ghana. Sub-surface and groundwater-based irrigation systems are not evenly distributed across the regions but are fast spreading beyond traditional enclaves such as the Keta strip in the Volta Region (Namara *et al*., 2011).

Kasena-Nankana

Kasena Nankana district is located in the Upper East Region. Agriculture is the main economic activity in this district with subsistence farming and extensive livestock production as the main features. The area, like most parts of Northern Ghana, is characterized by a single growing season that lasts from May to October. The uni modal rainfall regime has its peak around August and is often associated with floods and droughts that may occur in the same season. Rainfall patterns in the region are often very short and erratic, but rather intense, leading to high run-off rates. The average annual rainfall is approximately 1000 mm. The major crops grown are groundnuts, maize, rice, guinea corn and millet.

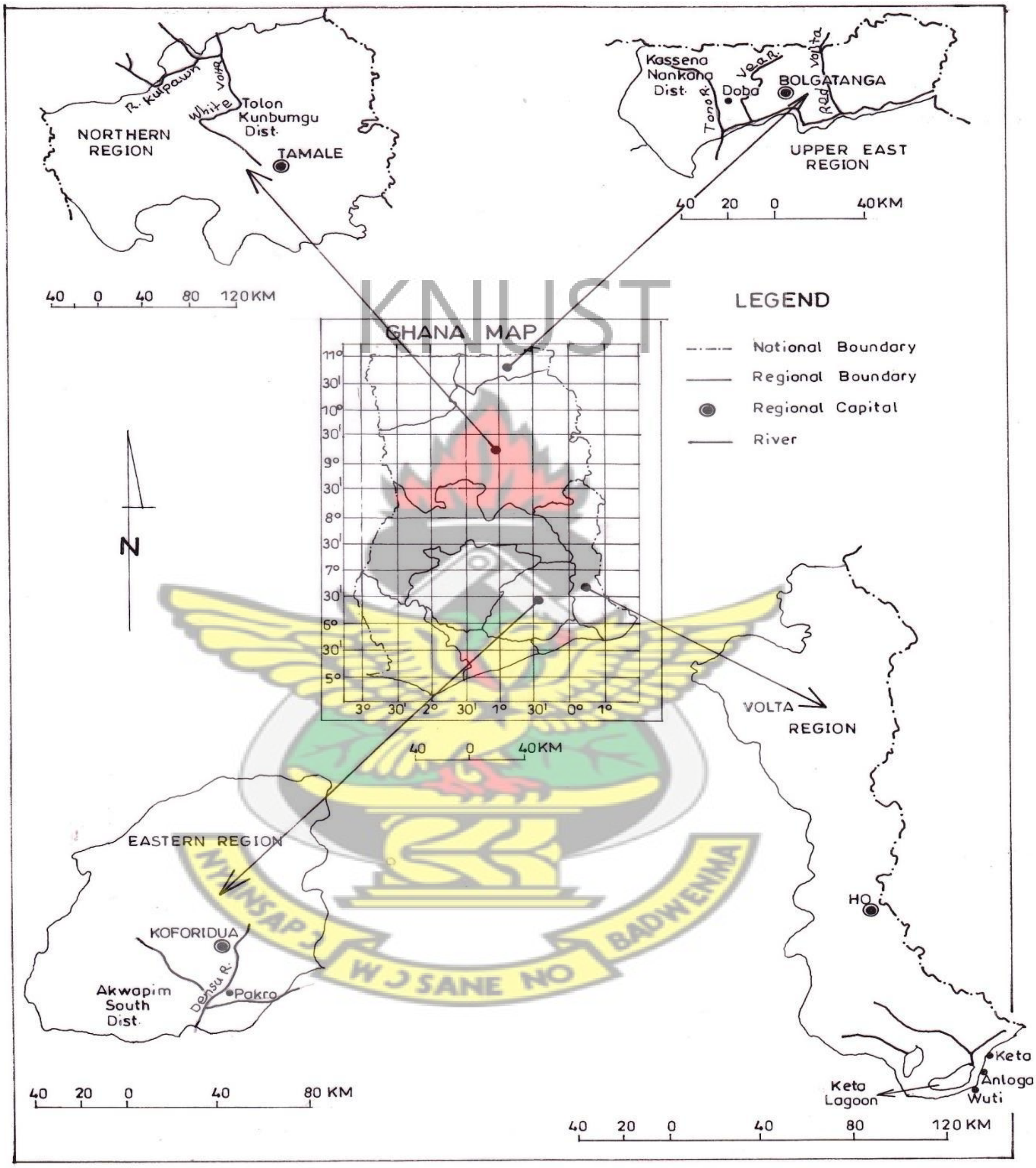
There are four major rivers in the Upper East Region. These are the White Volta, the Red Volta, the Sissili and the Kulpawn. Although a number of small streams also flow through the region, most of them reduce to series of ponds during the dry season. Large-scale irrigation systems found in the Upper East Region are the Tono and the Vea Irrigation Schemes. Tono is situated in the Kasena-Nankana district while Vea is located in the Bongo district. Apart from irrigation of crops and provision of water for livestock, the two irrigation schemes are the main sources of drinking water for the nearby urban and rural communities. In addition to the two main irrigation systems, small reservoirs (also referred to as small dams and dug-outs) are important water sources of irrigation water for dry season gardening, livestock watering and domestic water needs. Many of the small dams were constructed during the 1960s.

Keta Municipality

Keta Municipality is mainly an agricultural district, with the majority of the population engaged in crop farming, livestock keeping, fishing and other related trading activities. Farm sizes are small in the municipality compared to other parts of the Volta Region. The average farm size is about 0.5 ha. The municipality is one of the major vegetable producers in the Volta Region. It is well known for its shallots production along the flood plains of Angaw and Keta Lagoons and streams, and in the depressions created by some wealthy farmers. The main shallot producing areas are Anyanui, Agbledomi, Dzita, Atorkor, Srogbe, Whuti, Woe and Tegbi. Other vegetables such as okra, tomato and pepper are extensively cultivated either as pure stands or as intercrops depending on the season, with alluvial soils along the lagoons.

Maize and cassava are grown as off-season crops, along the littoral but as main season crops in the northern parts of the district. Coconut is also cultivated along the littoral even though it is no more the main source of income for the people as it used to be some years ago, as a result of the Cape St Paul Wilt Disease, which appeared in the district in the Woe area around 1932 and devastated large numbers of trees. Coconuts are also grown in the inland parts of the municipality around Afiadenyigba, Atiavi, Hatorgodo, Atsiame and Dorveme. Sugarcane is extensively cultivated in the flood-prone mid-western parts of the district, such as Atiavi, Hatorgodo, Bleamezad and Tregui. Cowpea is a major crop grown around Abor, Weme and other surrounding towns during the main cropping season and off-season as green manure (www.ghanadistricts.com).

Figure 3.2 Maps of the Study Area



Source: Geography Department, KNUST

Akuapem South Municipality

The Akuapem South Municipality is characteristically agricultural based with 60 percent of its population engaged in subsistence and commercial farming. However, most of them are poorly resourced. The population depends very much on farming for its livelihood. The total arable land in the municipality is about 20,000 hectares. About 600 hectares of land is also under cultivation along the Densu Basin. Efforts made by farmers to increase food production are sometimes frustrated by soil fertility decline, erratic rainfall, high cost of farm inputs and other production constraints. Crops cultivated include maize, cassava, pineapple, pawpaw, different types of local and exotic vegetables and tree crops like oil palm, citrus and cocoa. Besides crop production, the average family rears livestock and poultry. The most predominant livestock include cattle, sheep, goats and pigs.

