KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY,

KUMASI, GHANA

Management of Irrigation Schemes in Ghana:

Case Study of Subinja Irrigation Scheme, Akumadan Irrigation Scheme and Crops Research Institute Irrigation Scheme

By

Odamtten Tetteh Michael (BSc. Agriculture Technology)

A Thesis Submitted to the Department of Civil Engineering

College of Engineering

In Partial Fulfilment of the Requirements for the Degree of

MASTER OF SCIENCE

Water Resources Engineering and Management

June, 2016.

DECLARATION

I hereby declare that this submission is my own work towards the degree of Master of Science (MSc) in Water Resources Engineering and Management and that, to the best of my knowledge, it contains no material previously published by another person, nor material which has been accepted for the award of any other degree of the University, except where due acknowledgement has been made in the text.

Michael Tetteh Odamtten (PG9731413)	…………………… Signature	………………………… Date
Certified by:		
Dr. G. K. Anornu (Supervisor)	…………………… Signature	……………………. Date
Prof. Y. A. Tuffour (Head of Department)	…………………… Signature	……………......... Date

ACKNOWLEDGEMENT

This work has been in its present shape with considerable professional, financial, and material inputs from various sources. Therefore, it is an amazing excitement to come to this final point and to express my deepest gratitude to all individuals and organizations who contributed directly or indirectly to this study and the production of this thesis.

My first gratitude goes to God Almighty for his mercies and guidance through this work. Secondly, my supervisor Dr G.K Anornu for his professional and endless support and patience well from the planning stage of the research work to the production of this thesis.

My sincere thanks go to CSIR- Crops Research Institute and West Africa Agriculture Productivity Programme for funding my studies at the Kwame Nkrumah University of Science and Technology for its generous financial contribution for this thesis research programme.

I would like to express my appreciation to Dr G.A.A. Bolfrey, for her encouragement, which helped me obtain this opportunity. I thank Dr Richard Buamah, MSc. WRESP programme‟s coordinator and all the other lectures on this programme for the Knowledge imparted in me.

I would like to thank my wife, Mrs Patience Odamtten, parents, Mr and Mrs Odamtten and the entire family for their constant and unlimited encouragement, concern, understanding, moral and financial support.

ABSTRACT

This study aims to assess the effects of irrigation schemes management in Ghana on its sustainability and crop yield. The data used for the research was acquired through desk study, literature reviews, questionnaire administration, focus group discussion, interviews with key stakeholders, soil sampling (physical and chemical properties) to ascertain the soils relationship to crops yield. The results of the study revealed most of the people who work on these schemes have some level of basic education. The levels of basic education of respondents at the three schemes are 44 %, 39 % and 93 % for the Subinja, Akumadan and Crops Research Institute- Irrigation Schemes respectively. The low level of education at Subinja and Akumanda Irrigation Schemes has resulted in poor record keeping on cropping activities and lack of knowledge on the importance of soil nutrient analysis. The irrigation schemes at Akumadan and Subinja are jointly managed by Ghana Irrigation Development Authority and Farmers Co-operative Societies whilst that of Crops Research Institute had an irrigation unit responsible for the irrigation scheme. The research revealed that 70.6% and 92% of farmers at Subinja and Akumanda Irrigation Schemes respectively, lacks access to credit facilities from financial institutions. However funds for irrigation projects at Crops Research Institute are provided by donors (WAAPP, AGRA, DONATA etc) and the Government of Ghana. The soils at the three study areas are sandy loamy and needs to be improve in other to enhance crop production. The yields at Crops Research Institute-Irrigation Scheme are higher than that of Akumanda and Subinja Irrigation Schemes because of better management of the irrigation scheme and good agronomic practices. The research recommended that irrigation must be carried out early in the morning or late afternoon to avoid high wind speed leading to nonuniformity watering of crops.

