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Assessing Small Scale Irrigation Development in Upper West Region

By

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Declaration

I hereby declare that this thesis submitted to the Department of Civil Engineering for the award of MSc. Water Resources Engineering and Management is my own work 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 degree of the University, except where due acknowledgement has been made in the text.

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Dedication

To my family and friends.

Acknowledgement

I wish to first of all thank the Almighty God for His strength and protection throughout my study.

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List of Acronyms

AfDB	African Development Bank
AgWMS	Agriculture Water Management Solutions
AWM	Agriculture Water Management
FAO	Food and Agriculture Organization

FASDEP	Food and Agriculture Sector Development Policy
GIDA	Ghana Irrigation Development Authority
GoG	Government of Ghana
GSS	Ghana Statistical Service
IFAD	International Fund for Agricultural Development
IFPRI	International Food Policy Research Institute
JICA	Japanese International Corporation Agency
LACOSREP	Land Conservation and Smallholder Rehabilitation Project
METASIP	Medium Term Agriculture Sector Investment Plan
MOFA	Ministry of Food and Agriculture
NGOs	Non-Governmental Organizations
NRGP	Northern Rural Growth Project
SARI	Savannah Agricultural Research Institute
SSI	Small-scale Irrigation
SRI	Soil Research Institute
UWR	Upper West Region
UWADEP	Upper West Agricultural Development Project

CHAPTER 1:

INTRODUCTION

1.1 Background

All over the world developing nations have invested a chunk of their funds in infrastructure for irrigation development in the form of irrigation schemes over the last half century, noticing its importance for food cultivation for the rising population (Gorantiwar and Smout, 2005). This investment, together with modern farming practices such as the use of fertilizers, high yielding varieties and plant protection techniques has led to an increase in yield per acre of irrigated land compared to that obtained from rain-fed agriculture on the size of land (Shah, 2008). Notwithstanding this achievement, there is still doubt that many irrigation schemes are performing up to their desired levels or achieve the goals. Irrigation development is seen as a remedy to reducing poverty than any other public development in most dry and semi-dry countries as emphasized by Carruthers *et al*. (1997).

Although irrigation has a great potential and there have been public outcry in recent times in its development, the actual land under cultivation using irrigation is relatively low and insignificant as compared to the available land at most schemes. In addition, the performance and output of existing irrigation schemes, particularly government developed ones are generally low (GIDA/JICA, 2004). Moreover, what is fascinating is the fact that, researchers lack a clear understanding of where in Ghana different types of irrigation infrastructure are used and to what extent. Despite this situation, irrigation has contributed greatly to change the social fabric of most regions in the world; the provision of economic development in arid and semi-arid regions, stabilizing rural areas, increasing income and creating the opportunity for economic advancement (Dittoh *et al*., 2014).

In the case of Ghana, well-targeted interventions in water have significant potential to contribute to rapid improvements in the livelihoods of rural people (Santini, 2010). In whatever ways growth in agriculture can be achieved either by cultivation of more land or increasing the productivity of existing land, irrigation plays a significant role in achieving these objectives. According to Kyei-Baffour and Ofori, (2006), there is no way Ghana can succeed in increasing economic growth and reducing poverty to its target level without first and foremost investing greatly in the agricultural sector. There are enough water resources for irrigation in Ghana. The irrigation potential of the country ranges from 0.36-1.9 million hectares by different researchers (FAO, 2005; Agodzo and Bobobee, 1994). Irrigation development in Ghana has been justified as means to achieve food security, poverty reduction and rural employment. This argument is specifically related to the Northern regions, as they are characterized by only one rainy season with high erratic rainfall pattern. The development of irrigation schemes that provide all-year-round farming opportunities and increased productivity offers smallholder farmers permanent employment throughout the year and thereby increasing their annual incomes and purchasing power to help them meet their needs. Ali and Pernia (2003) estimated that 77 % of rural household incomes are higher with irrigated agriculture than those who resort to only rain-fed agriculture.

The wide poverty gap between the Southern and Northern Ghana has been attributed to the rainfall pattern of Ghana. The south experiences a bimodal rainfall pattern whiles the north have a unimodal rainfall pattern. Hence, farmers in Northern Ghana cannot engage in all-year-round farming with one rainy season. Having realized the shortcomings of rain-fed agriculture to guarantee food supply and all-year-round farming especially in Northern Ghana, the Government of Ghana and other development partners have developed some irrigation schemes in the Upper West Region to help enhance agricultural production and reduce poverty (National

Development Planning Commission, 2008). However, current Ghana Poverty Mapping report shows the Upper West Region has the highest poverty incidence (70.7 %) among all regions in Ghana (Ghana Statistical Service, 2015).Therefore, pragmatic steps need to be put in place to address the high poverty incidence in the region and key to this is to improve the development of small scale irrigation schemes considering the fact that the majority of the people are found in rural communities and are the most vulnerable. Unlike the Northern and Upper East regions, where there are well planned and properly developed irrigation schemes, most small scale irrigation schemes in the region have still not received the best of development. This situation compels farmers to develop their own strategies to irrigate crops in their fields and hence there is need to assess small scale irrigation development in Upper West Region.

1.2 Problem statement

Food insecurity and poverty are the major problems in the Upper West Region. The region is largely agrarian with about 86 per cent of the people engaged in subsistence farming who are been described as the most vulnerable and poor in terms of poverty analysis in Ghana (UWRCC, 2008). It has been captured in IFAD-Ghana (2005) report that not too many families practice irrigation and are idle during the dry season.

The inability to meet household food requirements leads to migration of indigenes out of the region to look for other miniature jobs during the dry season especially in southern Ghana where they have two rainfall patterns (Ghana Statistical Service, 2012). This study is intended to look at the reasons behind the under usage of most small-scale irrigation schemes in the region and to suggest appropriate solutions to revert the situation.

1.3 Justification of study

Water is one of the most important ingredients in agricultural production aside labour. The dependence on natural rainfall for agricultural production affects crop yield when the rains fail at the needed time (Kyei-Baffour and Ofori, 2006). The inability to control this natural input makes it difficult for farmers to produce effectively which subsequently result into low yields especially for those in the northern part of the country of which the study area is not an exception. Therefore, it is necessary to improve upon the development of irrigation schemes more importantly small scale ones to provide all-year-round-farming due to the long dry season and the erratic nature of rains which seriously affect agricultural productivity since it cannot be controlled (Kyei-Baffour, 1994).

Irrigation has the ability to solve these bottlenecks and helps reduce poverty by offering employment especially to rural households, ensuring food security and stabilizing food prices both in the rural and urban markets (Lipton *et al.,* 2003). It is estimated that 40 per cent of the total world food crops produced comes from irrigation under only 17 % of the total arable land in the world (Upton, 1996; IPTRID,
1999). This suggests that 60 % of food crops produced is through natural rainfall. However, research shows that, crop yield in irrigated farming are far better than those from natural rainfall (Kyei-Baffour, 1994; Swamikannu and Berger, 2009). This strengthens the argument that irrigation development is the solution to long lasting agriculture (Shah, 2008).

The good thing about irrigation is that, it can control and release water anytime to crops especially at peak demand for its growth and also has the potential to take away unused water, which is difficult or not possible to do with natural rainfall (Rydzewski, 1987). Therefore, it is important to assess the current state of small-scale irrigation development in Upper West Region of Ghana.

1.4 Main objective

The main objective of the study is to assess small-scale irrigation development in Upper West Region of Ghana.

The specific objectives are to:

- Assess the state of small scale irrigation structures in the study area.
- Examine the land suitability of small scale irrigation schemes in the region.
- Identify the challenges and potentials in small scale irrigation schemes in the region.
- Suggest solutions to improve small scale irrigation development in the region.

1.5 Scope of study

The research looked at small-scale irrigation development in four districts namely; Wa-West, Nadowli, Lambussie-Karni and Nandom with their respective schemes at Siru, Sankana, Karni and Kokoligu in the Upper West Region of Ghana.

1.6 Structure of study

The study is made up of five chapters in all. Chapter one illustrates the background, problem statement, justification, objectives of research, scope and the structure of thesis. Chapter 2 reviewed relevant literature on the research topic. Chapter 3 looked at the study area and methodology used in carrying out the research. Chapter 4 presents the results and discussions and in chapter 5, conclusions and recommendations are made based on the research.

CHAPTER 2:

LITERATURE REVIEW

This chapter reviews relevant literature on small-scale irrigation development, challenges and potentials which are in connection with the project objectives.

2.1 Irrigation in Ghana

Currently, the output of most irrigation schemes in the country is appalling and varies from one scheme to the other due to the over dependence on rainfall, particularly in the drought and flood prone Northern regions (Namara *et al*., 2011). There is a bright future for Ghana in terms of agricultural development through irrigation with available arable lands and sufficient water resources. Although most irrigation schemes in the country can boast of these resources, it is still evident that very small irrigable lands are developed. Even with these small irrigated lands, the performance and productivity of existing irrigation schemes particularly the formal ones are generally low (Namara *et al*., 2011).

2.2 Brief history of irrigation development in Ghana

History trace Ghana's irrigated agriculture to a little over a century ago (Namara *et al*., 2011; Smith, 1969) but the practice on a small-scale started far way back in the early 80s on farm lands that were high above flood level between the lagoon and the sandbar separating it from the sea (Kyei-Baffour and Ofori, 2006). As a result of the natural terrain in certain areas of the country, intensive farming methods by irrigation, manuring and crop rotation had to be employed (Kyei-Baffour and Ofori, 2006; Smith, 1969). The practice of serious irrigation in the 1960s and the year 1980 saw the development of approximately 19,000 ha of irrigated land and by the year 2007 the area under irrigation had increased to 33,800 ha (Namara *et al*., 2011).

In Ghanaian perspective, irrigation systems can be categorized into two different forms: formal systems and informal systems. Officially not much is known about the informal systems, but they are expanding at a faster rate as a result of easy access to relatively affordable pumping technologies and readily available markets for horticultural crops (Namara *et al*., 2011).

2.2.1 Formal / Modern irrigation schemes.

These kinds of schemes are capital intensive and normally undertaken by the Government of Ghana and its development partners from the initial phase of the projects to the end. These schemes ranges from few hectares to tens of hundreds of hectares, hence government developed schemes covers small, medium and large scale. Out of the total irrigated land, it is estimated that a little below 9,000 ha was developed by GoG with the remaining land been developed by the private sector (Namara *et al*., 2011). Several studies conducted in Africa and more especially West Africa reveals that most medium to large irrigation schemes developed by government has failed (Dittoh, 1991; Sarris and Ham, 1991; Musa, 1992; Mariko *et al.,* 2001). Indeed studies conducted on Ghana's twenty-two (22) public irrigation schemes suggest that most of them are not performing up to expectation (Dittoh *et al.,* 2014; Kyei-Baffour and Ofori, 2006). Moreover research shows that formal schemes appear not to favour small poor farmers (Pant, 2004).

2.2.2 Informal/Traditional irrigation

Informal or traditional systems are initiated and developed by private entrepreneurs and farmers. These systems rather seem to be doing well in terms of the area irrigated and yield obtained than the formal systems. In Ghana, it has been estimated that the area under traditional irrigation is five times more than the formal irrigation systems

(Dittoh *et al*., 2013). According to Nanes (2012), the area under traditional irrigation is far higher than what has been estimated. These forms of irrigation include groundwater or shallow well irrigation, tube-well irrigation, small pump irrigation and out-growers systems. The use of pumps to irrigate from surface waters is becoming popular among farmers in almost all Ghana's regional capitals (Namara *et al.,* 2011). In fact at the last final deliberation workshop of the AgWM Solutions in Accra, key participants came to a conclusion that 80 to 90 percent of Ghana's irrigation is smallholder based (Dittoh and Akuriba, 2012). Unlike formal irrigation systems, which seem to be primarily designed for rice production, the major crops grown under informal irrigation systems are horticultural. However, some staple crops such as maize, rice and cassava are cultivated either solely or in association with vegetables (Kyei-Baffour and Ofori, 2006).

2.3 Definition of small reservoirs and small scale irrigation

The World Commission on Reservoirs defines small reservoirs as "facilities with a height less than fifteen meters (15 m) with storage capacity between fifty thousand to one million cubic meters (50,000 to 1×10^6 m^3)".

Senzanje *et al*. (2008) defined small reservoirs as structures with a dam height that is $\leq$ 8 m and an impounded volume of $\leq$ 1 million m^3. According to the Agricultural Research Council (2004) definition, a small reservoir should have a dam wall with the height between 5 m and 12 m. The vital point worth noting is that, the reservoir should be put into use by smallholder farmers or use on a small-scale. In dry areas, small reservoirs have several uses such as irrigation, domestic, livestock watering, fishing etc (Senzanje *et al*., 2008).

A small-scale irrigation is defined as irrigation that could be large in terms of reservoir size and or height, but being operated by farmers with small land holdings (Senzanje *et al*., 2008). In Ghana, small-scale irrigation schemes are classified as schemes with less than or equal to 100 ha of land (Namara *et al*., 2011). In the context of this thesis work, small-scale irrigation refers to schemes with land size less than or equal to 100 ha.

2.3.1 Importance of reservoirs and dams

To prevent the unavailability of water alongside increasing income for household farmers, a number of small reservoirs were developed by the British administration in the colonial era and continued by the Government of Ghana with support from other donor agencies (Hauck, 2010). Venot *et al. (*2012) found that, a survey conducted in sixteen (16) reservoir sites of Ghana has indicated that, on an average, farmers can earn up to US$350/household/year; which is equivalent to 5 months of work of a single individual if the minimum daily wage set up by the Ministry of Finance and Economic Planning of Ghana is considered.

Renwick *et al*. (2007) outline the importance rural folk place on small reservoirs since they are said to be dynamic in terms of uses including;

- Water availability for agriculture purposes which results in food security, increased income and reduced migration.
- Reducing the risks of women and young girls in search of water for their household chores.
- Making water available for small-scale commercial purposes such as brick making, pottery and mat weaving.
- Improving the ecosystem and increased biodiversity.

Although the importance of small reservoirs cannot be under estimated, the high costs and under-performance with regard to their potential equally affects their development (Cecchi, 2007). Researchers therefore recommend investment into Water Users Associations to maintain reservoirs (Mdemu *et al.,* 2009).