Akuapem South Municipality is endowed with a number of water bodies. The water bodies are in the form of rivers, dams and dug-out wells, which provide the municipality with irrigation potential and reduce the over-dependency of rural farmers on rainfall agriculture and creating jobs for them through increasing area cultivation. The communities which currently practice dry season agriculture are Okubeyeyie, Akraman, Nsakye, Nyamebekyere Bowkrom, Pakro, Panpanso, Aburi and Dobro. Despite the agricultural potential of the municipality, farmers have not been better-off economically due to the limited market opportunities for their produce. Middle-men for instance, take advantage of farmers by offering low prizes for their agricultural produce. Farmers who cultivate horticultural crops do so in larger quantities for export rather than selling them on the local market. About 80 percent of the farmers practice mixed cropping of food crops for home consumption.

Some of the crops are also sold for income. Mono cropping is practiced by about 9.3 percent of the farmers. The dominant crops cultivated by mono cropped farmers are pineapple, pawpaw and orange. Cultivation of crops is concentrated near the River Densu by farmers who use motor pumps to convey water onto the fields. Majority of these farmers take advantage of the ready market for fresh maize and grow them for sale in and around the municipality. About 60 percent–70 percent are smallholder subsistence farmers whereas 20 percent–30 percent are commercial farmers. Most of the crops cultivated on a large scale are exported. Irrigation farmers grow mainly vegetables like okra, chili pepper, tomatoes, lettuce, cabbage, green pepper (www.ghanadistricts.com).

3.3.2 Farm Household Survey

Primary data was the main source of information used in the study. A structured questionnaire was used to collect quantitative data on production, sales, economics of irrigation and information on the various types of irrigation technologies practiced by smallholder farmers in selected areas. The questionnaire was pre-tested once in the selected communities and the necessary corrections were made in order to gather the right information. The survey was carried out in 2011, and the data was collected within January and March, 2011 on the production activities in the previous year. A multi-stage sampling procedure was used in the data collection. First of all, three districts were purposively selected based on evidence of the dominance of irrigation practiced in the local farming system. These districts were the Akuapem South Municipality in the Eastern Region, the Keta Municipality in the Volta Region and the Kasena Nankana East district in the Upper East Region. With the help of District Agricultural Extension Agents from the Ministry of Food and Agriculture (MoFA), five communities were randomly selected in each district. These communities were: Nania, Kazugu, Doba, Naghalkinia and Pungu in the Kasena Nankana District; Pakro, Nyamebekyere, Krokese, Akraman and Afumkrom in the Akuapem South Municipality and Anloga, Whuti, Woe, Srogbe and Tegbi in the Volta region.

For the household survey, a purposively stratified sampling procedure was used in the selection of the farmers. The target population was all the farmers within the communities. The location of the communities determined the source of water used for irrigation i.e. whether the farmers used groundwater or surface water on their farms. Farmers were first divided into two strata, namely adopters and non-adopters. Adopters were defined as those who used irrigation and thus farmed even in the dry season whilst non adopters were those who did not use any form of irrigation and relied solely on rainfall. List of farmers were not available at the district MoFA office but was rather obtained from the heads of the local farmer associations. Since the study was interested in a specific irrigation technology, farmers (adopters) were further classified into categories depending on the source of water used i.e. groundwater users or surface water users. Groundwater users are those farmers who use water from boreholes, wells and tube wells. Whilst surface water users, are those farmers who use water from reservoirs, streams and rivers. Finally, both the groundwater and surface water users were further classified into motor pump or manual pump operators; the sampling units were selected randomly from these four different strata for the household survey. The sample size consisted of 240 farmer respondent. From the list obtained within the various communities the farmers were grouped into groundwater manual pump irrigators, surface water motor pump irrigators, groundwater motor pump irrigators and rain fed farmers(non-adopters). Farmers were then selected at random from each category. In all 240 farmers were interviewed, 16 farmers from each community. The farmers were characterized as follows: 60 rain fed farmers, 60 groundwater manual pump irrigators, 75 motor pump irrigators on surface water e.g. rivers/streams, 45 motor pump irrigators on ground water sources i.e. shallow/deep wells or on motor pumps connected to boreholes. In addition, secondary information was collected from different sources including government agencies, library and the internet to supplement the primary data.

CHAPTER FOUR

RESULTS AND DISCUSSION

A summary of the characteristics of the surveyed sample are presented in this chapter. The first section gives a general description of the statistics on the sampled population. The second part presents the results of the empirical model estimated and the final section discussed the implicit wages of family labor and the gross margin analysis.

4.1 Descriptive Results

The basic descriptive statistics of the variables used in the model are summarized in Table 4.1 the average age for the respondents across the three districts was 41 years. On the average, 87% of the farmers were males whilst 13% were females. The average land holding was 4 acres. In terms of experience, farmers had an average of 16 years of experience in farming with about 66% of the farmers being part of farmer based organizations. Access to credit was on the low side, with 28% of the farmers having access to some form of credit for their farming activities. For extension contact, 62% of the farmers had access to information through Agricultural Extension Agents (AEA's). Out of the entire sample, 67% of the farmers owned their farmlands and had average household sizes of six (6) members.

Table 4.1 Descriptive statistics for the variables used in the study

Variable	Description	Mean	S.d
Age	Age of the respondent (yr)	40.75	12.49
Gender	1 if farmer is male, 0 otherwise	0.87	0.34
Education	Number of years of formal education (yr)	6.87	5.08
Farm size	Size of farm operation(hectares)	4.07	3.20
Extension contact	Access to technical information(1=yes,0=no)	0.62	0.49
Land tenure	Ownership of land(1=owned,0=rented)	0.67	0.51
Household size	Size of household (no)	5.69	2.35
Experience	Number of years in farming(yrs)	15.7	9.81
Credit availability	Accessibility of credit(1=yes,0=no)	0.28	0.45
Association	1 if farmer is a member of aFBO,0 otherwise	0.66	0.65

Source: Field survey, 2011.

Table 4.2 shows the distribution of farmers who have adopted the existing technologies in the sampled area. Three different irrigation systems were identified in the study area. These include; ground water motor pump irrigation, ground water manual pump irrigation and surface water motor pump irrigation. Majority of the farmers interviewed (75) were found to operate under the surface water motor pump irrigation system followed by 60 of the farmers who were ground water manual pump irrigators and then lastly 45 of the farmers that were ground water motor pump irrigators.

Table 4.2 Distribution of farmers under various systems

Irrigation system	Frequency	Percentage (%)
Ground water motor pump	45	18.75
Ground water manual pump	60	25
Surface water motor pump	75	31.25
Rain fed	60	25
Total	240	100

Source**:** Field survey, 2011

Table 4.3 shows the distribution of the major crops grown under the various systems and the total amount of land put into use. Crops grown were generally similar for the irrigation farmers (who grew vegetables including tomatoes, pepper, okra and shallots and staple crops such as maize as in the case of the surface water motor pump operators. However, the rain fed farmers grew more of the staple crops i.e. maize, cassava and legumes such as groundnuts. These findings were consistent with study by Namara *et al*. (2011) that groundwater and surface water pump based irrigators produced mainly vegetables with staple crops such as maize, rice and cassava on a rather smaller scale.

Table 4.3 Crop areas (acres) cultivated under various irrigation systems

Irrigation scheme	Maize	Cassava	Pepper	Tomatoes	Okra
Rain fed	15	8	-	-	7
Ground water motor pump	18	-	17	18	15
Ground water manual pump	7	-	28	35	18
Surface water motor pump	27	-	36	-	30

Source: Field survey, 2011

From the Table 4.3, it is observed that majority of the surface water irrigation farmers grew pepper followed by okra and finally fresh maize. Majority of the surface water motor pump irrigators were found in the Akuapem South Municipality who grow fresh maize and chili pepper in the dry season using the River Densu as their source of water. Growing chili pepper in this region is a thriving business because farmers get a ready market for it (i.e. exporters come to buy the fresh chili for exportation to the European market). Ground water manual and motor pump irrigators were concentrated in the Volta and the Upper East Regions. Here majority of the farmers produce tomatoes, pepper, okra and maize. Rain fed farmers on the contrary grew staples i.e. maize and cassava and some okra. Results were similar to results obtained by Owusu *et al.* (2011) in studies conducted in Ghana on the livelihood impact of improved on-farm water control in sub Saharan Africa.