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LIST OF ABBREVIATIONS AND ACRONYMS

AIS	Akumadan Irrigation Scheme
BK	Block
CRI-IS	Crops Research Institute Irrigation Scheme
FAO	Food and Agriculture organization
Ha	Hectare
ISC	Irrigation Service Charge
K	Potassium
Mg	Magnesium

MoFA	Ministry of Food and Agriculture
Mt	Metric Ton
Na	Sodium
P	Phosphorous
SIS	Subinja Irrigation Scheme
UN	United Nation

CHAPTER 1: INTRODUCTION

1.1 Background of Study

The rapid population growth and the consequential demand for food in developing countries have led to food insecurity. Aggravating the improved food demand, there has been a major growth in the prices of food products in the world market. To improve the demand for food and minimize the effect of inflated food prices, major investment in modifying current farming methods or developing new ones will be necessary (FAO,1997). Consequence to population increase, excessive deforestation, uninterrupted land degradation, unreliable and erratic rainfall including other causes have incapacitated and eroded resources coping mechanisms of farm households. Persistent drought has had a long lasting effect on the whole economy and livelihood of agricultural communities. In several countries in the world today, irrigation projects are of key importance in terms of agricultural production and food supply, public investment for rural improvement and income for the rural people. However, there is wide spread dissatisfaction with the performance of irrigation projects in developing countries (Kuscu *et al*., 2009). According to English *et al.* (2002) irrigated agriculture will need to increase the production of food products by twothirds as required by a larger population in the near future. The competition of water and the awareness of unplanned negative output of poor design and management coincide with an increasing reliance in irrigated agriculture (Cai *et al., 2003*)

Nevertheless, according to Hennessy (1993) no detailed studies have been conducted to discover the causes of these unproductive irrigation efforts to produce possible solutions to develop the overall efficiencies of the irrigation schemes with the beneficiary communities. For instance, in developing countries water use efficiencies are usually 30-50% and in few localities merely 20-30%. However, insignificant effective water conservation programs exist and irrigation system performance and management are not monitored by most countries.

Irrigation projects are designed and operated to deliver distinctive requirements of irrigation to each farm whilst regulating operational losses, runoff, evaporation and deep percolation (Merriam *et al*., 1980; Ait Kadi, 1994). The performance of an irrigation system is defined by the diversion, conveyance and uniformity of the efficiency with which the water is applied on the farm (Kanber, *et al*., 2005). Therefore, optimal water use efficiency in every irrigation system is based on improving water use efficiency, maintaining good water quality, avoiding irrigation water salinization and constant water delivery to the farm (Burt and Styles, 1999). Pereira and Trout (1999) as cited in Belay (2012) reported that field assessment of irrigation systems or schemes plays an essential role in producing data and information to improve surface irrigation systems. Furthermore, to determine the efficiency of the irrigation scheme, the performance of the scheme must be evaluated periodically. The results and recommendations of the assessment when implemented would contribute towards the irrigation schemes sustainability for economic use of the inadequate water resource and generate information and new data for the design and operation of new irrigation schemes.

1.2 Problem Statement

Over the years, irrigation schemes have suffered a setback due to pumps, laterals, hydrants and sprinklers deterioration; leading to low water use efficiency of the facilities. In addition, ineffective management practices have left most of the irrigation schemes partly operational. With the current trend of climate change, problems associated with irrigation projects needs to be tackled holistically for food security.

1.3 Main Objective

The main objective of this study is to determine the impact of management of irrigation schemes on food productivity.

The specific objectives of the study are to:

- Assess the management structure of the various irrigation schemes.
- Identify the schemes management problems and causes in relation to schemes actual conditions.
- Assess the crop yield and soil properties of the three selected irrigation schemes

1.4 Research Questions

This study is set out to address the following research questions:

- What are the management structures within the irrigation schemes?
- What are the causes of management problems in the schemes and their impacts on the sustainability of the schemes?
- What are the soil properties in the irrigation schemes?

1.5 Justification

In the last few decades, irrigated agriculture has been a very important source to food production. Improper management of irrigation schemes (low irrigation efficiency, inadequate water application, saline or marginal quality of irrigation water and inadequate drainage) leaves most irrigation schemes partly operational. Comparing three irrigation schemes at different areas will provide useful information for best irrigation management practices to be adapted. Generally, the outcome of this study will help scheme managers to operate irrigation at high efficiency and manage the application of irrigation water for high crop yield.

1.6 Scope of the Study

The research was conducted to assess the effects of irrigation schemes management in Ghana on its sustainability and crop yield. The study areas were CRI-Irrigation Scheme (CRI-IS), Akumadan Irrigation Scheme (AIS) all in the Ashanti region and Subinja Irrigation Scheme (SIS) at Wenchi in the Brong-Ahafo region. Forty-five (45) soil samples were taken from each of the three study areas for laboratory analysis to determine the soil pH, total nitrogen, exchangeable cation (Mg, Na, K and P), available phosphorus, and potassium. Also questionnaires were administered to respondents at the various study areas on the management of the irrigation schemes.