2.4 Small-scale irrigation in Ghana's irrigation policy and development plan

The Ghana Shared Growth and Development Agenda (2010-2013) at the national level proposed the development of appropriate irrigation schemes for smallholder famers as a follow-up of an earlier national and sector policies, as well as political debate (Dittoh *et al*., 2014). According to MOFA (2007), the Food and Agriculture

Sector Development Policy (FASDEP II) is the main agricultural policy with the Medium-Term Agricultural Sector Investment Plan (METASIP) 2011-2015 being the country's agricultural development plan carved out from the policy (MOFA, 2010). Both documents clearly listed the importance of irrigated farming and the potential for development. In 2002, FASDEP II estimated 11,000 hectares of land to be under formal irrigation. However, an estimated 500,000 ha of land including inland valleys could be developed for irrigation as noted by the policy. According to Dittoh *et al*. (2014), in 2000, GIDA identified 32,000 hectares of inland valleys in the country for food production with proper moisture capturing methods which were underutilized. Issues that hinder smallholder irrigation development were outlined in FASDEP II as "formal irrigation development is much dependent on external support and over dependence on the formal system has limited the area under irrigation". Moreover, the informal sector (Small Scale Irrigation) is not supported fully to achieve its potential. Despite these facts, the policy has not made any guideline to actualize small-scale irrigation development.

The value of Small-Scale Irrigation (SSI) have been outlined in the METASIP with priority placed on micro and small-scale irrigation systems in the short- and mediumterm as many of them have succeeded to a large extent. The policies equally outline plans in the long term to develop large scale irrigation systems in the near future and a number of valleys in the savanna zones. The METASIP outlines future development plans for SSI systems by 2015 which are yet to be realized.

It is therefore the objective of the country's irrigation policy to address the following four key areas in order to achieve the main goal of Ghana's agriculture sector (MOFA/FAO, 2010). They include:

- Inadequate production and low growth rates
- Constrained land and water resources
- Irrigated agriculture and environmental degradation
- Insufficient support to the irrigation sector.

The role of irrigation in enhancing food production and poverty reduction is categorically stated in the policy. However, the policy states that, the surest way to decrease the poverty level is by developing irrigation schemes. It also identifies different forms of irrigation practices as being part of the solution process. The Ghana irrigation policy does not treat SSI as important over large schemes, but rather explores the possible options in different parts of the country.

Lastly, the procedure for groundwater resources development especially for irrigation has been addressed in the Water Resources Commission Act (No. 522 of 1996) and Legislative Instrument (LI 1827- 2006) as provided in the National Water Policy (2007). The distinction between surface and groundwater resources and the importance of one over the other is clearly spelt out in the NWP (2007). The objectives of the irrigation policy are to:

- Provide good adequate water for crop, livestock and fish production
- Maintaining the ecosystem so as to provide alternative livelihoods by ensuring good quality water availability.

These objectives can be achieved through the following measures:

- District assemblies should promote small and valley bottom irrigation development.
- Assemblies should support in the utilization and maintenance of small irrigation structures.
- There is need to promote public private partnership in the provision of large irrigation infrastructure.
- Conserve water resources through the efficient fertilizer application methods.
- Improve water application methods and minimize losses in irrigation schemes.
- Prevent the silting up of water bodies by practicing good land use and control land degradation.

Although these policies envisage the importance of irrigation, including SSI to national development, it appears a little has been done so far. In 2014, the Ministry of Food and Agriculture reported that the combined area cropped under both formal and informal irrigation in 2013 was 21,677.9 ha, an increase of 8.1 % over 2012. This success was largely through small and private contributions.

2.5 Land suitability of cropping area

Land suitability is defined as the examination of land units for a particular purpose (He *et al*., 2011; Mu, 2006; Prakash, 2003). Suitability test is done to determine the type of crops that can do well in different soil types. To define the suitability of an area for a particular purpose means, evaluating several methods (Belka, 2005). There are several methods of assessing land suitability of an area. The Fuzzy Multi Criteria Method, Multi Criteria Decision Making (MCDM or Multi Criteria Evaluation (MCE) using Geographical Information System (GIS) and Remote System (RS) data or using the Soil Sampling Method. The Fuzzy and MCE methods are widely used for multiple criteria decision-making issues (Malczewski, 2006) and aims to investigate a number of choice possibilities in light of not only multiple criteria but also multiple objectives (Carver, 1991). The Fuzzy method is used when analysis relating to a particular activity is not known, but it cannot be used when information for analysis lacks accuracy and inconclusive. In such circumstances where one is in a dilemma, the fuzzy logic is employed (Prakash, 2003).

The soil sampling method is area specific and analysis of soil samples is dependent on the soil type of the area or region (UWR). The method requires that soil samples be picked at a particular depth depending on the type of crop, for vegetables (0–20 cm depth) for laboratory analysis. The major parameters considered for analysis include pH, N, P, K and cation exchange capacity CEC (Na, Ca, Mg, and acidity-Al +H) and soil texture. The suitability of the land is evaluated based on the relative proportions of these parameters taking into account the type of crops grown and the recommended ranges for these micro and macro nutrients by research institutions such as the Soil Research Institute (SRI).

2.6 Challenges in small-scale irrigation schemes

Studies have shown that several challenges hinder the development of small scale irrigation schemes. An IFPRI study on irrigation development in Ghana stated that "the economics of irrigation is questionable" in Ghana (Namara *et al.,* 2011). Irrigated farming is mostly limited to vegetable and rice production, because they are perceived by farmers to be the only profitable crops given the high costs of irrigation development and operation which is mostly noted as the major constraint to private investment in irrigation (Dittoh *et al*., 2014).

In order to improve and stabilized food security at household level, it is necessary for farmers to explore and diversify into other cereal crops production which are not irrigated because the high cost of irrigation makes their production unprofitable as perceived by farmers. Hence, the lack of efforts to irrigation limits staple food crops production (Al Hassan and Poulton, 2009).

However, Namara *et al*. (2011) classified the following factors as being influential to the profitability:

- Field water management as a factor which affects yield
- Irrigation cost
- Type of crops produced
- Use of several inputs

Above all, the development of reservoirs for irrigation which involves huge sums many a time is accompanied by improper procurement procedures as noted by (Venot *et al*., 2012). Although the study seems too focused on formal and public irrigation schemes, the majority of them are small scale irrigation systems. The adoption of water lifting method has been pointed out as major issue to irrigators and probably related to; limited access to equipment, high operational and maintenance costs, lack of access to finance, output market risks, and inadequate government support and extension services (Namara *et al*., 2014). The following factors have been identified as the main challenges to irrigation development whether small, medium or large scale.

- Financial and institutional issues
- Availability of inputs and services
- Technical challenges
- Pest and diseases
- Post-harvest losses
- Labour
- Markets

2.6.1 Financial and institution issues

Financial challenges can be looked at in two different perspectives, from the point of government and also from the side of the farmer. At the level of the scheme, money is needed for maintenance, operation and rehabilitation of structures. Meanwhile budgetary allocation from central government to institutions such as GIDA and MOFA is woefully inadequate, at the same time most schemes fail to fix fees for irrigators or fees collected are normally insufficient for running the schemes. As such most of these schemes depend on donor and NGO support to carry out their activities and this normally leads to deterioration to irrigation structures, breakage of canals, leakage of gates etc (Namara *et al*., 2011).

At the farmer level, most farmers will normally require financial services to meet their investment needs and working capital. However, access to credit for inputs, developing wells and financing crop production activities is problematic partly due to irrigators operating individually instead of a group or high interest rates on these loans. Therefore, pragmatic steps need to put in place to address the issue of access to credit in order to increase farmer incentives (Dittoh *et al.,* 2014).

2.6.2 Access to inputs and services

Production through irrigation requires the use of high yielding crop inputs at the right quantity, quality, cost and time. These may include but not limited to seeds, fertilizer, insecticides and herbicides. The availability of inputs particularly certified seeds and fertilizer is often a problem to farmers in Ghana. The use of low technology methods in lifting water coupled with the issue of low groundwater drilling technologies is a major factor that hinders groundwater irrigation development. Farmers' complain of the unavailability of these technologies to enhance production. The choice of irrigation equipment is essential; currently farmers procure pumps based on their ability to purchase instead of knowledge of the technical details of pumps (Namara *et al*., 2011). The use of hoe and cutlass in land preparation which suits slash and burn but not to irrigation farming, continue to impact on the cropping intensity, timeliness and size of land cultivated. Farmers require knowledge on the type of seeds, insecticides and rate of fertilizers on different crops for irrigation. However, extension personnel are not readily available and this affects irrigation service. Moreover, water management in irrigation fields is a big problem.

2.6.3 Post-harvest losses

Inadequate market availability affects agricultural production. The lack of market for certain crops after harvest leads to huge losses (Awulachew *et al*., 2005). In addition to diseases and sometimes inadequate water availability, market is another factor that limits the profits farmers stand to gain from irrigated farming and therefore, marketing of irrigated crops is suffering from a number of challenges (Ofosu, 2011; Laube *et al*., 2008).

Currently, crops grown in most schemes are perishable and require proper storage and transport facilities. The storage of these perishables such as tomato is rare. Little attention is given to post-harvest handling practices considering the perishable nature of these crops and this gives room to middle women and men to influence the price.

The inadequate nature of storage facilities and processing implies that perishable crops are sold as soon as they mature in the field (Namara *et al*., 2011).

2.6.4 Technical challenges

Research reveals that with adequate community involvement in planning, design and management, small scale irrigation schemes can be more viable and sustainable than conventional large-scale schemes (Merrey *et al*., 2002). It is necessary to include local knowledge in the design and construction of irrigation schemes. Irrigation infrastructure is normally developed to serve several purposes, including livestock watering, domestic use, crop production and fishing. However, irrigation infrastructure designs mostly fail to consider these purposes. For instance, in the dry season animals graze along the reservoir banks in search of grass to feed and this sometimes affect the stability of irrigation structures. Moreover, desilting of structures such as canals, laterals and reservoirs as a result of farming practices within the catchment can be financially demanding beyond farmers and when not done, affects the amount of water delivers to field.

The deplorable nature of these structures has resulted in most schemes been cultivated once only in the raining season. At many of the irrigation schemes, structures such as canals and laterals are destroyed resulting in water wastage and restricted irrigation schedules (Namara *et al.,* 2011). It is therefore generally accepted that irrigation technology should be able to meet the capacity of the users (Awulachew *et al.,* 2005).

2.6.5 Pest and diseases

Horticultural crops produced in the dry season suffer seriously from pest and diseases, affecting the yield obtain from fields. Farmers in an attempt to improving yields in their farms are compelled to buy chemicals at high prices to protect their crops. In most schemes, farmers suffer from tomato disease (nematode) and this normally affects their profit (Awulachew *et al*., 2005). In the dry season, birds and fowls tend to feed on irrigated crops as the main available food source and hence, destroyed most irrigated crops (Namara *et al*., 2011).

2.6.6 Labour availability

According to (Ofosu, 2011 as cited in Namara *et al*., 2011), farmers rely on labour whether skilled or unskilled to carry out their farming activities. In the normal year most savannah farmers tend to put much land under cultivation in order to maximize returns to labour. The high demand for labour in cropping compels farmers to find alternatives to costly labour saving practices such as the use of insecticides and herbicides which is sometimes difficult to afford by small scale farmers. In situation where pumps are not used and water is manually lifted and distributed, irrigation can be labour demanding, hence labour unavailability greatly hinder crop production.

2.6.7 Market access

Markets play an essential role in the development of irrigation schemes especially output markets. To a large extent, output markets determine the development of irrigation schemes or are the cause of failure of these schemes (Ofosu, 2011). Generally, irrigation farmers in Ghana and for that matter Upper West have a fair idea of market modalities by way of what they produced. Notwithstanding, the channels for selling produce or the various stakeholders involve are not enough. The limited availability of market routes and participants allow few buyers to determine prices of crops (Namara *et al*., 2011). The issue of market failure, government determination of prices which is always on the cheap side and market instability has resulted in huge losses and further impede irrigation development. These unfavourable market conditions are detrimental to successful irrigation development (Ofosu, 2011; Aw and Diemer, 2005).

2.7 Potentials for irrigation in Ghana

The total land available for irrigation has been estimated by a number of researchers and organizations. According to (Kyei-Baffour and Ofori, 2006 as cited in Sant Anna, 1997) of the FAO, Ghana has an irrigable potential of 360,000 ha. The World Bank (2005) reported that Ghana has the potential of putting 384,000 ha of land for irrigation with water and land availability. An earlier estimation put the irrigable potential of Ghana to over 500,000 ha (Agodzo and Bobobee, 1994). The current estimation put the figure to more than 1.9 million ha (FAO, 2005). Out of the overall
6.9 million ha of arable land for production in 2007, only 33,800 ha were irrigable (Namara *et al*., 2011).

The key factor considered in arriving at this estimation was based on whether the irrigation system is using only gravity to irrigate, gravity cum pump and pumps cum sprinklers (Kyei-Baffour and Ofori 2006). Since several methods can be used in irrigating crops such as the modern drip system, surface irrigation system, or even by the use of watering can or bucket, the term irrigable potential can be subjected to scrutiny depending on the method of irrigation employed in arriving at irrigable potential. Irrigation schemes designed to irrigate crops through canals and laterals by gravity can only be effective on lands that are low without taking into account the possibility of irrigating high lands on the same field using other alternative methods such as drip, sprinkler or by manual means using watering can or bucket. The availability of water, land, technology and government or NGO support together with the substantial amount of rainfall in certain parts of the country, makes the whole idea of irrigable potential in Ghana difficult to define (Kyei-Baffour and Ofori, 2006).

2.7.1 Water availability

A study by IFPRI reveals that there is enough water for irrigation increment in Ghana (Dittoh *et al*., 2014). The estimated renewable water resource of Ghana is 53.2 km^3 of which 0.25 km^3 is used for agriculture production (Alexandratos *et al., 2006*). Ghana has a cultivable land area of about 42 % which covers the entire country with a little of 4.25 % under intensive cultivation. This means that, water and land utilization in Ghana is very low for irrigation and rain-fed production (Venot *et al.,* 2012). Despite challenges to supply water to certain deprived areas, substantial amounts of water are lost due to evaporation, runoff, leakage and seepage. Water "lost" through processes are likely to returned to aquifers or streams which can be re-extracted for use if only the appropriate structures are available and the water quality has not gone beyond acceptable limits (Wallace, 2000).

2.7.2 Land availability

Agricultural land was last measured in 2011 at 69.88 % according to World Bank. The Ministry of Food and Agriculture (MOFA) statistical results indicate vast arable land availability for both irrigation and rain-fed production (Obeng, 2000). Of the total land area of 23.9 million hectares, 13.6 million hectares (57.1 %) was classified as agricultural land area with only 5.3 million (22.2 % of all agricultural land area) were under cultivation with just 4 percent under irrigation during the last count in 1995 as reported by MOFA. It is therefore not out of place when people make the assertion that land is abundant in Ghana.