4.2 Factors Affecting the Adoption of Irrigation Technologies

Adoption literature suggests various factors which influence adoption, but the notable factors identified amongst the sampled farmers include household characteristics, farm characteristics and socio-economic characteristics. This section is devoted to the discussion of these factors. The descriptive statistics of the variables used in the regression model are provided in Table 4.4

The average educational level of the farmers was 6 years for rain fed farmers, 7 years for both manual and motor pump operators. This shows that the average number of years of education for the farmers interviewed was 6 years which gives an indication that on the average farmers had basic education. Generally more male farmers were involved in dry season farming than females; especially in areas where the predominant technology was the motor pump. This can be explained by the tedious nature of this farming system. Though motor pump irrigation is a much more convenient way of irrigating the field, it can be very tedious. Because motor pump operators usually do not have sheds where they keep their machinery they have to carry their pumps any time they intend to irrigate their fields.

Table 4.4 Descriptive statistics of the variables used in the Probit model

Characteristic / variables	Description	Rain fed Farmers (N=60)	Groundwater manual pump Operators (N=60)	Groundwater Motor pump Operators (N=45)	Surface water motor pump operators
		Mean	Mean	Mean	Mean
AGE	Age of the respondent (yr)	43.47 (13.26)	42.30 (12.08)	43.51 (10.75)	35.68 (11.82)
FMSZE	Size of farm operation (hectares)	3.66 (2.34)	2.56 (1.90)	4.45 (2.95)	5.36 (4.10)
EDU	Number of years of formal education (yr)	6.03 (4.69)	6.97 (5.06)	9.31 (5.43)	5.99 (4.80)
EXT	Access to information (1=yes,0=no)	0.73 (0.45)	0.47 (0.50)	0.40 (0.50)	0.79 (0.41)
TEN	Ownership of land (1=owned,0=rented)	0.85 (0.25)	0.77 (0.43)	0.91 (0.29)	0.12 (0.33)
HHSIZE	Size of household (no)	5.00 (1.74)	6.42 (2.35)	6.64 (2.36)	5.08 (2.44)
GEN	1 if farmer is male, 0 other wise	0.83 (0.38)	0.77 (0.43)	0.96 (0.21)	0.93 (0.25)
XP	Number of years in farming (yrs)	18.53 (9.32)	16.25 (9.12)	15.20 (9.57)	13.29 (10.33)
CREDIT	Accessibility of credit (1=yes,0=no)	0.18 (0.39)	0.35 (0.48)	0.42 (0.50)	0.21 (0.41)
ASSOC	1 if farmer is a member of farmers organisation,0 otherwise	0.33 (0.48)	0.62 (0.49)	0.60 (0.50)	0.37 (0.49)

Source: Field survey, 2011. *Standard deviations* are in parenthesis

Asides that, depending on the distance of the source of water from the farm, farmers have to move their flexible pipes such that they can always have enough water for irrigation. The results are consistent with studies by Adeoti (2006) and Namara *et al*. (2011) in Ghana on irrigation development.

The mean sizes of the farm that were cultivated for the study were 3.66, 2.56, 4.45 and 5.36 acres respectively for rain fed farmers, groundwater manual pump operators, groundwater motor pump operators and surface water motor pump irrigators. For land ownership, 93.3% of rain fed farmers owned their lands whilst 6.7% of their counterparts rented their lands. For the groundwater manual pump operators 76.7% of them owned their lands whilst 23.3 % of them rented their lands. It was only in the case of the surface motor pump operators that 12% of farmers owned their lands and 88% of the farmers rented their lands. The results confirm the earlier results on gender. Since the motor pump is easy to move farmers do not have a problem in adopting the technology. Also because it is a common practice that surface water motor pump operators hire the lands they use for dry season cropping majority of the farmers rented the lands they used. The main problem hindering their adoption is the initial investment for the purchase of the machine and the accompanying equipment and the proximity and reliability of the source of water to be used for irrigation. Credit availability is an important factor which can influence the adoption of an innovation/technology. 18.3% of rain fed farmers received credit whilst 81.7% did not. For groundwater manual (bucket) farmers 35% had access to credit whilst 65% did not, for groundwater motor pump operators (42.2%) used credit whilst (57.8%) did not. And finally for surface water motor pump operators (21.3%) had access to credit whilst 78.7% did not have access to credit. Results are similar to findings by Namara *et al.* (2011) on Irrigation Development in Ghana.

4.3 Discussion of the Probit models

The Probit model was estimated using a maximum likelihood procedure. The Probit estimates of the adoption of smallholder irrigation technologies are presented in Table 4.5 with the marginal effects reported in Table 4.6.

Many, though not all of the explanatory variables have the expected signs. The results show that the probability to adopt groundwater motor pump irrigation had the correct a priori signs for education, farm size, land tenure, household size, gender and credit. The model predicted correctly 28.75% of the probability to adopt ground water motor pump irrigation.

Table 4.5 Probit Estimates of the Adoption of Irrigation Technologies

Variable	Groundwater manual pump	Groundwater motor pump	Surface water motor pump
Constant	0.9236 (0.84)	-3.7242 *** (-2.97)	-0.8702 (-0.49)
AGE	-0.0545 (-1.05)	0.0443 (0.78)	0.0548 (0.59)
AGE2	0.0554 (0.95)	-0.0159 (-0.25)	-0.1124 (-0.97)
EDU	-0.0273 (-1.18)	0.0540 ** (2.23)	-0.0318 (-0.84)
FMSIZE	-0.2782 *** (-4.69)	0.0628 * (1.72)	0.1182 ** (2.20)
EXT	-0.7864 *** (-3.54)	-0.9511 *** (-4.02)	2.1721 *** (4.36)
TEN	-0.0673 (-0.28)	0.8753 *** (3.01)	-3.3885 *** (-7.29)
HHSIZE	0.1647 *** (3.20)	0.0905 * (1.85)	0.0780 (1.09)
GEN	-0.3690 (-1.20)	0.7829 * (1.66)	0.2897 (0.51)
XP	0.0087 (0.57)	-0.0461 *** (-2.90)	0.0060 (0.22)
CREDIT	0.3237 (1.34)	0.7160 *** (2.62)	0.1064 (0.23)
ASSOC	0.6535 *** (2.78)	-0.4841 ** (-2.17)	-0.9797 *** (-3.42)
No of observations	240	240	240
Log likelihood	-102.6317	-82.5189	-40.7902
Pseudo R^2 (p-$value$)	0.2395(0.0000)	0.2875(0.0000)	0.7264(0.0000)

Source: Field survey, 2011. *** , ** , * are 1%,5% and 10% significant levels respectively z-$values$ are in parentheses

For surface water motor pump irrigators; age, farm size, extension, household size, gender, experience, and credit exhibited the correct a priori signs; however farm size, extension, land tenure and association where statistically significant. The model predicted correctly 72.6% of the probability to adopt surface water motor pump irrigation for the sample.

Table 4.6 Marginal Effects for Probit Estimates

Variable	Surface water motor pump	Groundwater motor pump	Groundwater manual
AGE	0.0112 (0.60)	0.0083 (0.78)	-0.0135 (-1.05)
AGE2	-0.0231 (-0.99)	-0.0030 (-0.25)	0.0138 (0.95)
EDU	-0.0065 (-0.85)	0.0101 ** (2.22)	-0.0068 (-1.20)
XP	0.0012 (0.12)	-0.0086 *** (-2.86)	0.0022 (0.57)
EXT	0.3646 *** (4.67)	-0.2047 *** (-3.61)	-0.2118 *** (-3.42)
TEN	-0.6952 *** (-4.79)	0.1646 *** (3.18)	-0.0167 (-0.28)
HHSIZE	0.0160 (1.07)	0.1633 ** (1.84)	0.0409 *** (3.33)
GEN	0.0523 (0.59)	0.1012 *** (2.55)	-0.1035 (-1.07)
FMSIZE	0.0243 ** (2.14)	0.0118 ** (1.71)	-0.0690 *** (-5.30)
CREDIT	0.0224 (0.23)	0.1608 ** (2.31)	0.0858 (1.29)
ASSOC	-0.2010 *** (-3.05)	-0.0903 ** (-2.19)	0.1653 *** (2.62)

Source: Field survey, 2011. ***,**, * are 1%,5% and 10% significant levels respectively *z -values* are in parentheses

Farm size, extension, household size and association were significantly different from zero though not all of the variables exhibited the correct a priori signs, for the groundwater manual pump irrigators. The model predicted correctly 23.95% of the probability to adopt ground water manual pump irrigation.