1.7 Limitation of the Study

Farmers were reluctant to release information especially on yields of their produce. Records keeping of activities at the irrigation schemes (SIS and AIS) were also not available.

1.8 Organization of Thesis

Chapter 1 presents an introduction to the research, problem statement, research objectives, scope of the study whilst Chapter 2 reviews the pertinent literature. Chapter 3 presents general methods applied in the research and profile of the study areas. Chapter 4 presents the results and discussions of the research focusing on the findings of the work. Finally, Chapter 5 of the research focuses on conclusions and recommendations.

CHAPTER 2: LITERATURE REVIEW

2.1 Role of Agriculture

Agriculture persists to be a significant sector in developing countries as it plays an important role to the general income and economic growth. As many regions in the world face water scarcity, improving irrigation management is becoming a matter of supreme concern (Hussain *et al*., 2007). According to Kyei-Baffour and Ofori (2006), economic development and poverty reduction goals cannot be attained in Ghana without major progress in the agricultural section. Agricultural growth may be attained through increasing the productivity of accessible land and cultivating more land. Irrigation, in the global perspective has raised millions of people out of poverty and led to substantial increase in supply of food (Faurès *et al.,* 2007). According to Holben (2004) food security is obtaining sufficient and nutritionally enough food that is safe for consumption and attained through socially suitable means.

The ecological distortion is as a result of the hydric stress and climate change that are preventing the accessibility of clean water, as well as excessive exploitation of the natural resources. Hence, our future ecology and economy may be affected deeply by the current judgments comparative to the management of hydric resources (Lermontov *et al*., 2011). The concern of farmers on irrigation projects in relation to water management practices generally varies based on supposed accessibility of water for irrigation (Braimah and Agodzo, 2015). The main difficulty in planning the management of scarce resources is how to distribute the resources among several users equitably and efficiently by taking into consideration the economical, political and social issues whilst bearing in mind the complication of water delivery methods and the heterogeneity in crops, climate and soils (Kilic and Ozgurel, 2005; Brumbelow *et al*., 2007; Chambers, 1988).

2.2 Irrigation

Irrigation-based agriculture intensification in Ghana is enriched with adequate water resources. The assessments of Ghana‟s irrigation potential are mainly divergent, ranging from 0.36-1.9 million ha to slightly more than 33,000 ha under irrigated cultivation (Agodzo and Bobobee, 1994; FAO, 2005). In Ghana, irrigation projects encounter some challenges that are facility and water management related; these occur as a result of unskilled water management techniques and lack of proper understanding of farmers‟ responsibility in the management of the irrigation schemes (Miyoshi and Nagayo, 2006). Irrigation water management entails deciding the time to irrigate, water quantity to apply at every irrigation schedule and throughout each plant stage, maintaining and operating the irrigation facility (Holzapfel *et al*., 2009).

2.3 History of Irrigation in Ghana

Historical accounts trace irrigated agriculture in Ghana to a little over a century ago (Smith, 1969). Approximately 40 years ever since its commencement in the 1960s, about 19,000 hectares (ha) of land has been established; of this, the Government of Ghana developed roughly 9,000 ha and the remaining 10,000 ha by the private sector. Currently in the whole country, there are 22 public irrigation districts (Irrigated Agriculture, 2000). Three key problems recognized to be hindering Ghana‟s irrigation subsector are: „„the socio-economic engagement with water resources and land, ecological degradation coupled with inadequate support services for irrigation and irrigated production, slow rates of growth and low agricultural productivity" (MoFA, 2011). Most of the irrigation projects and schemes output in Ghana are not encouraging and even some of the schemes are rendered unproductive because of poor maintenance culture (MoFA, 2013).

2.4 Design and Management of Irrigation System

A good-design and appropriate use of irrigation method will have the maximum efficiency and water delivery ranges, leading to a high product value and better production (Holzapfel *et al*., 2000; 2004). Proficient irrigation schemes design at farm levels shows a significant feature for irrigated agriculture and major issue owing to water resources competition with other areas and to allow the environmental and economic maintenance of agriculture. Several researchers and studies have considered the design of efficient irrigation systems at farm levels as an important aspect to increase agriculture sustainability (Pannunzio, 2008; Khan *et al.,* 2006; Pannunzio *et al.,* 2008; Hsiao *et al.,* 2007; Hillel and Vlek, 2005). Holzapfel *et al.* (2009) and Pannunzio *et al.* (2004) also reported that designing of irrigation schemes is significant in enhancing irrigation efficiency, application and economical returns in the development processes. According to Holzapfel *et al*. (2009) irrigation systems have precise application that depends on numerous issues, among the most significant are the water quality and availability, crop, soil type and topography. Holzapfel and Arumi (2006) indicated that application efficiency of dissimilar pressurized and surface irrigation techniques differs and rely on the design, operation and management. For a satisfactory operation and management of the surface irrigation schemes, a chain of support components have been established, as well as derivation and control structures for example, adduction systems and simulation models.