2.7.3 Technical know-how

According to Ofosu (2011) irrigation development requires technical knowledge for the appropriate management of water. One way to promote agricultural productivity is through the introduction of improved agricultural technologies and management systems (Doss, 2006). The lack of appropriate technology investment constrains irrigation performance and development. Irrigation funding should able to enhance simple but modern technologies which enable irrigators to have much control on their production activities as well as properly fit into the local context (Ofosu, 2011). The unavailability of efficient water lifting and affordable well drilling technologies constrain the development of groundwater irrigation. Farmers' claim these technologies are not available in the ways that meet their capacity (Namara *et al*., 2011).

2.7.4 Support from government/NGOs

At the moment, funding from central government (GoG) for developing irrigation schemes is not forth coming and normally very abysmal. Inadequate funds from government have been identified as the major challenge to irrigation development in Ghana (Dittoh *et al.,* 2014). The Ghana Irrigation Development Authority (GIDA) which is the main body in-charge of irrigation development in the country, its Chief Executive disclose plans to developed 23,000 hectares of bankable irrigation projects but adding that funding has not been forth coming (Nyamadi, 2012).

According to Dittoh *et al.* (2014), MOFA recently provided pumps at 33 % of the market price to farmers as a stop gap until other projects can be implemented." In addition to public schemes, donor agencies and NGO projects and programmes have supported irrigated agriculture. The most prominent of them has been the IFAD sponsored Upper West Agricultural Development Project (UWADEP) which rehabilitated and built a few dams in the Upper West Region (Dittoh *et al*., 2014). Unfortunately the performance of rehabilitated and new small dams has still been below expectation due to several constraints (Birner *et al.,* 2010). Another IFAD and

Africa Development Bank (AfDB) supported programme, the Northern Rural Growth Project (NRGP), has an elaborate irrigation plan, although much has not been implemented yet. Several NGOs, including Care International and Plan International in Upper West has supported irrigation activities in the region (Inkoom and Nanguo, 2011).

CHAPTER 3:

STUDY AREA AND METHODOLOGY

3.1 Geographical location and administrative boundaries

The Upper West Region is situated at the north western corner of Ghana between latitudes 9º 35' and 11º 0' North and longitudes 1º 30' and 2º54' West (Upper West Agricultural Development Project, 1998). The region covers 18,847 km^2 that is 7.7 % of the total area of Ghana (Ghana Statistical Service, 2012). The region is bordered by Northern Region to the south, Upper East Region to the east and Cote d Ivoire to the west. There are currently eleven districts in the region (Wa Municipal, Nadowli, Jirapa, Lawra, Sissala East, Sissala West, Wa West, Wa East, Daffiama-Bussie-Issah, Lambussie-Karni and Nandom) as shown in figure 3.1.

The 2010 Population and Housing Census by Ghana Statistical Service (GSS, 2012) shows that, the region has a total population of 702,110, made up of 360, 928 females (51.41 %) and 341,182 males (48.59 %). The region's population is about 2.8 per cent of the total population of the country with a growth rate of 1.7 percent. Approximately 82.5 percent of the population is in the rural areas. The Region is ethnically heterogeneous. There are six (6) different ethnic groups that are found in the region and form part of the over 100 groups that are found in Ghana. These are distinguishable by language and cultural differences. The main ethnic groups include the Dagaaba, Sissala, Wala, Chakali Birifor and Lobi (Ghana Statistical Service, 2012).

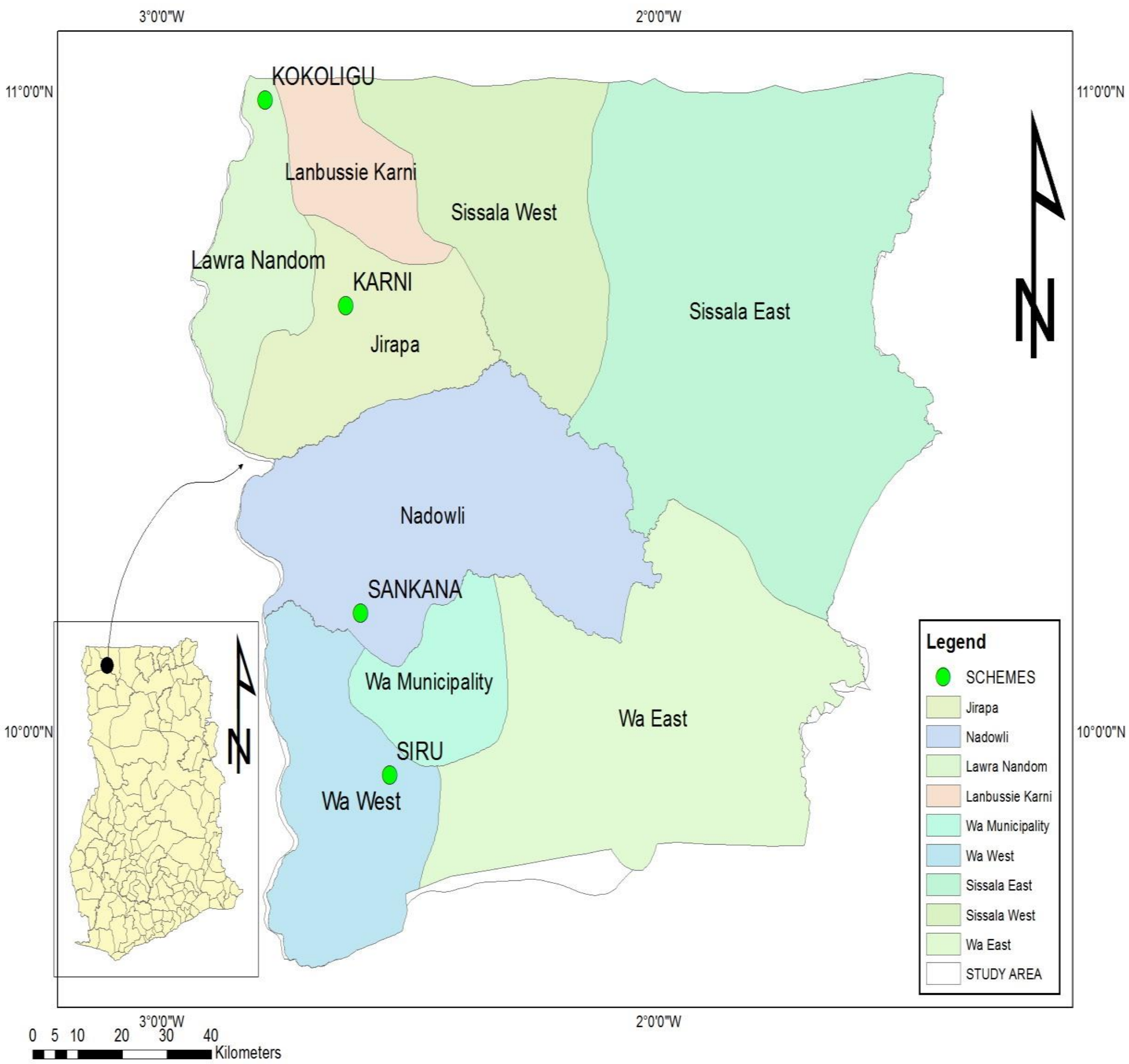

Figure 3.1: Map showing the geographical location and administrative boundaries of the UWR.

3.2 Rainfall, evapotranspiration and climate in UWR

The region experiences unimodal rainfall pattern with a very long dry season spanning from October to the end of April. The tropical climate belongs to the southern part of the region with a distinct dry season, whereas the northern part is described as a dry climate with annual potential evaporation higher than the annual precipitation. The rainfall pattern can be attributed to the region's location in the subequatorial zone with varying wind regimes in the course of the year. The region experiences the dry North-Eastern trade wind (Harmattan) in the dry season resulting to relative humidity dropping to a minimum of 16 % in January. The South West monsoon wind which comes from the maritime air result in high rainfall and relative humidity levels reaching 69 % in August.

The average annual rainfall increases from north to south with the total annual rainfall distribution varying considerably from year to year. In some years, the rain starts in April and May which is followed by a short dry spell of three to five weeks, resulting in serious crop damage. The long term mean annual temperature is about 27.2°C, the mean maximum is about 35.5 °C and the mean minimum is about 18.8 °C (DFARD, 2015). Figure 3.2 shows the rainfall and potential evapotranspiration distribution of the region.

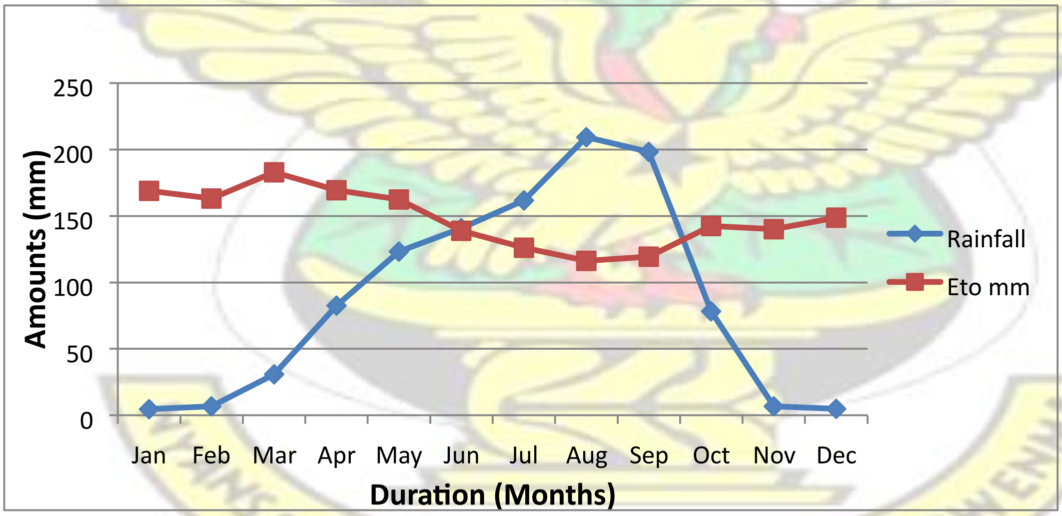

Figure 3.2: Mean rainfall and evapotranspiration in UWR.

Source: Derived from Meteorological Service Department (1960-2011).

3.3 Geology and topography

The geology of the region is that of a wide plateau made up of Birimian and post Birimian granites along with their weathered material. The surface have been leveled with denudation as well as by wind and rain, and the topography is generally flat with altitudes varying from 200 m in the west (bordered by the Black Volta River) to 350 m on the ridge that stretches from Wa in the south, northwards to the Burkina Faso border and beyond. The ridge forms the watershed between the Black Volta in west and the Kulpawn and the White Volta in the east.

3.4 Soils

In the Upper West Region, the soils are largely developed over granite and few areas developed over Lower Birimian phyllite. Most of the soils vary in depth ranging from less than 30 cm to more than 80cm with the latter being dominant. In most cases, the soil types that dominate in the region are laterite, sandy and sandy loam (Savannah Ochrosols). They are generally poor in organic matter and nutrients as a result of the absence of high vegetative cover, due to indiscriminate annual bush burning, overgrazing, over-cultivation and protracted erosion, and are heavily leached (DFARD, 2015).

3.5 Vegetation and land use

The vegetation of the region is subdivided into two agro-ecological zones, the Guinea Savannah zone in the south and west and the Sudan savannah zone in the north and east part, with the borderline between the two zones passes almost half way between Jirapa and Nadowli. The Sudan Savannah is made up of scattered trees and a sparse ground cover of grasses and shrubs. The Guinea Savannah is characterized by higher density of trees, more bunched grasses and shrubs. Acacia sp and baobab trees are common in the north and east while mahogany, ebony, *Isoberina spp*, *Daniella spp* is more predominant in the south. The vegetation has been seriously affected as a result of human activities such as burning and only certain species are able to resist.

The most common and economically vital trees are *Butyrospernum parkii* (sheanut) and *parkia filicoidea* (dawadawa). In most densely populated areas, these are only the remaining native trees. Land use data are limited and indicate that about 13% to 15% of land is cultivated annually with the remaining land left as bush or for grazing animals.

3.6 Drainage

The topography of the region is flat with elevation ranging between 150m to 320m. The main natural drainage is the Black Volta which bounds the region in the west followed by the Kamba valley which serves as a tributary of the Black Volta. Generally there are a number of valleys which are linked and aid in draining runoff in the region.

3.7 Socio-economic activities

The region is basically agrarian with about 80% of the economically active population engaged in agriculture. Other economic activities are commerce, weaving and manufacture of traditional textiles, basket weaving and some amount of fishing, and, lately mining, which is fast catching up with other activities. Crops grown include but not limited to; maize, guinea corn, millet, yam, soya bean, rice and cotton. In addition, there is rearing of some small scale of farm animals. The unemployment situation in the region is still high about 11.1 percent as compared to the national average of about 7.8 percent (Ghana Statistical Service, 2012). The only industry in the region is the Ghana Cotton Company Limited which is operating at a very low pace and almost at the verge of collapse.

3.8 Materials and methods

3.8.1 Introduction

There are about ninety-two (92) small reservoirs and dugouts in the region of which small scale irrigation is practiced according to GIDA-UWR records. Forty-six (46) are bad, twenty-seven (27) are good, fourteen (14) are fair and five (5) poor by GIDA own assessment of these schemes in the region. In assessing small scale irrigation development in UWR, data were collected from selected small-scale irrigation schemes in four districts (Wa West, Nadowli, Nandom and Lambussie-Karni) for detailed study. They include; Siru, Sankana, Kokoligu and Karni systems. The criteria used in selecting these schemes were based on GIDA-UWR preliminary survey to identify schemes with several challenges that require immediate attention, proximity of the scheme, cost and timing of the research. Figure 3.3 outlines the methods used in carrying out the research.