Education which represents a human capital variable was hypothesized to have a positive effect on adoption. It is believed to permit a more critical evaluation of the productive characteristics and costs of adopting innovations. Education was significant and positively related to the adoption of groundwater motor pump adoption. The results are consistent with studies conducted by Karami (2006), Zhou *et al.* (2008), Bhandari *et al*. (2006) and Namara *et al.* (2007) who conducted various studies on the adoption of irrigation technologies and found education to have a positive effect on irrigation technology adoption. However, the results were inconsistent with Foltz (2003) who found education level to have a negative relationship with the adoption of drip irrigation systems in Tunisia. Marginal effect of 0.0540 suggests a 1.0% higher probability to adopt groundwater motor pump irrigation by 5.4% as farmer's number of years of education increases.

Farm experience was hypothesized to have a positive influence on adoption of technology. However empirical results exhibited a negative sign which was significantly different from zero. This contradicts the general perception that the longer a farmer stayed in farming, the more he gets acquainted with practices associated with a particular technology. The results explain the fact that farmers who adopted emerging irrigation technologies did not have so many years of experience. For experience, a marginal effect of -0.0086 suggests a 0.86% decrease in the probability of adoption for a unit increase in farming experience. The results is however inconsistent with DiGennaro (2010) who observed that farmers agricultural knowledge of correct agricultural practices positively impacted the adoption of micro irrigation equipment in Zambia.

Gender is an important determinant in technology adoption, the gender of the household head was hypothesized to impact the adoption decisions but its effects could be negative or positive. Empirical evidence showed that gender exhibited a positive sign which was significantly different from zero for groundwater motor pump irrigators. This suggests that males were more likely to adopt motor pumps than women. Generally, male farmers dominate the irrigation farming; this is consistent with a study by Adeoti (2009) on the impact of irrigation technology on poverty in Ghana and Owusu *et al.* (2011) on the livelihood impact of improved on-farm water control in sub Saharan Africa. The results were however inconsistent with DiGennaro (2010) who found out that the female farmers were more likely to adopt micro irrigation technologies. A marginal effect of 0.1012 suggests that a 1% higher probability to adopt ground water motor pump irrigation by 10.12 % as gender increases.

Farm size is considered to be a very important determinant since the larger a farmers land, the higher the farmer's tendency to diversify. As such farm size was hypothesized to exhibit a positive sign. Empirical results showed positive signs for both groundwater motor pump and surface water motor pump estimates, but were negative for groundwater manual pump operators. Results are consistent with various studies on adoption of irrigation technologies by Shretha *et al.* (1993), Green *et al.* (1996) and Bhandari *et al*. (2006), who in various studies on the adoption of irrigation technologies found farm size to have a positive and significant effect on adoption. Marginal effects of 0.0243, 0.0117 and -0.0690 for surface water motor pump, ground water motor pump and ground water manual pumps respectively suggests that a unit increase in farm size will cause a 2.43% and
11.7% increase in adoption of both the surface water and ground water motor pump technologies but however a 6.90% decrease in manual pump adoption. The traditional rope and bucket system of irrigation is more tedious as compared with the use of the motor pump, since farmers have to take the pain of carrying heavy buckets to and from the water source (in this case the well, either a temporary or permanently dug well). An increase in the size of the farm would mean that farmers would have to carry these watering cans and buckets over a comparatively longer distance in order to water the crops. But with the motor pumps, this distance is usually catered for by the flexible rubber pipes and tubes that are connected to the pumps through which the water is conveniently conveyed through to reach any area on the farm as required.

Land tenure was hypothesized to have a positive effect on adoption. Empirical results showed that land tenure was positively related to the adoption of ground water motor pump irrigation. However, surface water motor pump irrigation exhibited a negative sign with both technologies being statistically significant at the 1% significance level. Both results concurred with Namara *et al.* (2007) in their study in India which found land tenure to have a positive effect on micro irrigation adoption since farmers who owned their own wells had a higher degree of control over their water source than farmers who rented the lands. Surface water irrigation results was also agreed with Schuck *et al*. (2005) who in their study on the adoption of sprinkler irrigation by Colorado farmers found land tenure to exhibit a negative relationship. Marginal effects of 0.1633 for groundwater motor pump and -0.6952 for surface water motor pump irrigators suggests that a unit increase in land ownership would cause a 16.33% higher probability to adopt the technology when lands are owned by the farmers and a 69.52% lower probability when the lands are not owned by farmers.

Household size is an alternative to labour availability and influences the adoption of a new technology positively as its availability reduces the labour constraints. Household size was statistically significant and positively related to the adoption of ground water manual pump and motor pump irrigation at the 1% and 10% significance levels respectively. The results agreed with Adeoti (2009) in the study on the adoption of treadle pumps in Ghana who found a positive effect, since the technologies require labor for operation. But however, did not agree with Namara *et al*. (2007) which revealed that micro irrigation had a negative relationship with adoption in India. Results reveal that the micro irrigation technologies have lower labor requirements as compared with the traditional rope and bucket technologies. A marginal effect of 0.0169 and 0.0409 for ground water motor pump and ground water manual pump estimates respectively suggests that an increase in household size will increase the probability to adopt manual pump irrigation by 1.69% and 4.09% for ground water motor pump irrigators increases a farmer's probability to adopt ground water motor pump irrigation as family labour (household size) increases.

Access to credit is also an important factor in new technology adoption. Access to capital in the form of either accumulated savings or capital markets is necessary in financing the adoption of many of the new agricultural technologies. Access to credit is hypothesized to positively affect the adoption of irrigation technologies. Empirical results showed that access to credit had a positive and significant effect on the adoption of groundwater motor pump technology. Results concurred with Bhandari *et al*. (2006) who found credit availability to positively affect the adoption of shallow tube wells in India. Marginal effects of 0.1608 suggest that a unit increase in credit availability will increase a farmer's probability to adopt groundwater motor pump irrigation by 16.08%.

Extension contact in developing countries serve as a way of providing information for farmers. Extension contact is hypothesized to have a positive effect on the adoption of irrigation technologies. Results exhibited a positive sign for surface water motor pump irrigation whilst both ground water manual and motor pump irrigation exhibited a negative sign. The three technologies were all significantly different from zero at the 1% significance level. Results agreed with Abdulai *et al.* (2005); Adeoti *et al.* (2007); Karami (2006) who in various studies found extension contact to positively affect the adoption of various irrigation technologies. A marginal effect of - 0.2118, -0.2047 and 0.3646 means that a 1% increase in extension causes a 21.18% and 20.47% decrease in adoption of manual pump and ground water motor pump adoption, whilst a 36.46% increase in the adoption of the surface water motor pump irrigation.

Information is acquired through informal sources like the media, extension personnel visits, meetings and farm organization about new technologies as such significantly affects farmer's choice about it. Membership of FBO's was hypothesized to positively affect the adoption of new technologies. Generally, membership in a farmers' association constitutes a social network through which farmers can obtain information about new technologies. Results showed that association was positively related to the adoption of ground water manual pump irrigation whilst its effect was negative on both the groundwater motor pump and surface water motor pump operators. Empirical results indicate a 16.5% higher probability to adopt groundwater manual pump irrigation as more irrigation farmers join farmer-based organizations. However, a -0.2010 and -0.0903 for both surface and ground water motor pump irrigation suggests a 20.10% and 9.03% decrease in adoption as farmer-based organizational membership increases. The results concur with those of Bouma *et al.* (2008) and Bandiera *et al.* (2006) who found a positive correlation between social networks and adoption of irrigation technologies.