The application efficiency of diverse pressurized and surface irrigation techniques differ and rely on the design, operation and management (Holzapfel and Arumi, 2006) In the case of pressurized irrigation methods, massive progress have resulted in better mechanization in its function, application accuracy and integration of chemical components for growth of plant and disease management into the irrigation method (Ravindra *et al*., 2008; Holzapfel and Arumí, 2006). Efficient irrigation schemes at farms means choosing the correct irrigation systems and planning accordingly to the climate characteristics, availability of water, social and economic conditions, crop and soil and the limitation of the allocation systems (Playán and Mateos, 2006).

2.5 Management of Irrigation Project in Ghana

Irrigated agriculture in Ghana consists of small-scale farmers. GIDA is mandated to survey applicant sites for irrigation establishment across Ghana; designing and construct facilities, disseminate farming technology among farmers, maintain and manage irrigation development areas under advance improvement. However, maintaining the previous "Government led Management" had become difficult in terms of finance and personnel, so a „„Participatory Irrigation Management"" was initiated whereby beneficiary farmers and others may perhaps have the opportunity to manage the irrigation systems (Irrigated Agriculture, 2000).

2.6 Financing Irrigation Projects in Ghana

There has been technological and financial support through bilateral collaboration with foreign nations including the Republic of Korea, Japan, China, Taiwan, and the former Soviet Union or from international organizations, such as the World Bank and

UN Food and Agriculture Organization (FAO) to develop majority of these public irrigation districts (Irrigated Agriculture, 2000). The explanation for the support are that; Ghana lacked the financial ability to bear the full cost of irrigation development (currently, irrigation development costs are between roughly US$ 4,000 and US$ 10,000 per ha) and also lacked accumulated systems and technology essential for irrigation development (Irrigated Agriculture, 2000).

Irrigation schemes have primary costs and benefits but unfortunately the cost/benefit ratio of several irrigation projects; particularly in the developing countries are unfavourable because the primary benefits (irrigated area and crop yields) are lower than anticipated and also the primary costs (recurrent and investment) are greater than predicted (Hotes, 1984).

2.7 Irrigation Water Management

The adoption of appropriate and holistic water management policies will lead to substantially increased crop production with regards to yield per hectare, which on the average is higher than under rainfed conditions (Ofori, 2005). Irrigation water management is a problem to present irrigation systems in Ghana as well as farmers in developed countries. Managers of irrigation schemes in several events have considered water delivered to their irrigation farms as irregular and insufficient (KyeiBaffour and Ofori, 2006; Dinye and Ayitio, 2013). Proper land preparation is needed to ensure efficient water management for the predominant surface irrigation methods. For example, a levelled field can make efficient use of expensive water and save irrigation time. Water will run to the end of every row (as in furrow irrigation) and each plant will conceptually receive its share if the land is levelled correctly (Ofori, 2005). Proper water management will lead to less wastage and as a sequel reduce environmental hazards like the rise of water tables, water logging, leaching of nutrients, erosion, as well as water- borne and water-related diseases (Ofori, 2005).

2.8 Farming Support Systems

According to Irrigation Agriculture (2000) the agricultural support systems are describe as the joint shipment of agricultural produce, financing system for farming funds, group usage of agricultural machinery, joint procurement of agricultural equipment and materials etc. As long as the essential farming support systems remain unimproved, sustained advancement of irrigated agriculture would not be achieved
(Irrigation Agriculture, 2000). Interview with management of Agriculture Development Bank revealed that loans to farmers for agricultural activities stand at
31.5% per annum.

2.9 Water Application Systems

The application of irrigation systems could be categorized under two extensive scheme types: pressurized and gravity-flow schemes. Generally, pressurized and surface irrigation systems can achieve practical efficiency levels when appropriately selected, designed and sufficiently operated (Holzapfel *et al*., 2009). Sprinkler systems that are well designed applies water evenly to the surface of the soil and it also have the ability to distribute sufficient water to satisfy the high demand of the crops devoid of generating extra runoff (Hill, 2002).