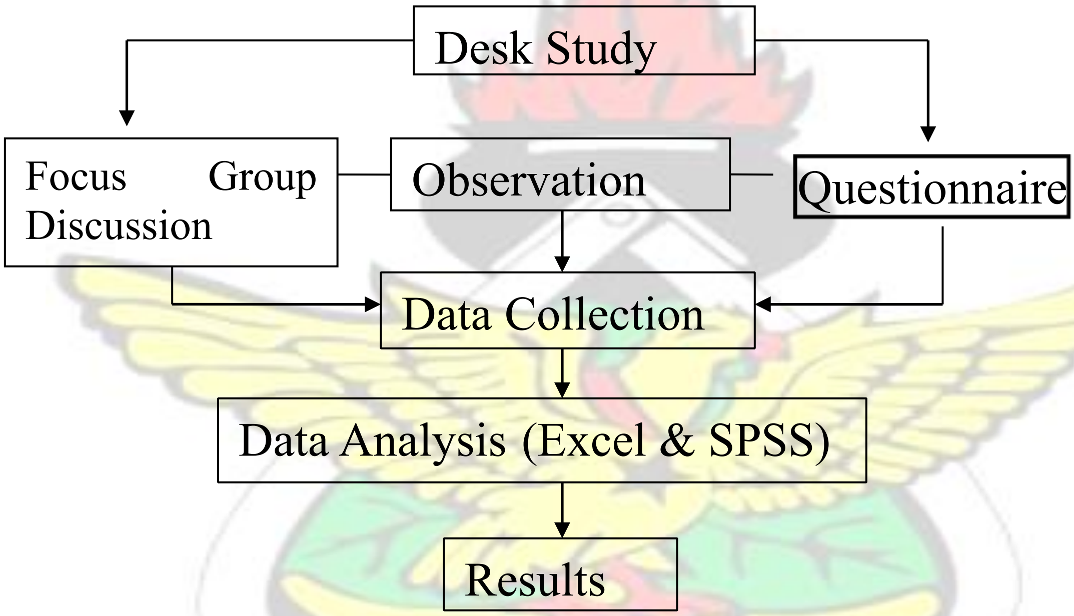

Figure 3.3: Outlined the methodology in carrying out the research

3.8.2 Desk study

Secondary data were collected from GIDA for study. They include reports, journals, and articles. Official records were obtained from GIDA which gave some information on small scale irrigation schemes in the region. The data provided information on the various schemes in the region, their date of construction and rehabilitation, technical state, water use, potential irrigable land and developed area.

3.8.3 Focus group discussions (FGD's)

Departmental heads of GIDA and MOFA at both the regional and district levels were interviewed on their own assessment of small scale irrigation development in the region. The Water Users Association (WUA) executives and other opinion leaders were also interviewed on the challenges facing the schemes and the way forward to improve the development of these schemes.

3.8.4 Observations

Field observations were made at the various selected schemes to look at irrigation structures in the respective areas, how they are utilize by farmers and constrains affecting their performance. This was done together with some farmers and opinion leaders in the respective communities.

3.8.5 Administration of questionnaire

Questionnaires were administered to farmers at the selected schemes to obtained detailed information on small scale irrigation development in the region. Data on the challenges and potentials of these schemes were also collected. The data was then analyzed using Excel and SPSS.

3.9 Field work

3.9.1 Assessment of irrigation structures

Field visits were carried out at the selected schemes to assess the state of existing irrigation structures on the ground. This was done through measurement of some structures (canals, laterals and bunds), observation and interviews.

3.9.2 Methodology for land suitability analysis

The study mainly involved the sampling of two dam sites and examination of the soils (Wa West-Siru and Nadowli-Sankana). In each dam site, an area to be cultivated under irrigation was identified and soil samples taken. Composite soil samples from 0-20 cm depth were collected randomly from each dam site and analyzed for initial physical and chemical properties of the soil. In addition, auger bores were made at each scheme to examine the soil for depth, drainage, texture and coarse fragment content. Standard laboratory procedures were followed in soil samples preparation. Soil samples were mixed, homogenized, air dried in shade, ground and passed through a 2 mm sieve, and analyzed for total N, available P, pH, organic carbon, exchangeable cations (K+, $Ca^{2+,}$ Mg^{2+}), exchangeable acidity (Al+H) and soil texture. Accordingly, soil pH was measured using a soil to water ratio of 1:1 (w/v). Organic carbon was determined following the Walkley and Black wet oxidation method. Total nitrogen was determined by the micro-Kjeldahl digestion, distillation and titration method.

The available phosphorus was extracted by Bray-1 procedures and was determined calorimetrically. Exchangeable potassium was determined by the ammonium acetate method. Soil texture was determined using Bouyoucos hydrometer method.

3.9.3 Calculation of rainfall and evapotranspiration

The annual precipitation and potential evapotranspiration was estimated using available rainfall data from 1960-2011 as provided in appendix B8 from the Meteorological Service Department (MSD). The Penman Monteith equation was used to estimate potential evapotranspiration using climatic data recorded from Wa weather station.

$$\mathbf{ETo} = \frac{\mathbf{0.408\Delta(Rn - G) + \gamma\frac{900}{T + 273}U_2(e_s - e_a)}}{\mathbf{\Delta + \gamma(1 + 0.34U_2)}} \qquad (3.1)$$

Where ETo is the evapotranspiration (mm/day), Rn is the net radiation ($MJ/m^2/day$), G is soil heat flux density ($MJ/m^2/day$), which approximate to be equal to zero for daily interval calculation of ETo, T is average daily temperature (^0C), U_2 is the wind speed at

2m height (m/s), e_s is the saturation vapour pressure (KPa), e_a is the actual vapour pressure (KPa), e_s-e_a is the saturated vapour pressure deficit (KPa), Δ is the slope of the vapour pressure (KPa/ ^oC) and γ is the psychometric constant (KPa/^oC).

CHAPTER 4:

RESULTS AND DISCUSSIONS

4.1 Introduction

This chapter present and discuss the results obtained from field assessment of irrigation structures and questionnaires administered. Tables 4.1 and 4.2 give details of the selected schemes and their geographical coordinates.

Table 4.1: Selected schemes

Scheme	District	Command Area (ha)	Area Cultivated (ha)	Height of Dam (m)	Irrigable Potential (ha)	Land Developed, (ha)
Siru	Wa West	60	12	5.5	25	0
Sankana	Nadowli	60	12	6.5	40	20
Kokoligu	Nandom	15	10	4.0	15	10
Karni	Lambussie-Karni	29	10	4.5	15	10

Source: GIDA-UWR, 2015.

Table 4.2: Capacities and coordinates of the scheme locations

Location	Capacity of Reservoirs Million m^3	Geographic Coordinates	
		Latitude	Longitude
Siru	0.73	9^0 55’50. 26” N	2^0 32’ 34.71” W
Sankana	1.6	10^0 11’ 0.85” N	2^0 36’ 05.99” W
Kokoligu	0.320	10^{0}59’ 08.84” N	2^0 47’ 37.14” W
Karni	0.365	10^0 39’ 50.70”N	2^0 37’ 52.09” W

Source: Field Survey, 2015

4.1.1 State of structures at the schemes

The state of irrigation structures in the selected schemes comprising Siru, Sankana, Karni and Kokoligu was done based on field assessment, measurement and observation. Detail description on the technical state of structures at the various schemes is provided below. Questionnaires were also administered to 231 farmers to obtain their views on the state of structures at the respective schemes. Figure 4.1 indicates the responses of farmers on the state of structures in the selected schemes.

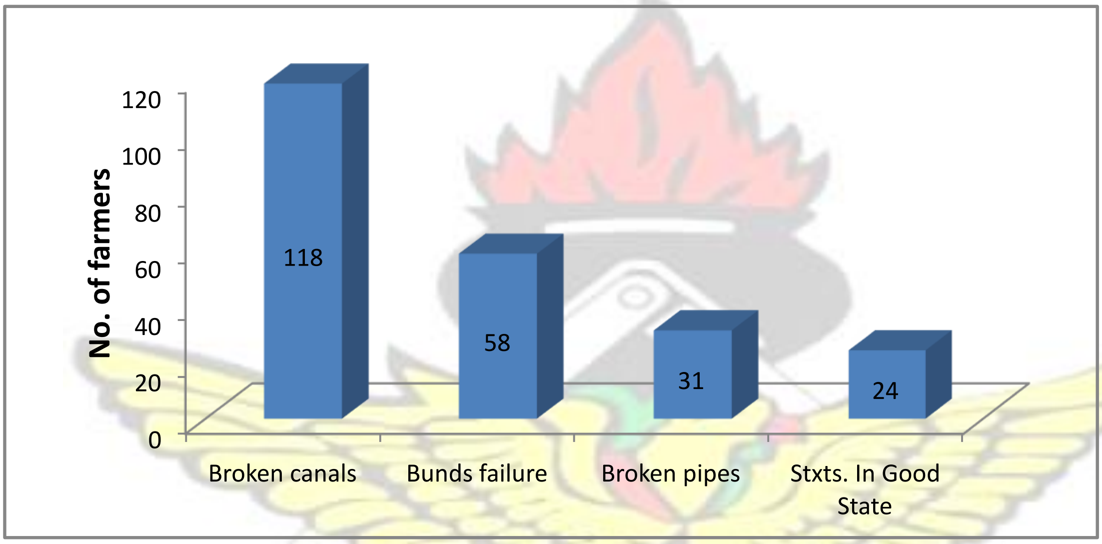

Figure 4.1: State of irrigation structures

Source: Field Survey, 2015.

- At Siru, the ongoing irrigation practiced is basically private led by farmers. The system has no major infrastructure in place aside a V-notch as shown in figure 4.2. Thus conveyance of water is done along the river course within irrigable area using pumps of varying capacities which have been acquired by farmers. The farmers who are not able to purchase pumping machines resort to the digging of shallow wells near their plots for water to irrigate and others also flood their fields with water from the reservoir through the notch.

Farmers construct bunds and gullies of various sizes for efficient water use and control. Bunds average length ranges between 0.5 m and 0.4 m. The lack of technical expertise or advice in constructing bunds normally leads to failure of most of these bunds due to the continuous flooding of fields and sometimes due to rain. Therefore, there is an urgent need to provide a facelift at Siru by constructing conveyance system, which will reduce wastage of water and also increase yield with good water management structures and provision of farmers' technical extension services.

Figure 4.2: State of bunds and v-notch at Siru

- The Sankana irrigation scheme has a gravity system of irrigation. The conveyance canals are two, being the right and left bank canals of which both are in bad state making it difficult for farmers to get enough water to irrigate crops. From field assessment and observation, both canals are trapezoidal in shape and lined. The extent of deterioration of the canals and laterals as shown in figure 4.3 will require complete reconstruction with proper water management structures like check gates, turn outs, division boxes, and canal crossings.

The right and left bank canals are 1.03 km and 1.17 km respectively. The bottom width of the right bank canal is 0.3 m and the top width is 1.9 m. The depth of the canal is 0.9 m. The left bank canal measures 0.2 m, 0.5 m and 0.3 m accordingly. A section of the left bank canal consists of 2Nr. 300 mm diameter Asbestos pipe aqueducts in parallel across an 18 m spillway channel. There are 26 laterals constructed under UWADEP of which 9 are on the right bank canal and 17 on the left bank canal (GIDA-UWR, 2014). The total length of the laterals is estimated to be about 3.9 km. They are lined with slabs and trapezoidal in shape. The average length of the laterals is about 150 m, with spacing of 75-100 m. The right bank laterals irrigate 40 % (24 ha) of the developed area and left bank 60 % (36 ha). The drainage system consists of the main Bulipielaa and tertiary drains. The main drain is 1.1km long. The tertiary drains are from plot to plot and discharge into the main drain from the last plot. There are no secondary drains on the scheme. The dilapidated state of canals in this scheme make it difficult or if not impossible to deliver the right amount of water to the fields. Siltation and non control gates results in a lot of water seepage from both canals.

Figure 4.3: State of left and right bank canals at Sankana

- At Karni, the scheme consists of one (1) main canal and seven (7) laterals. The main canal is in a very deplorable state as presented in figure 4.4. The laterals are fairly good but due to the bad nature of the main canal, farmers find it difficult to get enough water to irrigate their crops as a result of water seepage into the bare ground.

Moreover, farmers upstream breached through the main canal to tap water into their fields. Hence, instead of water flowing through the already dilapidated canal downstream, it flows into farmer wells upstream leading to inadequate water supply downstream. The main canal is about 845 m (0.845 km) long, with a section (300 m) completely silted with sand. The bottom width is 0.3m and top width of

0.6m. The depth of the canal is 0.5 m. The average length of each lateral is about 343m and with spacing of 70-100 m. The bottom and top width is 0.3 m and 0.4 m respectively. Lateral depth is 0.3 m. There are no gates to control water into the fields. Farmers in this scheme rely greatly on groundwater/shallow wells for irrigation. Management of this scheme is done basically by farmers themselves.

Figure 4.4: State of main canal and lateral at Karni

- At Kokoligu, the scheme is made of pipes which serve as canals and discharges water into chambers for farmers to fetch and irrigate their crops as shown in figure 4.5. The scheme was originally fenced but due to in- vigilance on the site of community members, the fence has been stolen. This has provided a lean way for animals to graze in the fields. These animals trampled on the pipes causing them to break and this leads to water wastage and seepage. Hence, farmers in the community fence their fields with mud and dig shallow wells to irrigate.

Figure 4.5: State of pipes and chambers at Kokoligu

4.2 Land suitability of cropping area

Land suitability examination of two schemes (Siru and Sankana) was performed and various soil chemical and physical properties analyzed to determine the suitability of the cropping area. The procedure for the analysis of these parameters is provided in the methodology. Table 4.3 and 4.4 shows the results on the soil pH and mineral content at Siru and Sankana.

Table 4.3: Soil pH at Siru and Sankana

Siru	Sankana	Soil Research Institute interpretations	
5.86	5.71	< 5	Very Acidic
		5.1-5.5	Acidic
		5.6- 6.0	Moderately Acidic
		6.1- 6.5	Slightly Acidic
		6.6-7.0	Neutral

Source: Field Work, 2015.

Table 4.4: Soil chemical properties (Mineral content) at Siru and Sankana

Nutrient	Unit	Dam at Siru	Dam at Sankana	Soil Research Institute recommended levels		
				Low	Moderate	High
P Bray-1	Mg/kg	6.452	5.687	< 10	10-20	>20
K	Mg/kg	64.95	78.59	<50	50-100	>100
Ca	Mg/kg	1.94	2.57	<5	5-10	>10

ECEC	(cmol/kg)	3.13	4.12	<10	10-20	>20
OM	%	1.345	2.155	<1.5	1.6-3.0	>3.0
N	%	0.056	0.099	<0.1	0.1-0.2	>0.2
Exchangeable K	(cmol /kg)	0.57	0.78	<0.2	0.2-0.4	>0.4
Particle Size %						
• sand	82.72		64.84			
• Silt	2.96		6.96			
• Clay	14.32		28.2			
• Texture	Sandyloam		Sandyclay loam			

Source: Field Work, 2015.