4.4 Discussion of the Cobb- Douglas production function

This section is presents the discussion of the results on the empirical determination of the marginal product of family labour. The empirical procedure involved in the estimation of the production function which was used to derive the shadow wages of family labour directly from the marginal agricultural productivity. A Cobb Douglas production function form was used as in Jacoby (1993); Picazo-tadeo *et al*. (2005). The production data in the analysis of the production function comprises of four separate data files on the sampled households. This included data on rain fed farmers, ground water manual, ground water motor pump and surface water motor pump operators.

Output was measured as the value of output from production in GH¢/hectare of the crops grown by the farmers. For farmers who used irrigation for farming inputs such as land and capital used in investment were considered as fixed inputs. Capital for the rain fed farmers was measured as the costs of bullock in GH¢. The variable inputs were seed, chemical, fertilizer and labour. Seeds were measured in kg/Ha. The family and hired labour inputs were made up of both male and female labour both measured in man-days/Ha. Chemicals used by the farmers include: herbicides, insecticide and fungicide. Fertilizers were made up of NPK and Sulphate of ammonia both measured in GH¢/Ha.

The descriptive statistics of the variables used in the production functions of the smallholder irrigation farmers are shown the Appendix 1. The mean output for rain fed, motor pump (ground water and surface water respectively) and groundwater manual pump irrigators GH¢1,040.84/Ha, GH¢ 3,826.47 /Ha, GH¢1,635.20 /Ha and GH¢ 2,288.64/Ha respectively. The mean cost of family labour used on the farm was GH¢207.57/Ha for rain fed farmers, GH¢106.63/Ha for groundwater motor pump operators, and GH¢119.17 /Ha for surface water motor pump operators and GH¢283.27 /Ha for groundwater manual operators. The mean years of schooling was 6.03 years for rain fed farmers, 7.00 years for ground water manual operators ,9.31 years for ground water motor pump operators and 5.43 for surface water motor pump operators. The average farm sizes for rain fed, motor (ground water and surface water respectively) and manual pump irrigators was 1.48 acres, 1.80 acres and 2.17 acres and 1.04 acres respectively.

Table 4.7 Parameter estimates of the Cobb-Douglas production function

Variables	Rain fed	Groundwater motor pump	Groundwater manual pump	Surface water motor pump
Age	0.0340 *** (2.78)	0.0634 *** (4.06)	0.0139 (0.90)	0.0634 *** (4.06)
Education	0.0640 (1.59)	0.0993 ** (2.69)	0.0530 (1.00)	0.0994 *** (2.69)
Infamlab	0.0222 (0.21)	0.3966 *** (3.57)	0.1507 * (1.69)	0.3966 *** (3.57)
Inhiredlab	0.3725 *** (3.09)	0.0696 (0.62)	0.0868 (0.67)	0.0696 (0.62)
Inseed	0.5602 *** (2.85)	0.0125 (0.06)	0.3017 (1.29)	0.0125 (0.06)
Inchemicals	0.3274 ** (2.01)	0.2774 ** (2.27)	0.0956 (0.48)	0.2774 ** (2.27)
Infertilizer	0.1225 (0.93)	0.2278 ** (1.96)	0.3467 ** (2.28)	0.2278 ** (1.96)
Incapital	-0.0122 (-0.11)	0.5178 ** (3.10)	0.3478 ** (2.28)	0.2111 (0.70)
Infarmsize	-0.0821 (-0.22)	-0.1745 (-0.59)	-0.1938 (-0.54)	0.2384 (0.71)
Constant	1.4196 (1.30)	7.4260	4.4105 *** (3.33)	6.2359 ** (3.09)
No. of observations	60	45	60	75
Adjusted R^2	0.9401	0.9906	0.9642	0.9701
f-statistic(*p-value*)	105.57(0.0000)	60.58(0.0000)	180.43(0.0000)	191.36(0.0000)

Source: Field survey, 2011, ***, **,* are 1%, 5% and 10% significant levels respectively t-values are in parentheses.

The parameters of the Cobb Douglas production function were estimated using a maximum likelihood approach. Some personal characteristics were included in the model; these are age and educational level of farmers. Under rain fed farming hired labor, seed and chemicals are significantly different from zero; this indicates that the allocation of these resources in production is profitable. The positive significant marginal effects of hired labor, seeds and chemicals indicate that a 1 % increase in the level of each input leads to an increase of 21.30%, 27.25% and 12.72%

respectively in the value of output. Under groundwater motor pump irrigation, family labour; hired labour, chemicals, fertilizer and capital are positive and significant. The significant positive marginal effects imply that each additional unit of these inputs employed by the farmers results in an increase of 7.16%, 9.66% 12.41%, 21.62% and 51.34% respectively. For groundwater manual pump irrigators a positive significant relationship is observed for family labor, fertilizer, and capital. The marginal effects of the inputs reported for in the table above implies that a 1% increase in fertilizer and capital lead to a 23.47% and 25.60% increase in the value of output respectively. Family labour, chemicals, fertilizer and capital inputs by surface water motor pump operators has a positive relationship with the value of output. The marginal effects of the inputs reported for surface water motor pump irrigators implies that a 1% increase in family labor, chemicals, fertilizer and capital will lead to 23.91%, 16.24%, 14.87% and 93.40% increase in the value of output respectively. Results are similar to studies conducted by Owusu *et al.* (2011) in Ghana on the Livelihood impacts of improved on-farm water control in sub Saharan Africa.

Table 4.8 Marginal Effects of the Inputs of Production

Variables	Rain fed	Groundwater motor pump	Groundwater manual pump	Surface water motor pump
Infamlab	0.0141 (0.21)	0.0716 ∗∗ (2.28)	0.0789 (1.69)	0.2391 ∗∗∗ (3.59)
Inhiredlab	0.2130 ∗∗∗ (3.09)	0.0966 ∗∗ (2.49)	0.0533 (0.67)	0.0306 (0.62)
Inseed	0.2725 ∗∗∗ (2.84)	0.0080 (0.10)	0.1753 (1.29)	0.0055 (0.06)
Inchemicals	0.1272 ∗∗ (2.01)	0.1241 ∗∗ (2.15)	0.0589 (0.48)	0.1624 ∗∗ (2.27)
Infertilizer	0.0644 (0.93)	0.2162 ∗∗∗ (2.94)	0.2347 ∗∗ (2.57)	0.1487 ∗ (1.96)
Incapital	-0.0023 (-0.11)	0.5134 ∗∗∗ (3.11)	0.2560 ∗∗ (2.29)	0.9340 ∗∗∗ (8.59)
Infarmsize	-0.0030 (-0.22)	-0.0093 (-0.59)	0.0039 (0.54)	0.0173 (0.72)

Source: Field survey, 2011. ***, **,* are 1%, 5% and 10% significant levels respectively. t-values are in parentheses.

4.5 Implicit Wages of Family Labor

This section is devoted to the discussion of the empirical analysis of implicit wage of family labor. The implicit wages is determined from the estimation of a production function of the sampled farmers, in order to derive the shadow wages of family labor directly from the marginal agricultural productivity.

The estimated implicit wages for family labour for the smallholders under three (3) systems are presented in the table 4.9. On the average the computed shadow wages for family labour equals 1.05 GH¢/man-day, 3.21 GH¢/man-day, 1.47 GH¢/man-day and 3.32 GH¢/man-day respectively for rain fed farmers, ground water motor pump, ground water manual pump operators and surface water motor pump operators. The results was consistent with results from other studies where researchers found significant differences in shadow wages from inputs used amongst different farms.