4.2.1 Soil reaction (pH)

The top soil (0 – 20 cm) pH from Siru and Sankana dam sites is moderately acidic (5.6 – 6.0). Maintaining soil pH between 5.5 and 7.0 will enhance the availability of nutrients such as nitrogen (N) and phosphorus (P) as well as microbial breakdown of crop residue as stated by the Savannah Agricultural Research Institute (SARI), WaStation.

4.2.2 Organic matter and nitrogen status (OM and N)

Topsoil organic matter and nitrogen status of the various dam sites are low OM (<1.5 %) for Siru and moderate OM (1.6 - 3.0 %) for Sankana. Nitrogen however for both site is low (<0.1 %) on the whole, the organic matter status of all the sites can be improved. Soil nutrient depletion is a principal concern. Moreover, most of the cultivated soils are inherently low in natural fertility and even the relatively better soils are increasingly being depleted through many years of continuous cropping without adequate nutrient additions. It is worthy of note that soil organic matter is critical in both nutrient and water retention. It is also a nutrient reservoir holding and releasing nutrients during mineralization. Organic material is not easily available in the savanna environment due to bush burning, the use of crop residue as fuel and animal feed and free roaming animals feeding on crop residue.

4.2.3 Available phosphorus (P)

The soils in Siru and Sankana have low phosphorus content (<10 mg/kg). According to SARI-Wa Station, the availability of P is low in most Ghanaian soils with a high Pfixation capacity and the problem becomes more serious when the organic matter status of the soil are low. P deficiency reduces the efficiency of biological nitrogen fixation .

4.2.4 Exchangeable potassium (K)

Exchangeable K levels for the sites are moderate (50–100 mg/kg). Potassium is released into the soil solution as plants deplete the soluble potassium, allowing for a regular supply. Potassium is associated with the movement of water, nutrients and carbohydrates in plant tissue. If K is deficient, or not supplied in adequate amounts, growth is stunted and yields are reduced. Most northern soils are high in potassium including the UWR as a result of the continuous burning of farmlands which increases the potash levels in the fields (SARI, Wa-Station).

4.2.5 Effective cation exchange capacity (ECEC)

ECEC, the exchangeable cations (Ca, Mg, K, Na) contents for Siru and Sankana are low (<10 cmol (+)/kg). It is a measure of soil's ability to hold positively charged ions. Moreover, it is a very important soil property influencing soil structure ability, nutrients availability, soil pH and soil's reaction to fertilizers. In general, ECEC is an indicator of the fertility. Low ECEC implies low fertility and vice versa. The availability of these bases depends largely on a higher organic matter.

4.2.6 Soil physical properties

The texture for soils from Siru dam site is Sandyloam and that of Sankana is Sandyclayloam. They both have significant clay percentages of 14.32 % and 28.2 %

respectively. The high clay contents compared to most soils from the region suggest a higher ability to hold plant available nutrients for plant growth. Water holding capacity will be high and less susceptible to erosion.

4.2.7 Soil analysis conclusion and recommendations

In general, the two sites sampled had low chemical properties than reported values for productive soils. Thus soil fertility is generally low. The levels of organic matter, total nitrogen and available phosphorus are generally low. The low organic carbon and total N contents may be attributed to the low biomass production and a high rate of decomposition. Potassium is mostly abundant in the soils of northern Ghana, including UWR.

Though the nutrients levels are low, the high clay contents compared to most soils from the region suggest a higher ability to hold plant available nutrients for plant growth. Water holding capacity will be high and less susceptible to erosion. An increasingly erratic rainfall pattern is without doubt the most limiting factor to crop production in the UWR. Thus measures to mitigate water deficit created by the low rainfall are indispensable.

4.3 Questionnaire analysis

4.3.1 Age distribution of respondents

The age distributions of respondents in the four irrigation schemes are presented in table 4.5. The statistics shows that, 45.5 % of the respondent had their age between 31-40 years which is the highest. The age group between 41- 50 years represent 25.5 % of the respondents which is the second highest follow by the next group of between 20 – 30 years which represent 21.6 % of the respondents with 7.4 % of the respondent having their age between 51-60 years which is the least.

Table 4.5: Age distribution of the respondents in the communities

Age group	Frequency	Percent	Valid Percent	Cumulative Percent
20-30	50	21.6	21.6	21.6
31-40	105	45.5	45.5	67.1
41-50	59	25.5	25.5	92.6
51-60	17	7.4	7.4	100.0
Total	231	100.0	100.0	100.0

Source: Field Survey, 2015.

4.3.2 Gender distribution in relation to irrigation

Table 4.6 presents the gender distribution of respondents. From the table, 155 farmers which represent 67.1 % of respondents are male with 76 of them representing 32.9 % being female, thus few female in the area engaged in irrigation farming. Women play a vital role in the production, processing, value addition and preparing food for their families. However, they are the most deprived section of the economy in almost everywhere in the rural areas especially in the case of female land rights. It was observed on the field that women produced the same crops, acreage and quantity as the men. This suggests that if women are given the technical training on irrigation management, roles and responsibilities of WUAs and water regulations there are greater chances of increasing productivity as well as improving upon household food security and nutrition.

Table 4.6: Gender distribution in relation to irrigation

Gender	Frequency	Percent	Valid Percent	Cumulative Percent
Male	155	67.1	67.1	67.1
Female	76	32.9	32.9	100.0
Total	231	100.0	100.0	100.0

Source: Field Survey, 2015.

4.4 Land acquisition and crops grown

4.4.1 Land ownership

Land ownership has positive and significant impact on productivity as it affects the size of land that can be cultivated by a farmer. Land is an important factor of production, it serves as collateral to get loans and provide security against natural hazards in rural settings. From the questionnaire administered, it was revealed that 83 farmers representing 35.9 % of the respondents owned their irrigation lands through inheritance with 148 of them representing 64.1 % respondents having their lands through leasehold, sharecropping or rent. The results in table 4.7 show that the majority of farmers in the selected schemes owned their land for irrigation. The advantage farmers who owned their plot of land have is that, they are assured of continuous cropping and sustained level of production as compared to those who had their lands through leasehold, sharecropping or rent which involve arrangements between the landlords and the operators, such that a fixed percentage of produce is given to the land owner as a charge for using that land.

Table 4.7: Systems of land ownership

Land ownership type	Number of farmers	Percentage (%)
Inheritance	83	35.9
Leasehold	80	34.6
Sharecropping	61	26.4
Rent	7	3.03

Source: Field Survey, 2015.

4.4.2 Size of irrigation fields

The size of irrigation fields under cultivation was found to be relatively small per farmer as presented in figure 4.6. Although there are vast lands at the various dam sites, factors such inadequate access to water, labor availability, inputs, extension services etc led to the under utilization of irrigable lands. In general, farmers complain of these factors as a hindrance to their output.

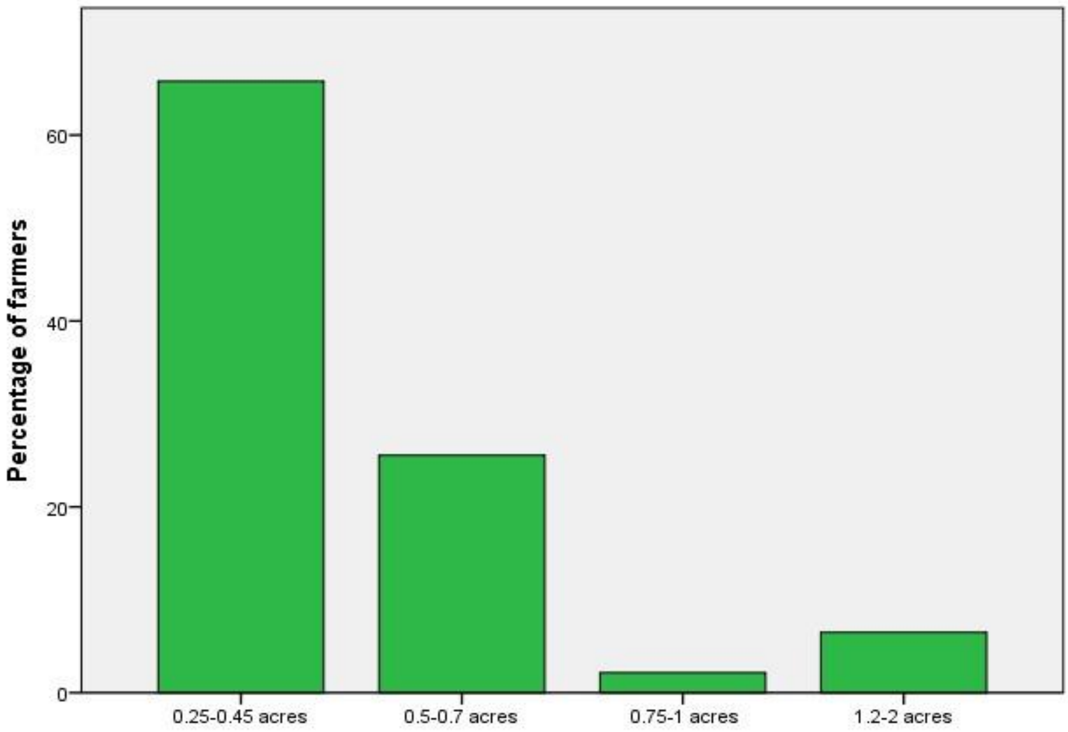

Figure 4.6: Size of irrigation fields

Source: Field Survey, 2015.

4.4.3 Inputs (fertilizer)

Although majority of farmers in the study area use both organic and inorganic fertilizer, the amounts applied are generally low especially inorganic fertilizer. Figure 4.7 shows the fertilizer application quantities by farmers. In general, farmers buy fertilizer from market in bowls and do not apply at the right time. In order to ensure productivity, key inputs such as seeds, fertilizers, insecticides and herbicides needs to be applied in the right quantity and time. Unfortunately, most farmers in the study area apply these inputs as and when are able to afford them and this also affect crop performance. According to Ofosu (2011), low use of fertilizer is one the major hindrance to agricultural productivity.

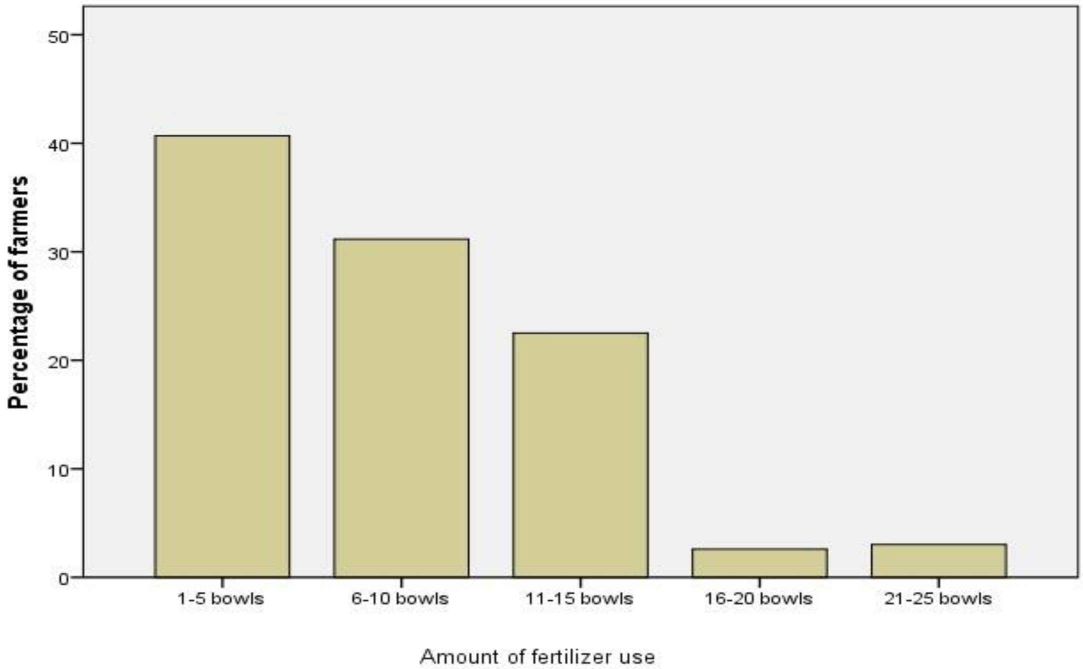

Figure 4.7: Use of inorganic fertilizer

Source: Field Survey, 2015.

4.4.4 Seeds source

Seed for cultivation is mostly produced by farmers themselves. About 86.6 % of the respondents indicated that seeds for vegetable production are usually produced by them. 10.4 % of the respondents purchase seed from the market. 1.7 % of the respondents get their seeds from MOFA in the region with 1.3 % of the respondents obtaining seeds from friends. Therefore it is necessary to encourage farmers to get their seeds from reliable sources such MOFA and other certified seed dealers in the region.

4.4.5 Crops grown using small-scale irrigation

In the raining season, both irrigation and non irrigation farmers produced major crops such as maize, rice, guinea corn, millet, cowpea, groundnuts, sorghum and yam. Majority of the farmers in the study area will either grow one or multiple of the crops during the rainy season. In addition to rain-fed production, irrigation farmers produce vegetable crops in the dry season as shown in figure 4.8 using various sources of water. They include tomato, pepper, onion, garden eggs and leafy vegetables. Access to irrigation has been regarded as a powerful tool that provides a greater opportunity for multiple cropping, higher cropping intensity and crop diversification. Farmers who have access to small scale irrigation can cultivate twice a year. Thus irrigation increases the intensity of cropping. The cultivation of vegetable crops using small scale irrigation is mostly for household consumption and not purposely for sale.

Agricultural production resources in the study area include land, labour force, motorized diesel pumps, agricultural extension personnel, water resources and local markets. The presence of these production resources has several benefits including increase wealth of farmers; improve food security and nutritional value of diet. Hence farmers need to be encouraged to produce more for both household consumption and
sale.