From the results, it is observed that implicit wages for family labour in the case of rain fed farmers is lower than both motor and manual pump irrigators. Low productivity of labour on farms needs to be improved by employing more family labour in order to guarantee higher output. Motor pump operators are observed to generate the highest implicit wage than motor pump and rain fed farmers. The empirical findings concur with the hypothesis that motor pump irrigators are able to generate the highest implicit wage for family labour. These empirical findings agree with studies conducted in Ghana by Owusu *et al*, (2011). In their study they found out that motor pump irrigators generated the highest implicit wage rate for family labour which was the key in the decision making of smallholder farmers in sub-Saharan Africa.

Table 4.9 Estimated implicit wages of family labour for smallholders

Statistic	Rain fed	Groundwater motor pump	Groundwater manual pump	Surface water motor pump
Mean	1.05	3.21	1.47	3.32
Standard Deviation	2.04	2.61	1.37	2.39
Maximum	9.08	10.18	5.41	9.19
Minimum	0	0.39	0	0.34

Source: Field survey, 2011

4.6 Gross Margin Analysis

This section presents the gross margin analysis of the four systems under study and gives a comprehensive layout of the profitability associated with each system. Gross margins were calculated to determine the profitability of production under the four systems of irrigation and also to analyze the costs and returns to each farmer.

The tables of the results for the gross margin analysis are presented in Appendix 2.

The Table 4.10 shows the costs incurred by the three categories of farmers, their incomes received and the gross margins. Empirical results show that the average income received by the farmers was GH¢1060.87 for rain fed farmers, GH¢2602.47 for ground water motor pump irrigators, GH¢1546.18 for surface water motor pump irrigators and GH¢1403.72 for ground water manual pump operators.

Total cost incurred was highest for motor pump irrigators who incurred a total cost of GH¢55,168.80 and GH¢49,182.38 respectively for groundwater motor pump and surface water motor pump operators respectively followed by the groundwater manual pump irrigators who incurred an average cost of GH¢31, 611.96 and finally rain fed farmers incurring a cost of GH¢13,124.13. The high cost of the motor pump irrigators can be explained by the fact that these farmers have to either buy fuel or pay electricity bills which they explained can be quite expensive.

Note:

Crop 1, Crop 2……Crop7 are the list of crops according to their importance in terms of area planted.

Table 4.11 Distribution of Crops Grown

Crops	Surface water motor pump	Ground water motor pump	Ground water manual pump	Rain fed
Crop1	Maize, tomatoes, okra, pepper, shallots	Tomatoes, okra, Pepper, maize, carrot, cabbage	Tomatoes, shallots, millet, maize, okra,	Maize, millet, Rice, green pepper, yam
Crop 2	Pepper, okra, tomatoes, maize, cassava, garden eggs, green	Pepper, okra, tomatoes, onion, shallots, carrots, maize	Pepper, tomatoes, shallots, maize, okra, groundnut	Cassava, maize, groundnut, lettuce, rice, yam
Crop3	Okra, pepper, maize, cabbage, garden eggs, onion and tinda	Pepper, okra, tomatoes, onion, shallots, carrots, maize	Okra, pepper, tomatoes, groundnut, shallots, cassava	Rice, okra, groundnut, pepper, yam, soya beans,
Crop 4	Maize, pepper, tobacco, garden eggs, cabbage, okra, tomatoes	Maize, okra, tomatoes, onions, carrots, cassava,	Pepper, maize, okra, cassava, tomatoes, ayoyo,	Groundnut, cow pea, okra, pepper,
Crop 5	Maize, groundnut, Tomatoes, onion, millet, watermelon, yam	Maize, carrot, pepper, tomatoes, groundnut, onions	Maize, pepper, cassava, tomatoes, cassava, okra,	Cowpea, soya beans, ayoyo, yam
Crop 6	Watermelon, cabbage, Groundnut, sorghum	Cassava, maize, pepper, carrot	Maize, cassava, okra	
Crop 7	Cassava	Cassava, maize	Cassava	

On the whole, motor pump irrigators are able to generate a gross margin of GH¢ 2602.46 per farmer and Gh¢1546.118 per farmer respectively for groundwater and surface water respectively at the end of the farming season per farmer; ground water manual pump irrigators also earned a gross margin of Gh¢1403.72 per farmer with rain fed farmers earning the least margin of Gh¢1060.87 per farmer.

From the results shown in the budgetary table above, groundwater motor pump irrigators had the highest revenue for crops sold followed by surface water motor pump irrigators then ground water manual irrigators and finally the rain fed farmers. The results concur with the study conducted by Dittoh et al.2010) in their study on sustainable micro-irrigation systems for poverty alleviation in the Sahel who found permanent well motorized pump method to be the most profitable micro- irrigation system. High revenue achieved by the ground water motor pump irrigators can be explained by the fact that they have a reliable source of water enabling the farmer more control over his water resources and affording him the ability to crop two or three times (all year round) depending on the farmers resources and labour availability.

4.7 Analysis of the Irrigation Farmers Constraints

Constraints to the expansion of the irrigation farming during the 2011 crop year were ranked. Farmers were asked to rank the three most important factors affecting the expansion of their irrigation activities. The responses were coded into three classes from very important to least important (1=very important, 2=important, 3=least important, 4= none). The responses from the constraints were averaged to obtain the mean rank for each constraint. The constraint with the least mean was ranked the most pressing problem with highest mean being the least pressing. The agreement in the ranking of the constraints was also tested.

From table 4.11, the most pressing problem faced by irrigation farmers was the same for all the different irrigation farmers. The Kendall's coefficient of concordance (W) indicates that there was 40.2%, 47.1% and 63.3% agreement among rankings by smallholder irrigation farmers in groundwater motor pump, surface water motor pump and groundwater manual pump irrigators respectively and these were significant at one percent. Therefore it can be concluded that there is a reasonable degree of agreement among the respondents in the ranking of constraints for the expansion of irrigation farming. Working capital was the most pressing issue affecting the expansion of irrigation by the smallholder farmers. The mean ranks of 1.93, 1.99 and 1.35 were obtained for groundwater motor pump, surface water motor pump and groundwater manual pump irrigators respectively.

Table 4.11 Ranks of constraints faced by irrigation farmers

Constraints	Groundwater motor		Groundwater manual pump		Surface water motor pump	
	Mean rank	Rank	Mean rank	Rank	Mean rank	Rank
Land availability	4.53	5	3.45	3	4.32	5
Family labour	4.58	6	3.50	4	4.88	6
Fuel cost	3.21	3	-		2.13	2
Working capital	1.93	1	1.35	1	1.99	1
Repair and maintenance	4.22	4	-		4.25	4
Market for produce	2.53	2	2.22	2	3.43	3
Storage facilities for produce	-	-	4.48	5	-	-
N	45		60		75	
Kendall's *W*	0.405		0.633		0.471	
Chi square	90.434		151.965		176.798	
Degree of freedom	5		4		5	
Asymptotic significance	0.000***		0.000***		0.000***	

Source: Field Survey, 2011

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 Summary of Findings

Growth in the agricultural economy may be achieved both through extensification and intensification. Irrigation is central to the intensification strategy. Irrigation potential is huge but untapped. The adoption and profitability of smallholder irrigation technology by 240 smallholder farm households in three regions of Ghana has been investigated in this study.

The study was carried out between January and March, 2011 amongst 240 smallholder farmers in five communities from Kasena Nankana District of the Upper East Region, Akuapem South Municipality of the Eastern Region and the Keta Municipality in the Volta Region. The main objective of the study was to identify the factors influencing the adoption of smallholder irrigation technologies and their profitability. The descriptive statistics revealed that majority of the farmers interviewed were males. The econometric results of this study generally indicate that farm size, extension contact and FBO membership influenced the adoption of the irrigation technologies amongst all the farmers.

The empirical results for the ground water motor pump irrigators showed that education, farm size, land tenure, household size, gender and credit showed the correct a priori sign and significantly affected the adoption.

For manual pump irrigation; house hold size and FBO membership exhibited a positive relationship whilst farm size and extension exhibited negative relationships with the adoption of irrigation technologies, though they were all significantly related to adoption. For Surface water motor pump irrigators: farm size and extension had a positive relationship with adoption whilst land tenure and association with farmer-based society exhibited a negative relationship.