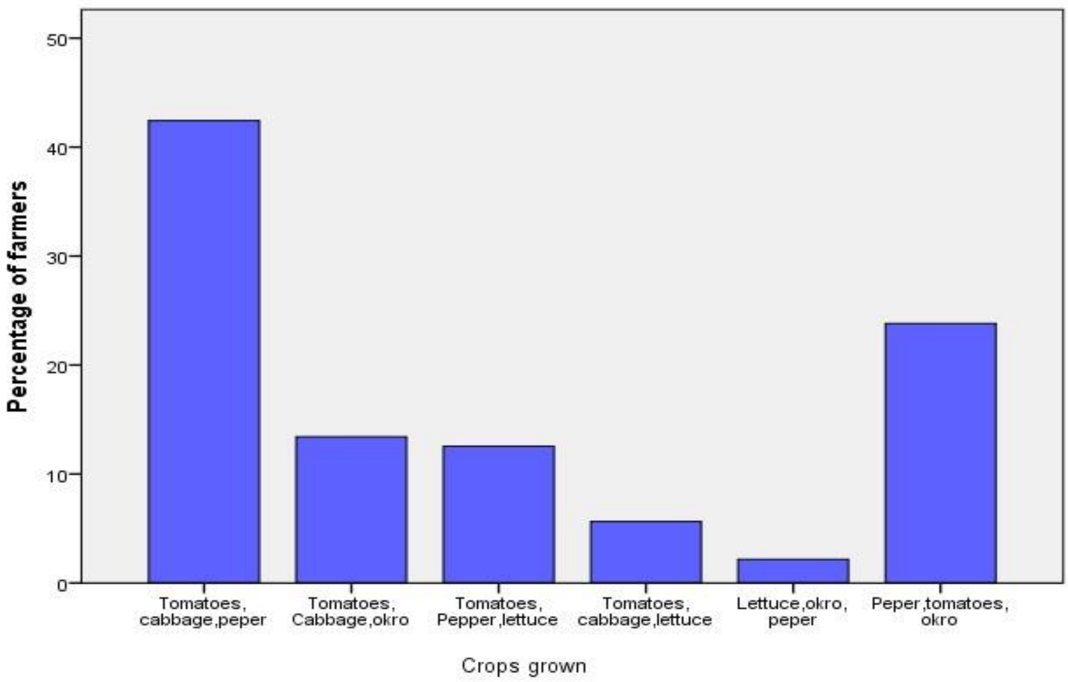

Figure 4.8: Crops grown by farmers

Source: Field Survey, 2015

4.4.6 Yield from irrigation fields

Yield estimate was done using tomato crop in the various field sizes to get an overview of how much a farmer makes only from the tomato crop. Although a number of farmers could not estimate their own yield, information gathered from field indicate an improvement in yield. This then means that with the sale of other vegetable crops after meeting household demand, farmers could be making gains from their fields. Figure 4.9 indicates the estimated yield of tomato in basins from different farm sizes.

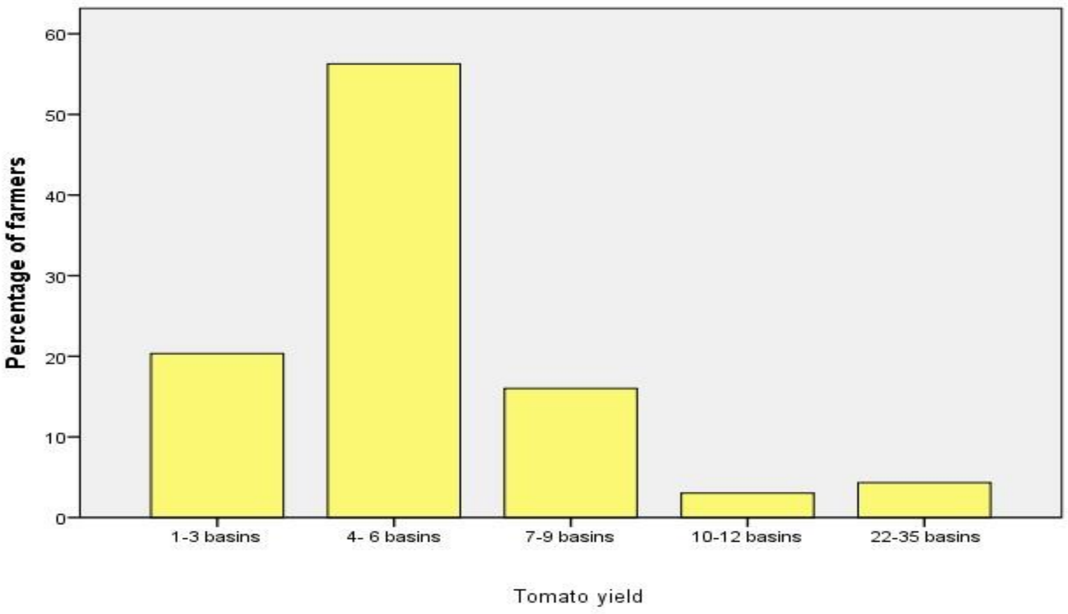

Figure 4.9: Indicate tomato yield of farmers

Source: Field Survey, 2015.

4.4.7 Cost of production

Cost is one of the major factors that affect production and to some extent determines how much land a farmer can cultivate. Cultivating large acres of land implies higher cost as compared to smaller acres. From the interview conducted, it was observed that, cost incurred by farmers were basically from hiring of labour to plough, buying of inputs (fertilizer/insecticides) or buying fuel for those using pumps. Moreover, majority of farmers cultivate smaller land with the support of some family members and do not hire labour. Hence, major cost incurred comes from the purchase of fertilizer and insecticides. The figure 4.10 shows the cost incurred by farmers on their fields.

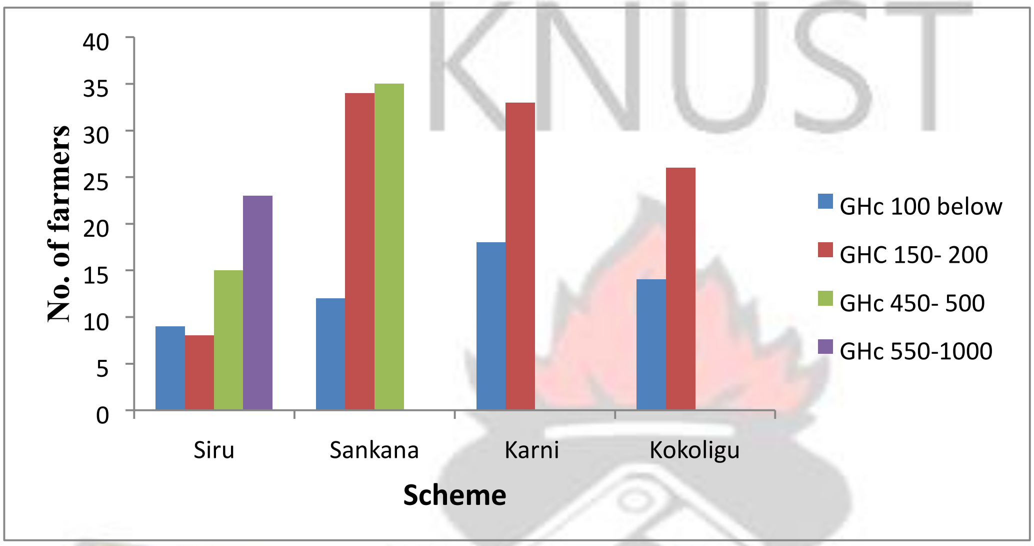

Figure 4.10: Cost of production

Source: Field Survey, 2015.

4.4.8 Profit margins from production

Considering the cost farmers incurred on their fields and how much money they get from selling their produce (tomato) after meeting household consumption, one can conclude that dry season garden is profitable. Figure 4.11 present the estimated yield of farmers in their fields. Although some farmers found it difficult to tell how much they are able to get from selling their produce, a good number could tell. This presupposes that with irrigation, farmers are able to improve their income. Most of them alluded to the fact they are now able to save reasonable amounts towards the next farming season and also being able to solve minor problems at household level.

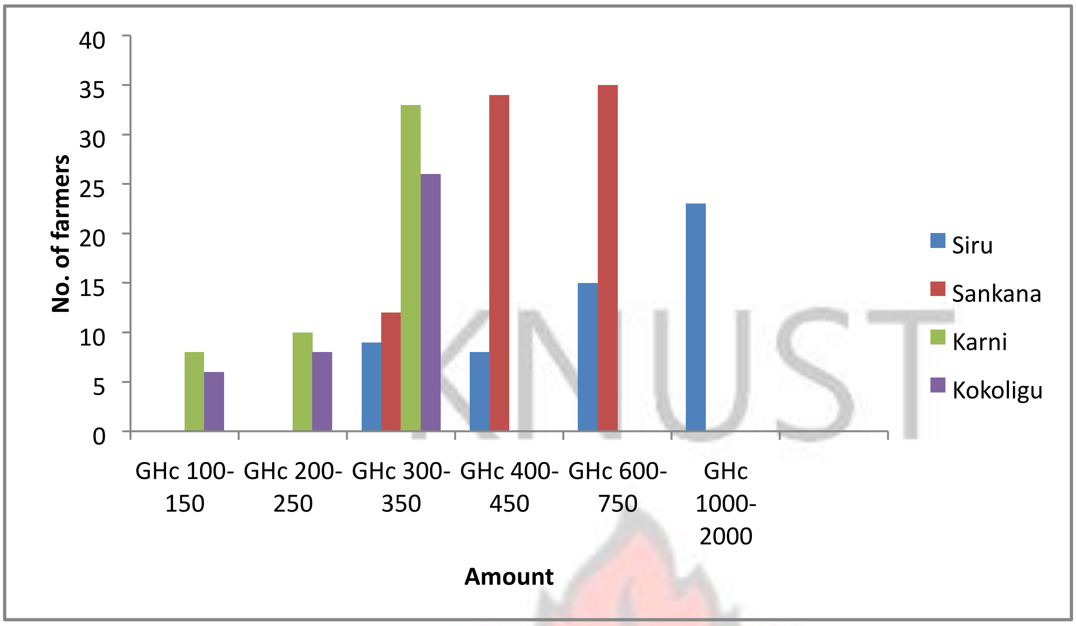

Figure 4.11: Profit margins from tomato production

Source: Field Survey, 2015.

4.5 Irrigation

4.5.1 Source of water for irrigation in the selected schemes

The main source of irrigation water for farmers is groundwater or shallow well which represents 51.1 %. River or stream source represents 25.1 % of the respondents. Those who depend on the scheme structures for irrigation represent 10.4 % of the respondents. It was also found out that 13.4 % of the farmers use a combination of two sources for irrigation. The reason that accounts for the high usage of groundwater is because, irrigation structures such as canals and laterals are in a deplorable state and cannot supply the desired amounts of water as in the case of Sankana Karni and Kokoligu. At Siru, greater number of farmers uses pumps to draw water along the river course to irrigate since there are no canals and laterals in place as shown in figure 4.12.

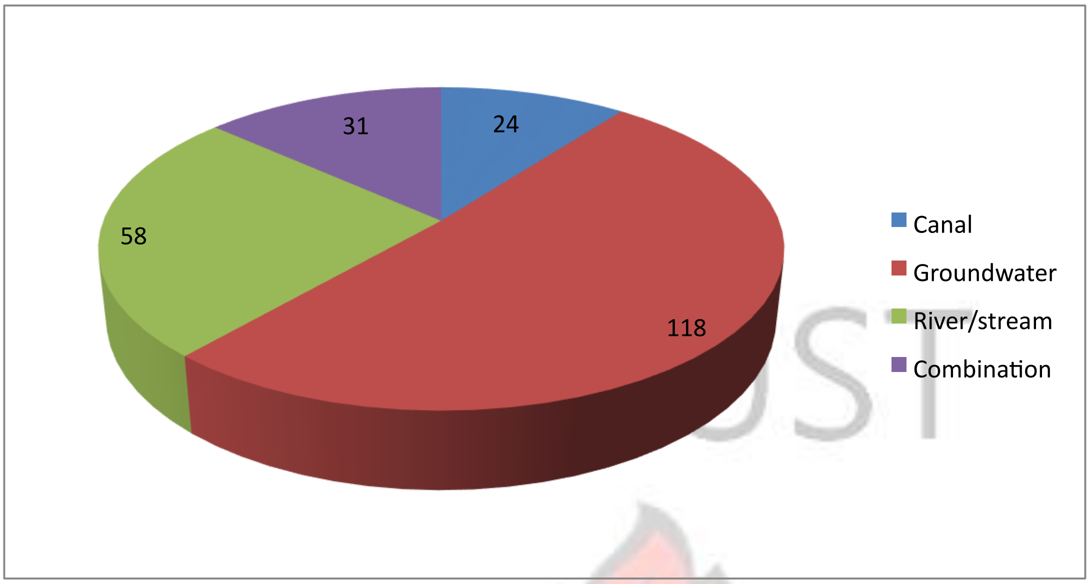

Figure 4.12: Source of water for irrigation

Source: Field Survey, 2015

4.5.2 Stored water availability for irrigation

From field survey, farmers complain of not getting enough water to irrigate their crops due to the bad state of structures. Moreover, the majority of farmers depend on groundwater or shallow wells to irrigate of which they claim it dries up in few months (January towards March ending) making it difficult to get water. Farmers who rely on the river or reservoir for irrigation do not see water as a challenge but rather the appropriate technology to harness the water aside those who use pumps to irrigate.

Figure 4.13 presents farmers response to stored water availability for irrigation.

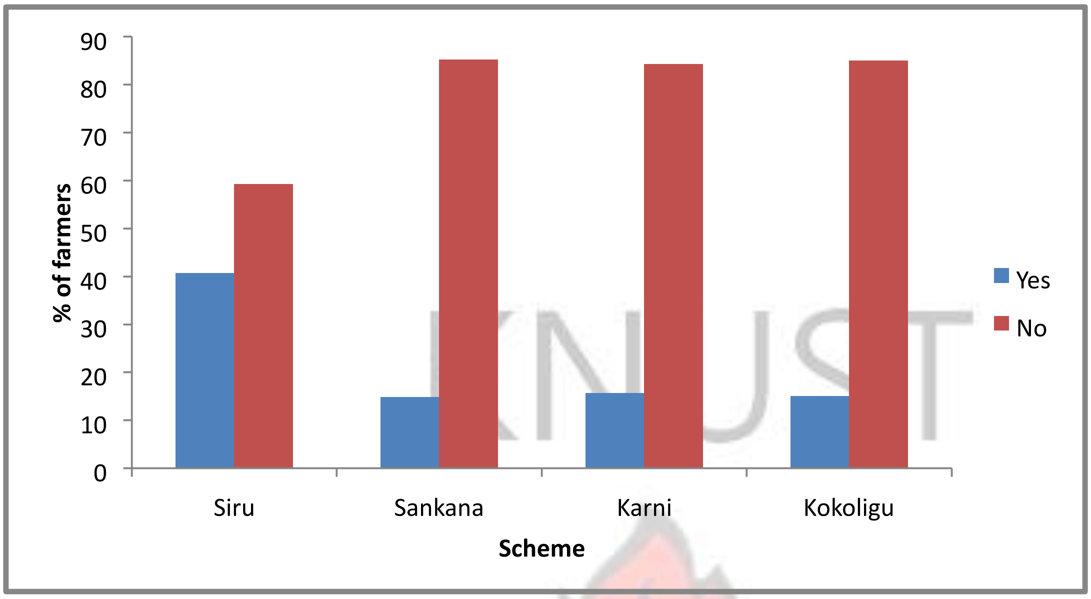

Figure 4.13: Stored water availability at the schemes

Source: Field Survey, 2015.