Production function estimations revealed that an additional unit of hired labor, seeds and chemicals leads to a 21.3%, 27.25% and 12.75% increase in the value of output respectively for rain fed farmers. For groundwater motor pump irrigation, any additional unit increase in family labor, hired labor, chemicals, fertilizer and capital results in 7.16%, 9.66%, 12.41%, 21.62% and 51.34% increase in output respectively. For groundwater manual pump irrigators, an additional unit increase in family labor, fertilizer and capital leads to a 23.47% and 25.60% increase in the value of output. For surface water motor pump irrigators an additional unit of family labor, chemicals, fertilizer and capital results in a 23.91%, 16.24%, 14.87% and 93.40% increase in the value of output. Motor pump irrigators were found to generate the highest implicit wage rate for family labor as hypothesized.

Gross margin analysis indicated that ground water motor pump irrigators earned the highest profits followed by surface water motor pump operators then ground water manual pump irrigators and finally rain fed farmers just as hypothesized. Ground water motor pump can be concluded to be the most profitable and as such farmers, NGO's, government institutions and private individuals who want to enter into irrigation are advised to use the motorized pump on a groundwater source.

5.2 Recommendations

Results showed that irrigation farmers received very little extension contact. Ministry of Food and Agriculture (MoFA) through its extension officers (AEA's) should empower farmers by giving them training regarding the appropriate choice of crops for irrigation, chemical use and on general good agronomic practices to enhance their productivity. From the, the most pressing issue affecting the expansion of the smallholder irrigation was working capital. In order to promote irrigation farming in Ghana farmers must be supported with micro-credit facilities for the acquisition of inputs especially low cost irrigation pumps. In the study it was realized that motor pump irrigators were more profitable, motor pump irrigation should be promoted through capacity building to update farmers on skills and improve their knowledge on irrigation technologies, record keeping from workshops and trainings. Initial investments for the use of the motor pumps were found to be high which made it difficult for farmers to purchase equipment. It is therefore recommended that credit institutions provide loans to the farmers at reasonable interest rates to enable farmers purchase them. Adoption of equipment for irrigation should be encouraged by the Government, and Non- Governmental Organizations (NGO's). Farmers should be encouraged to go into groundwater use for their ventures where applicable since it was found to be reliable and available all year round.

5.3 Limitations of the Study and Suggestions for Further Research

The study looked at factors affecting the adoption of these small scale irrigation technologies and their profitability. Due to time and budget constraints the impact of adoption of the irrigation technologies on the food security status of the farmers was not investigated. Only three regions were surveyed. Other regions should be covered for further research. The research also concentrated only on rural smallholder farmers. Further research should compare both the rural and peri urban farmers. The study did not explore the water use efficiency of the systems. Since the small holder irrigation systems are not too old a phenomenon in Ghana further study should be undertaken to investigate the profitability of these systems by calculating their water use efficiency. So that water is not overexploited as it has been the case in southern Asia (India being an example). This could help serve as a guide to famers and all interested investors looking for the most convenient system to promote for smallholder farming. In recent times low cost irrigation technologies have also been introduced, however, the effectiveness and impact of these technologies have not been investigated. Further study should be undertaken to find out the profitability of these micro-irrigation technologies. Lastly, the study was technology specific and did not take into consideration specific crops; further studies can be done on specific crops, comparing their profitability's under the existing irrigation technologies.

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APPENDICES

APPENDIX 1

Descriptive Statistics of the Variables Used in the Cobb-Douglas Production Functions

Variable	Units	Rain fed		Groundwater manual pump		Groundwater motor pump		Surface water motor pump	
		Mean	S.d	Mean	S.d	Mean	S.d	Mean	S.d
Output	Gh¢/Ha	1040.84	1350.92	2288.64	2481.67	3826.47	4868.21	1635.20	1508.31
Age	Years	43.47	13.26	42.30	12.08	42.51	10.75	35.68	11.82
Education	Years	6.03	4.69	7.00	5.06	9.31	5.43	5.99	4.80
Family labour	Gh¢/Ha	207.57	259.26	283.27	540.74	106.63	100.90	119.17	159.17
Hired labour	Gh¢ /Ha	210.67	417.50	339.47	361.70	230.46	281.33	73.90	76.20
Seed	Gh¢/Ha	35.31	50.05	89.90	70.47	132.51	119.44	31.19	39.57
Chemical	Gh¢/Ha	23.13	28.05	123.57	95.71	147.71	138.16	140.21	118.61
Fertilizer	Gh¢/Ha	61.53	62.32	229.66	188.70	224.09	176.24	191.81	189.77
Capital	Gh¢	75.42	242.82	347.53	374.72	2844.44	3256.95	1066.40	2492.65
Farm size	Ha	1.48	0.95	1.04	0.77	1.80	1.19	2.17	1.66

APPENDIX 2

Table 4.10 Results for the Gross Margin Analysis

	Rain fed	**GW motor pump**	**SW motor pump**	**GW manual pump**
Cost (GH¢/Ha) (Variable cost)				
Wage for land prep.	1778.249	2558.671	1886.494	4859.74
Wage for sowing	1214.446	2142.612	2646.177	3022.167
Wage for weeding	1617.955	1992.784	1566.268	2997.617
Wage for harvesting	687.738	1804.947	1452.304	2134.08
Seed cost	2182.651	8021.928	2225.2	7624.761
Insecticide cost	365.889	1959.994	1527.457	2185.647
Herbicide cost	824.865	975.2755	1056.609	710.2935
Fungicide cost	137.084	839.6746	651.1665	662.7339
Neem cost	0	262.6367	79.0734	258.7108
NPK cost	2655.752	4707.496	4865.133	4655.242
SA cost	1035.79	1859.342	2122.678	2468.52
Urea cost	397.238	2162.358	1605.245	4218.51
Animal manure cost	226.468	19437.89	1060.643	12295.21
Green manure cost	0	31.4272	38.713	127.9177
Compost cost	0	0	16.4736	90.1931
Water cost	0	0	226.5123	871.0429
Fuel cost	0	6411.759	8585.814	0
Total variable Cost (GH¢/Ha)	**13,124.13**	**55,168.80**	**31,611.96**	**49,182.39**
Revenue (GH¢/Ha)				
Crop 1	21467.94	50067.03	48018.21	60093.3
Crop 2	16994.82	39326.74	59748.04	36739.87
Crop 3	21441.98	37432.06	29991.87	24089.62
Crop 4	196.6126	22014.02	7426.859	9369.086

Crop5	12.3552	15585.23	1783.448	2322.781
Crop6	16624.16	7766.255	570.1933	642.4714
Crop 7	38.5483	88.2516	37.0657	148.2626
Total Revenue (GH¢/Ha)	**76,776.42**	**172,279.59**	**147,575.69**	**133,405.39**
Gross margin (GHC/Ha)	**63,652.29**	**117,110.79**	**115,963.73**	**84,223.01**
Gross margin per farmer	**1,060.87**	**2,602.46**	**1,546.18**	**1,403.72**

Source: Field survey, 2011.

APPENDIX 3

ILLUSTRATIONS OF IRRIGATION TECHNOLOGIES

a. Groundwater Motor Pump

b. Surface Water Motor Pump

c. Groundwater Manual Pump

d. Groundwater manual pump

Source: Field Survey, 2011.

APPENDIX 4

FARM HOUSEHOLD QUESTIONNAIRE

Personal characteristics

1. Name of the Investigator:____;
2. Mobile # with country code: ____
3. Name of the respondent:____
4. Male/Female:___________; Age:_____years; years of education:_____________
5. Village_________________; District_________________;
6. Province/Zone/Region________________; Country:____________________
7. Mobile Number: Country code: __________; Mobile Number:______________________
8. (i) Are you a member of any farmer association? 1)Yes 2)No

(ii) If yes, what assistance do you receive from the association

…………………………………………………………………………………………

…………………………………………………………………………………………

9. (i) Did you have extension contact in 2009/2010? 1)Yes 2) No

(ii) If yes, how many times in the 2009/2010 planting season? ___________________________

10. (i) Have you attended any workshop concerning irrigation in 2009/2010? 1)Yes 2)No

(ii) If yes what did you learn from the workshop?

____

____

11. Did you receive any cash and/or input (formal and informal) credit in the 2009/2010 crop season? 1)Yes 2)No

i. If yes, what was the source of your credit?

a. Bank

b.Money

c. NGO/

d. Government (project)

e.Relative. f . Others(specify)_______________________________________

ii. How much credit did you receive?____________________________________

12. If No, please state why?

i. No facility

ii. Did not bother to look for credit

iii. No collateral to guarantee credit

iv. High interest rate

v. Other(specify)____

13. Number of years in farming____________________________________

14. Household details:

#	Name	Age(Years)	Male/Female	Relationship to the respondent	Occupation: [1] education; [2] farming own land; [3] labor for other farmers; [4] non-farm casual work; [5] small trade/enterprise [4] regular job; [5] retired	Is the member available for work on the household farm? [a] full time; [b] part time; [c] not at all
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						

15. Household Asset Base:

#	Asset	detail	Approximate replacement value[1]	Detail	Response
1	Dwelling	Thatched roof: [1] Cement & bricks [2]			
2	Total Farm Land held	Acres		Do you have forma	
	Total Farm Land cultivated	Acres		# of parcels	
3	Large livestock				
	Cattle Sheep Goat Rabbits Other(specify) ______	Number Number Number Number Number			
4	Small livestock				
	Guinea fowl Duck Chicken	Number Number			
5	Work animals				
	Bullock Donkey	Number Number			
6	Groundwater structure/s	Borehole [1] Open well		Depth in feet	

1 To find the replacement value, you may ask: “How much would it cost to buy/acquire/construct this now?”

7	Manual pump:	[1] foot pump; [2] hand pump; [3] rower pump; [4] other, pl specify			Brand/ Supplier	
8	Motor pumps	Electric [1] Diesel [2] Petrol[3]			Brandname	
9	Flexible rubber pipes	Feet			Brandname	
10	Bicycle	Treadle[1] Other[2]			Brandname	
11	Pesticide Spraying pump	Number			Brandname	
12	Mobile phone	Number			Brandname	
13	Motor cycle	Number			Brandname	
14	Motor car	Number			Brandname	
15	Color TV	Number			Brandname	
16	Transistor radio	Number			Brandname	

16. Irrigation Profile:

Mode of water access for crop cultivation	Source of Irrigation water: 1. own well; 2. own borehole; 3. community borehole; 4. small reservoir; 5. canal 6. river/stream Other, specify	Lifting device: 1. bucket 2. manual 3.motor pump; 4.electric pump	Means of Water transport from source: 1. earthen field channels; 2. lined channels; 3.flexible rubber pipes Other, specify	Water application to crops: 1. furrows; 2.basin; 3. drips; 4. sprinklers Other, specify	Names of all crops grown during the last 12 months from different modes of water access in column 1. (please list these in descending order of the land devoted to each crop)
Rainfall	NA	NA	NA	NA	
Lift					

17. Economics of Irrigation Farming:

(i) Crop cultivation and sales (for both rain fed and irrigation farmers)

#	Crop mentioned in last column.	Area planted (acres or Hectares)	*Number of times the crop was watered till harvested	*(for pump irrigators) Total hours of pump operation for irrigation during the	Total Production (kg)	Total income from the sale of crop in local currency*
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
*US $=___________ local currency						

*for irrigation farmers only.

Questions for Rain fed Farmers:

#	question	Response	Remark
1.	What are the crops that you grow without any irrigation?	1. 2. 3.	
2	How many rain fed crop cycles can you grow within one year?	1.one cycle 2.two cycles	
3.	In the last five years, how many years of good rainfall season did you have?	1.one year 2.two years 3.three years	
4	If you were offered an irrigation source of your choice, how would you rank the	Rank	
	a. Government canal irrigation scheme		
	b. Canal drawn from a small reservoir		
	c. Own well, motor pump and 500 feet of		
	d. Own well, treadle pump and 500 feet of		
	e. Motor pump, 500 feet of rubber pipe to be used on a small reservoir or stream, canal or a community pond		

Questions for Manual Pump Irrigators

#	Question	Response	Remark
1	What kind of a manual pump do you own?		
2	When did you acquire it? (Year)		
3	What was the total investment you made in pump, pipes and water source?		
4	From where did you acquire the pump and pipes?		
5	Who if any assisted you in acquiring the pump and pipes?		
6	Did you receive subsidy in the cost of pump, pipes and water source, and if so, how much?		
7	How many other farmers in your neighborhood use similar manual pump for irrigation?		
8	Please indicate the names of family members (or # from table under question 14) who work on the pump during the irrigation season		
9	Do you find manual irrigation profitable?		
10	What are the <u>**three**</u> most important limiting factors in expanding your area under irrigation? [1] land availability; [2] family labor; [c] working capital; [d] market for the produce; [e] any other (pl specify.		
11	What is the most serious problem you face in your irrigation agriculture?		

Questions for Motor Pump Irrigators

#	Question	Response	Remark
	What is the capacity of your pump (horsepower or KV)		
2	What does it use as the source of power? Diesel, Petrol or Electricity		
2	When did you acquire it? (Year)		
3	What was the total investment you made in pump, pipes and the water source?		
4	From where did you acquire the pump and pipes?		
5	Who assisted you in acquiring the pump and pipes? 1.self 2.government		
6	How much subsidy did you receive in the cost of pump, pipes and water source?		
7	How many other farmers in your neighborhood use similar motor pump for irrigation? 1. 1-5 2. 6-10		
8	Please indicate the names of family members (or # from table under question 14) who help you in managing irrigation during growing season.		
9	Do you find motor pump irrigation profitable? 1.yes		

10	What are the **<u>three</u>** most important limiting factors in expanding irrigation? [1] land availability; [2] family labor; [c] fuel cost; [d] repair and maintenance of the motor pump; [e] working capital; [d] market for the produce; [e] any other (pl specify.		
11	What is the most serious problem you face in your irrigation agriculture?		

22.labor use

Activity	Family labor						Hired labor		
	Adult male			Adult female					
	number	days	hrs	number	days	hrs	number	days	Wage
Land preparation									
Sowing/planting									
weeding									
harvesting									

24. Inputs used

Input	Quantity	Unit	Price	Total cost
Seeds				
Insecticides				
Herbicides				
Fungicides				
Neem extracts				
NPK				
SA				
Urea				
Animal manure				
Green manure				
Compost				
Water				
Fuel (diesel)				

25. Household expenditure on food

Household commodity	Quantity		Unit quantity	Unit price GHȻ	Total expenditure GHȻ
	Own production	Bought or any other source			
1.maize					
2.wheat					
3.millet					
4.sorghum					
5.cassava					
6.plantain					
7.cowpea					
8.pepper					
9.onions					
10.tomatoes					
11.beef					
12.fish					
13.sheep					
14.goat					
15.chicken					
16.eggs					
17.milk					
18.sugar					
19.cooking oil					
20.salt					
21.coffee					
22.Local beer					
23.alcohol					
24.others,(specify)_____					

26. Non-labour income

#	Question	Response	Remark
1.	Do you receive any other form of income in 2010 in cash or in kind?	1.yes 2.no	
2.	How much did you receive?	GH₵______	
3..	How often do you receive this income?		

27. Non-farm income

#	Question	Response	Remark
1.	Were you involved in any off/non-farm activity in 2009?	1.yes 2.no	
2.	If yes, what activity are you involved in?	1.government work 2.small business 3.other,(specify)	
3.	On the average how long do you spend in a day on your non/off farm activity?		
4.	How much do you earn from your non/off farm activity monthly?		