4.5.3 Methods of water application

From figure 4.14, it can be deduced that 84 % of the respondents use bucket and calabash to irrigate their crops. Those who use watering can to irrigate represent 7 % of the farmers with 9 % of the farmers using simple motorized diesel pumps for water application. Thus irrigation scheduling is compromised, as farmers can either over or under apply water to crops based on their own imagination and this affects crop yield. Moreover, farmers using bucket and watering can spend greater portion of their time to irrigate crops instead of attending to other pressing activities on the field.

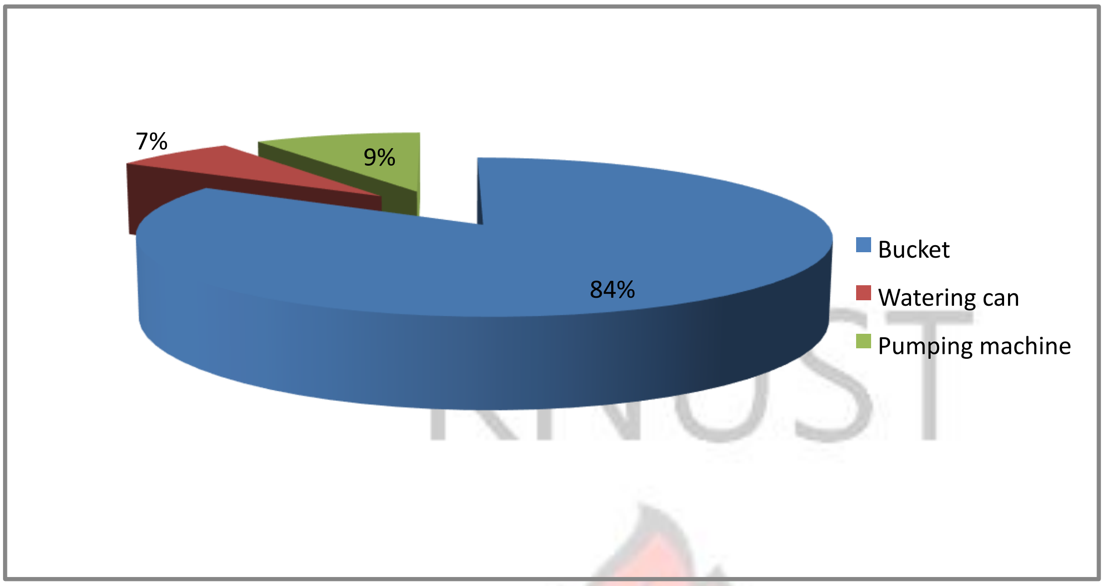

Figure 4.14: Water application method

Source: Field Survey, 2015.

4.6 Challenges and potentials identified

4.6.1 Challenges identified

Farmers in the selected schemes identify the following poor water structures, labour, inputs, extension services, energy (fuel) and market as the key constraints to their production.

4.6.1.1 Water

Access to reliable source of water is vital to irrigation farming. In ensuring that farmers get adequate water for their production, it is important to put the right structures in place for water capturing and delivering to fields. From the field survey, it was realized that structures such as canals and laterals were in a very bad state making it almost impossible to send the right volumes of water to the fields.

Moreover, there are no gates or proper drains for controlling, regulating and draining off water in all the schemes. This situation has compelled the majority of farmers to resort to groundwater or shallow wells for irrigation which requires a lot of labour.

4.6.1.2 Availability of labour

Labour is one of the major ingredients that affect production greatly in the study area. In most instances on these small farms, the farmers and their families provide the labour force for irrigation farming and no direct cash payment is made for outside help. In this case, the cost of labour may not be included in the operating cost calculations. However, in some cases the farmer and some members of family may be engaged elsewhere and have to hire labour for ploughing. In this case, the cost of the labour will need to be included. This can be a significant cost and may have an influence on the values and choice of system, particularly as some systems are more labour intensive than others. A particular case is where farmers spend a chunk of their time to irrigate their fields using water from wells. Lifting water from wells to irrigate once or twice daily can be labour intensive. Farmers can save a lot of time and energy for other activities on their fields if irrigation structures are functioning properly and this can help improve productivity.

4.6.1.3 Inputs and credit

The cost of inputs such as fertilizer, seeds, insecticides, herbicides and equipment especially pumping machines comes with a lot of cost. Most of the farmers do not have collateral to safeguard loans from the banks and this makes it difficult for farmers to secure loans for their production activities.

4.6.1.4 Marketing

Crops are sold either directly by farmers to consumers in the local markets or through middlemen. Market information is not readily available to farmers; hence farmers who transport their produce to distant towns may find the market flooded with the produce. Middlemen and women take advantage of the situation and lieu farmers into selling their produce in a much cheaper price. They buy the commodities at low prices and sell them at much higher prices. Clearly, farmers need some protection, may be in the form of better market information.

4.6.1.5 Extension service

Farmers complain of crops failure as a result of diseases. This has not only affected farmers yield but also demoralized them in cultivating certain crops. Agricultural Extension Agents (AEAs) hardly visit farmers to identify their challenges in order to provide them with appropriate solutions. Farmers therefore rely on their own 'try and error methods' to solve their challenges and this affect their output and income. Extension service is a medium by which information and technologies are delivered to farmers (Moris and Thom, 1985). According to the World Bank definition of extension service, it is the process by which farmers are aware of improved technologies and adopt them in order to improve their efficiency, income and welfare (Purcell and Anderson 1997: and Pedon, 2006). In the four selected schemes in the region, statistics reveal that most of the farmers can neither read nor write. Therefore in order to ensure that farmers get the right agricultural information, it must be done through extension agents and field facilitators of NGOs. At the moment farmers in the study area are practicing irrigation without much knowledge on agronomy, proper water application techniques and crop protection. A clear example is the case of Siru, where farmers construct bunds and gullies for efficient water use and control, but due to lack of proper technical advice they are failing as a result of the continuous flooding of fields from the notch. In all the four selected schemes, vegetable farmers were not using the right amount and method of fertilizer application, they apply as and when there is money to buy fertilizer.

4.6.1.6 Energy and pumps breakdown

Farmers acquire these pumps based on their ability to afford instead of technical knowledge on how to use and maintain them properly since they do not normally come with spare parts. The cost of fuel is also becoming increasingly high and this increases the cost of production for farmers. Moreover, spare parts for these pumps are normally difficult to acquire as stated by Namara *et al.* (2011).

4.6.2 Potentials identified

According to the 2015 GIDA-UWR field assessment report, the region has abundant water and land resources. The limiting factor in harnessing these resources is access to appropriate technology, poor irrigation structures and inadequate support services from institutions. The potentials identified in these schemes include:

4.6.2.1 District Assemblies (DAs)

All the four schemes are under the jurisdiction of a particular district. The first point of call as far as development is concern in the districts is the DA. Moreover, the 1992 Constitution of the Republic of Ghana, in Article 240, tasks the local government authorities (Metropolitan, Municipal, and District Assemblies- MMDAs) to plan, initiate, co-ordinate, manage and execute policies in respect of all matters affecting the people within their areas. In view of that mandate, the Local Government Act, 1993 Act 462 defines some functions for the MMDAs such as to:

- Formulate and execute plans, programmes and strategies for the effective mobilization of the resources necessary for the overall development of the district.
- Promote and support productive activity and social development in the district and remove any obstacles to initiative and development.

- Initiate programmes for the development of basic infrastructure and provide municipal works and services in the district.

4.6.2.2 District Agricultural Development Units (DADUs)

Another potential that was found to be present in all the selected schemes is the DADUs. Their objectives are to:

- Manage and co-ordinate the District Department of Food and Agriculture within the District Assembly.
- Ensure the development and effective implementation of the district agricultural programmes.

Their responsibilities include:

- Oversee the preparation of the District Agricultural Development Plan and its incorporation into overall District Assembly Plan.
- Prepare District Annual Agricultural Work Programs and Budget for submission to the District Assembly.
- Ensure that scheduled training programmes are implemented and technical backstopping provided.
- Facilitate liaison between Department of Food and Agriculture and stakeholders on programmes related to the development of agriculture in the District.
- Ensure effective monitoring and evaluation of agricultural programmes in the districts.
- Establish relevant demonstrations, field days, and farmer fora in the districts.
- Advise the District Assembly on matters related to agriculture in the district and
- Ensure food safety in the District.

4.6.2.3 Opinion leaders

Opinion leaders such as the Traditional Chiefs, District Assemblymen and women also owe their people the duty to lobby and push for development in their respective zones. In Ghana, a mixture of customary law and modern law coexists creating a mixed governance system (legal pluralism) which affects water resources management. Traditional institutions are recognized in Ghana's constitution and are represented by the House of Chiefs at the National and Regional levels. Even though they are not represented at the district level, they play major roles in decision making at their traditional level. According to the customs of the people in the Upper West Region, chiefs are responsible for the rivers and streams that flow through their traditional areas. Traditional authorities are major stakeholders in water resources management. In the Upper West Region the *tendanas* or earth priests are responsible for the earth shrine and for the distribution of agricultural land. They play major roles in allocating land for irrigation development in the region. The *tendanas* are the spiritual heads of the region. Assemblymen and women represent their area councils in General Assembly meetings in the district. In such meetings, matters concerning the development of each area council are discussed and new projects and programmes identified. Assembly men and women can used this opportunity to lobby for projects in their area or better still question the authorities for non development in their

localities.

4.6.2.4 Financial institutions and NGOs

In 1976, the Ghanaian government, through the Bank of Ghana, established Rural Banks to channel credit to productive rural ventures and promote rural development. This strategy was intended to improve the economic and social life of the rural poor. It is expected that, in the long term, credit will enable the poor to invest in agricultural and non-agricultural productive assets, as well as adopt new technologies and farming methods among others. Therefore, it is envisaged that financial institutions operating in these districts will assist rural farmers with loans to enable them finance their agriculture activities. At Sankana and Karni farmers attested to fact that they have gotten some support from MOFA, Plan Ghana and Catholic Relief Service in a form credit, inputs and technology some years ago. Although for some time now they have not received such aids, the presence of these NGOs in the districts implies that farmers still stand the chance of benefiting from these benevolent organizations. From the field survey in the four different schemes, it was clear that water management techniques vary from one farmer to the other. Assessment of market in the study area shows a good potential if exploited efficiently, it would contribute significantly towards improving farmer income and also help them strategize well on the type of crops to produce and this can help improve the country's food insecurity problems, especially if emphasis is place on bringing market information to the door steps of farmers.

CHAPTER 5:

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

There is no doubt that the Upper West Region is well endowed with agricultural potential that if tapped properly can help improve food security and reduce poverty in the region and the country as a whole. The area has a number of lowland and inland valley areas which are potentially reliable for rice production and also suitable for the production of vegetables. There are equally many factors that affect the performance of irrigation schemes in the region. These include poor irrigation structures, soil infertility, lack of access to credit, mechanized labour, poor extension services, lack of markets and high cost of inputs. The Upper West Region is in the savannah ecological zone and is prone to prolong drought. Access to irrigation increases the opportunity for crop intensity and diversification, which has the potential of increasing farmer income. Irrigation is becoming a practice to increase total annual income for many household in the study area. In addition to their normal rain-fed cultivation, farmers cultivate vegetable crops during the dry season using small-scale irrigation. The main irrigated vegetables are tomato, pepper, onion, garden eggs and leafy vegetables. With the introduction of cereal crops such as rice and maize, using irrigation, farmers stand the chance of stabilizing production and making more profit.

The use of small diesel pump for water delivery and application during the dry season vegetable production is far better than the use of watering can, bucket and calabash form of water application which is labour intensive. Farmers who use pumps to irrigate reduce the time and energy used in irrigation as compared to those lifting from shallow wells.

The four reservoirs namely Siru, Sankana Karni and Kokoligu of which studies were conducted in the study area are capable of storing enough water for irrigation farming in the dry season.

5.2 Recommendations

Based on the study, the following recommendations may contribute to improving small scale irrigation development in Upper West Region. The quest to search for measures and solutions to alleviate poverty and food insecurity in the region has been on the fore for many years which requires various interventions. In doing that, it is important to give attention to the different social class of the rural community in the region which consists of groups of poor people with unequal level of assets and endowment. With this at the fore, the following possible solutions are recommended for the improvement of present and future small-scale irrigation in the region.

They include;

- Government through district assemblies should rehabilitate and prioritize capacity utilization of existing irrigation systems before starting new developments in order to learn from the weakness and plan for new ones in the region.
- Farmers must be encouraged to use more organic manure as compared to chemical fertilizer in order to improve their soil fertility.
- GIDA-UWR needs to outsource financial assistance from other development agencies through proposals in order to address major structural defects in irrigation schemes.

- There is the need to form vibrant Water Users Association and farmer groups to enable them plan and take decision that will improve schemes performance such as fee fixing for irrigation water use.
- MOFA through Agricultural Extension Agents (AEAs) need to organize regular in-service training for farmers in order to keep them abreast with new skills, technologies and especially on the use of inputs.
- Farmers need to focus and diversify from current crop production to other highly profitable cereal crops considering the high cost of irrigation development.
- Government and other developmental agencies should facilitate groundwater or shallow wells development in order to further improve access to irrigation water at existing schemes.
- A Regional Maintenance Unit should be created and attached to GIDA to do regular monitoring and prompt repairs of facilities instead of allowing the WUAs to contract their own masons to do repairs. This would ensure quality of work and prolong the lifespan of facilities.
- Irrigation projects should be identified from the District Medium Term Development Plans since all area councils in the district submit their developmental proposals for consideration.
- The District Assemblies should put in place programs that link irrigation farmers to institutions such as junior and senior high schools so that perishable crops such tomato can easily be sold.

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APPENDICES

APPENDIX A: SAMPLE OF QUESTIONNAIRE

Profile of respondents

1. Name of farmer …………………………………………………
2. Gender ☐ Male ☐ Female

3. Age (i) 20 – 30 ☐ (ii) 31 – 40 ☐ (iii) 41 – 50 ☐ (iv) 51 – 60 ☐

4. Name of Community ………………………………………………

5. Educational status ☐ (i) No education/Primary ☐ (ii) Middle school/J.H.S. ☐

(iii)S.H.S. /O level ☐ (iv) Tertiary ☐ (v) Others (state)…………………

Small scale irrigation development

6. Do you know the organization or people who developed the scheme? Yes ☐ No ☐

7. If yes, who? (a) Government ☐ (GIDA) ☐ NGO ☐ Private entity ☐ Community

Others………………………

8. When or how many year now? ………………

9. Were the community involved in the development process? Yes ☐ No ☐

10. if yes, what role did the community play in the development process (state few)
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
………………………………………

11. Who owns the irrigation infrastructure? Government ☐ NGO ☐ Community

Others………………………

12. Are the irrigation structures functioning properly? Yes ☐ No ☐

13. If no why? …………………………………………………………

14. Does the community play any role in maintaining these structures? Yes ☐ No ☐

15. If yes, explain..

16. If no, why…………………………………………………………………….
17. Have the structures undergone any rehabilitation? Yes ☐ No ☐

18. If yes, when or how many years now…………………….

Source of water
19. What is the source of water for your irrigation (a) Stream ☐ (b) River ☐

(c) Reservoir ☐ (d) Hand dug well ☐ (e) others……………..

20. How do you apply water to your crops (a) Bucket ☐ (b) Watering can ☐

(c) Pumping machine ☐ (d) Diversion of water to the ☐ field

21. Do you get enough water for irrigation? Yes ☐ No ☐

22. If no, why………………………………………………………………………

23. Do you pay for abstracting or using the water? Yes ☐ No ☐

24. If yes, how much in the entire irrigation period……………………..

25. If no, why……………………………………………………………

Challenges in small scale irrigation
26. Do you face any challenges in irrigating your crops? Yes ☐ No ☐

27. Which of these challenges affect your production?

a. Water ☐ b) Labour ☐ (c) Energy ☐ (d) Inputs ☐ (e) Extension Service ☐ (e) Market ☐

Identification of potentials in small scale irrigation schemes
28. Which of these potentials exist in your community with regards to the scheme?

a. Water ☐ b) Land ☐ (c) Technology ☐ (d) Government/NGO support

(e) Banks ☐

Land acquisition
29. Do you own the plot of land for your irrigation farming? Yes ☐ No ☐

30. If no, what is your plot ownership agreement?

(a)Leasehold ☐ (b) Rent ☐ (c) Purchase ☐ Sharecropping

31. If yes, how did you acquire it (a) Gift ☐ (b) Purchase ☐ (c) ☐ Inheritance ☐

32. What is the size of your irrigation farm in acres, you apply water to? (State)………

33. What was the size of your farm in the previous year? (State) ………………

34. Did you encounter any problem in acquiring your plot of land? Yes ☐ No ☐

35. If yes, what were the problems? (a) High cost of land ☐ (b) Land litigation c) others (State) …………………………………..

Crop cultivation

36. Which periods of the year do you usually start land preparation for irrigation farming?

State……….............

37. Which crops do you cultivate on your irrigated farm? …………………………

(a) Tomatoes ☐ (b) Cabbage ☐ (c) Pepper ☐ (d) Okro ☐ (e) Lettuce (f) others

(State)……………………………

38. State the yield of the various crops (a) Tomatoes……….. (b) Cabbage………. (c) Pepper……...... (d) Okro………… (e) Lettuce…………

39. Do you have any problem with regards to your crop cultivation? Yes ☐ No ☐

40. If yes, indicate (a) inadequate water supply ☐ (b) High labour cost

(c) Inadequate labour ☐ (d) Problem of viable seed ☐ (e) Unsuitable weather condition ☐ (f) others……………………………

41. How do you acquire seeds? (a) Produce it myself ☐ (b) Purchased from market

(c) Supplied by MOFA ☐ (d) Supplied by friends ☐ (e) Supplied by NGO ☐

(f) Others………………………………………………………………

42. Do you belong to any vegetable growers association or group? Yes ☐ ☐ No ☐

43. Which of the following fertilizers do you apply to your plot? (a) Organic manure

(b) Inorganic fertilizer ☐ (c) None ☐

44. If organic manure how many kilograms do you apply to your crops?...........

45. How many quantities of fertilizer do you apply to your crops? ....

47. If none, why………………………………………………………………………

48. How will you rate the land suitable for the various crops you grow?

(a) Excellent (b) Good (c) Average (d) Poor

End of Questionnaire Many Thanks

APPENDIX B: TABLE OF RESULTS

B 1: Monthly rainfall and evapotranspiration values

	Min Temp	Max Temp	Tmean	Humidity	Wind speed	Sunhine	Radiation	Eto
Month	**Deg. Cel.**	**Deg. Cel.**	**Deg. Cel.**	**%**	**km/day**	**hours**	**MJ/m^2 day**	**mm**
Jan	20.4	34.8	27.6	27	138	8.8	20.2	168.95
Feb	22.4	36.8	29.6	28	134	8.6	21.3	163.24
Mar	24.5	37.2	30.9	42	127	7.9	21.4	182.9
Apr	25.1	35.7	30.4	59	128	7.6	21.2	169.5
May	23.8	33.3	28.6	68	123	8	21.4	162.44
Jun	23.1	32.1	27.6	75	112	7.5	20.3	138.9
Jul	22.2	30.1	26.2	79	109	6.2	18.5	126.17
Aug	21.8	29.3	25.6	81	9	5.3	17.4	116.25
Sept	21.6	30.4	26.0	79	74	6.3	18.9	119.4
Oct	22.1	33.3	27.7	71	84	8.3	21.1	142.6
Nov	21.7	34.8	28.3	52	88	8.8	20.4	140.1
Dec	20.0	34.1	27.0	35	110	8.7	19.6	148.8
Ave	22.4	33.5	27.9	58.0	103.0	7.7	20.1	148.3

B 2: Estimation of farmers' production cost

Scheme	Below GHC 100	GHc 150-200	GHc 450-500	GHc 550-1000
Siru	9	8	19	23
Sankana	12	19	35	0
Karni	18	33	0	0
Kokoligu	14	26	0	0

B 3: Estimation of farmers' profit margins

Income from Production/C'mty	GHc 100-150	GHc 200250	GHc 300-350	GHc 400-450	GHc 600-750	GHc 1000-2000
Siru	0	0	9	8	15	23
Sankana	0	0	12	34	35	0
Karni	8	10	33	0	0	0
Kokoligu	6	8	26	0	0	0

B 4: Estimation of farmers' tomato yield (Basins)

Scheme	0.25-0.45 ac	0.5-0.70 ac	0.75-1 ac	1.2-2 ac
Siru	5	9	15	25
Sankana	4	8	12	0
Karni	2	6	0	0
Kokoligu	3	7	0	0

B 5: Soil mineral content and interpretation

Nutrient	Unit	Low	Moderate	High
P Bray-1	Mg/kg	< 10	10-20	>20
K	Mg/kg	<50	50-100	>100
Ca	Mg/kg	<5	5-10	>10
ECEC	(cmol/kg)	<10	10-20	>20
OM	%	<1.5	1.6-3.0	>3.0
N	%	<0.1	0.1-0.2	>0.2
Exchangeable K	(cmol /kg)	<0.2	0.2-0.4	>0.4

B 6: Soil pH (Distilled water method) ranges and interpretation

Soil pH	Interpretation
<5	Very Acidic
5.1-5.5	Acidic
5.6-6.0	Modrately Acidic
6.1-6.5	Slightly Acidic
6.6-7.0	Neutral
7.1-7.5	Slightly Alkaline
7.6-8.5	Alkaline
>8.5	Very Alkaline

B 7: Soil chemical properties (Mineral content) at Siru and Sankana

Properties	Siru dam site	Sankana dam site
pH (1:1H_2O)	5.86	5.71
Organic C (%)	0.780	1.250
Organic M (%)	1.345	2.155
Total N (%)	0.056	0.099
Bray-1 available P (mg/kg)	6.452	5.687
Potassium K (mg/kg)	64.95	78.59
Exchangeable bases: (cmol/kg)		
• Ca	1.94	2.57
• Mg	0.49	0.61

• K	0.57	0.78
• Na	0.05	0.07
Exchangeable acidity (cmol/kg)	0.08	0.09
ECEC (cmol/kg)	3.13	4.12
Particle Size: (%)		
• Sand	82.72	64.84
• Silt	2.96	6.96
• Clay	14.32	28.2
• Texture	Sandy loam	Sandyclayloam

B 8: Average monthly rainfall in(mm) from 1960-2011

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1960	0	0	55.9	96.6	161.1	156.5	91	180.9	243.2	119.5	0	12.2
1961	0	0	16	142.5	152.4	195.9	66.3	91.7	141.1	3.8	8.4	0
1962	0	0	132.2	170.1	168.5	136.9	66.1	434.9	182.2	43.4	69.6	0
1963	0	87.7	0	81	110.3	157.5	321.6	278.4	318.1	181.8	6.6	0
1964	0	0	55.7	32	129.3	220	218.6	128.5	154	29.8	24.7	40.5
1965	25.7	1.3	33.1	86.4	90.4	161.7	156.7	352.2	250.7	36.5	0	0
1966	0	1.8	32.5	120.4	130.9	174.2	143.3	176.4	188.6	90.3	0	0
1967	0	0	68.3	74.3	133.9	102.7	115.3	140	213.1	53.5	14.2	4.8
1968	0	54.1	93	68.2	124.6	181	330.2	263.3	293.4	77.1	7.2	41.7
1969	0	8.1	42.5	47.8	63	165.4	257.9	241.9	205.8	159.1	14.5	0
1970	0	0	0.3	47.8	157.6	69.1	122.2	162.7	153.1	48	2.3	0
1971	0	9.1	87.4	27.4	100.3	90.7	180.8	162.3	224.7	44	0	34
1972	0	3.3	60.2	128.9	122	119.7	176.3	173.2	129.7	81.9	0	0
1973	0	0	14.1	60.4	134.6	135	160.1	155	139.3	88.5	5.3	30.5
1974	0	0	20.1	39.9	81.3	190.5	271.9	115	257	69.4	6.1	0
1975	0	0	31.8	96.8	100.4	96.6	192.1	216.1	227.1	27.7	7.1	0.3
1976	0	2.3	2.5	74.5	143.8	98.1	105.2	124.3	150.9	288.1	9.4	0
1977	55.9	3.8	42.7	19.7	189.8	96.1	236.5	250.7	284.5	46	0	0
1978	0	0.6	51.2	47.3	76.7	81.5	191.6	112.5	239.5	152.5	1.8	2.5
1979	0	0	45.8	114.4	150.8	248.1	247.4	276	192.4	45.8	4.8	0
1980	18.1	4.5	7.3	142.7	70.4	63	134.8	219.7	227.1	162.3	25.9	28.2
1981	0	0	90.8	29.5	160.2	85.7	109.7	136	98.3	45.5	0	0
1982	0	19.4	26	119.4	58.8	116.5	222.2	230.9	357.1	0	0	0
1983	0	6.8	20.9	83.7	85.9	89.9	116.3	52	139.3	68.7	6.8	0
1984	0	0	40.6	64.3	129.2	137.9	167	152.5	179.7	63.7	1.8	0
1985	0	0	72.8	77.5	130.5	155.6	186.3	225	194	0	19	0
1986	0	2.3	8.1	33.2	69.2	59.3	107.9	81.5	134.3	24.9	2.2	0
1987	0	0	18.6	30.3	30.4	104.2	96.6	294.4	104.6	97.5	0	0
1988	0	0.9	1.1	74.9	114.1	140.1	230.1	104.7	193.2	64.4	7	0
1989	0	0	43.5	41.9	92.9	151.8	114.2	236.7	219.2	105.1	0	37
1990	0	0	0	83.2	168.4	87.8	175.3	248.4	106.4	15.9	13.1	7.8
1991	0	0.4	23.1	115.1	171.6	80.4	237	186.1	63.2	130.9	0	0
1992	0	0	0	28.2	136.7	205.3	124.7	99.2	180.4	66.7	0	0
1993	0	2.5	18.8	152.8	83.9	157.1	183.6	306.5	159.6	64.7	0.7	0
1994	0	0	17.1	38.9	154.3	176.3	132.1	101.1	245.2	131	3.8	0
1995	0	1.9	17.6	101.9	175.6	123.8	188.7	319.6	229.6	68.5	8.6	8.3

1996	0	0	26.4	44.2	133.2	94.8	135.8	395.9	196.1	108.2	0	0
1997	0	0	39.2	98	188.6	290.6	124.8	128.9	278.1	191.2	18.4	0
1998	0	11.4	0	66.3	55.1	96.7	117.5	264.8	113.2	42.3	0	0
1999	5.8	68.9	39.2	60.2	92	250.2	150.9	193	353.3	75.8	1.1	0
2000	67.5	0	2.6	76.2	85.1	243.8	149.6	213.8	229.3	73.3	0	0
2001	0	0	0	85.8	210.9	191.8	84.6	270	136.7	26	0	0
2002	0	0	7.6	95.5	130	122.2	240.3	157.7	139.5	41.8	4.7	0
2003	0	11.7	16.7	100	181.8	219.5	91.3	220.9	272.6	68.6	16.3	0
2004	26.6	13	21.4	84.2	105.1	133.1	177.9	288.7	179.1	43.8	7.3	0
2005	0	0	18.6	186	149.3	135.5	121.3	200.3	215.1	34.7	0	0
2006	35.9	13.8	18	50.3	41	143.4	100.9	304.7	219.4	83.4	0	0
2007	0	0	17.4	156.9	198	72.4	121.8	186.7	103.3	113.3	26.9	0
2008	0	0	43.8	80	109.3	109.3	220.1	315.3	277.8	119.5	0	0
2009	0	12.8	38.8	74.4	104.1	228.6	162.7	191	216	111.8	1.5	0
2010	0	4	0	186.9	145.4	48.4	123.4	295	156.6	70.7	1.8	0
2011	0	8.8	17.8	58.2	124.2	131.1	104.2	228.5	208.6	63.1	1.5	0
Rainfall(mm)	4.5	6.8	30.8	82.6	123.2	140.8	161.6	209.3	198.4	78.2	6.7	4.8

APPENDIX C: FIELD SURVEY PICTURES

Bunds measurement at Siru Sampled soil at Siru

Sampled soil at Sankana Soil sampling at Sankan

Questionnaire administration at Kokoligu Lateral measurement at Karni