An improvement in irrigation schemes needs consideration of issues controlling the infiltration of water, hydraulic methods and consistency of the application of water to the whole farm. The frequency or timing of water application will rely on the texture of the soil (for example, clay and sand), the irrigation systems used (for example, sprinkler and drip), plants water consumption rates and the general growth of the root systems of plants (Pereira, 1999; Holzapfel *et al*., 2009). The capacity of irrigation systems to distribute water efficiently and uniformly to the irrigated areas is a key issue controlling the economic and agronomic viability of the agricultural establishment (Solomon, 1988). Irrigation efficiency would be increased if the water were applied and kept at rate needed by the crop to achieve the desired yield (AlJamal *et al*., 1999). The methods of water application are trickle irrigation (Point

Source Emitters and Line Source Products), sprinkler irrigation (Traveling Gun,

Linear and Center Pivot, and Portable or Hand Move) and surface irrigation (Border, Furrow and Basin). However, according to Holzapfel and Arumi (2006), the commonest and oldest irrigation system used is the furrow irrigation and even lately, it is now significant due to the expensive prices of energy in pressurized irrigation systems and the integration of mechanization in its operations. On the contrary, as reported by Lehrsch *et al*. (2000) ; Popova *et al*. (2005), different researchers have studied the ecological consequences of furrow irrigation and established that, the risks of nitrate leaching in irrigation relies on fertilizer and water applications.

2.10 Training and Capacity Building

Direct competence builders and ultimate aim groups are to be trained on their duties and tasks, which for an essential component consist of social and managerial expertise. Irrigation training and capacity building is aimed at excellent design, microirrigation schemes, build and manage small-scale irrigation. Trainers assist to improve the incomes of farmers and to provide access to extra secure water sources (Canada, 2015).

2.11 Operation and Maintenance

The most important service that the scheme operators provide to farmers is the delivery of irrigation water. Operation of the irrigation takes into account the timing, flow-rate, and duration of irrigation applications (Sagardoy *et al*., 1986). Perhaps, irrigation network is the most expensive component of an irrigation system and designed to last longer. Weed invasion, structures malfunctioning, silt deposition and further detrimental circumstances make it virtually unattainable to manage the flow of water in canals. Due to this, the irrigation system is incapable of distributing the required quantity of water evenly. Maintaining the activities in an irrigation reservoir consist of: monitoring the water quality, removal of floating debris in the water which may collapse hydraulic installations and controlling aquatic weeds (Sagardoy *et al*., 1986).

2.12 Crop Yield

An improvement in irrigation generates better income to farmers which result in high demand for local non-tradable services and goods. Irrigation promotes local agroenterprises, provides employment opportunity to the underprivileged sections of the population and inspires the agricultural sector entirely (Smith, 2004). Increase performance of irrigation could lead to increase in crops yield. According to MoFA (2013), the achievable crops yields for maize, cowpea, tomatoes and pepper were 7.50 Mt/ha, 3.00 Mt/ha, 20 Mt/ha and 32.30 Mt/ha respectively. These yields could only be achieved if all the necessary agronomic practices are followed strictly and improved crops varieties are used.

2.13 Soil Properties

Soil is heterogeneous in texture, drainage, slope or terrain, organic matter content, vegetation of agricultural field variability and previous application of fertilizer can all influence the fertility of soil uniformity requirements (Oldham *et al*., 2010). In traditional agricultural methods, farmers utilize plant residues, household refuse, manures of animal, bush fallow and diverse organic nutrients sources to conserve soil organic matter and fertility of the soil. Even though the dependence on biological nutrient sources for the fertility of soil renewal is sufficient with small cultivation intensity, it turns out to be unsustainable with further intensive cultivation except for fertilizer applications (Mulongey and Merck, 1993). Most unproductive soils can be improved with the addition of adequate organic matter (Wallace *et al*., 1990).

One of the most significant steps to achieve successful crop production is through soil sampling and testing for soil nutrient availability. Testing of the soil provides essential facts on deficiency of nutrients and plant uptake accessibility and however, directs the farmer on deciding the suitable adjustment of nutrient that is in consonant with crop requirements (Oldham *et al*., 2010). According to Peck and Soltanpour (1990), the general objectives of soil sampling and testing are to: determine accurate status of soil nutrient, communicate to the supervisor the seriousness of any deficiency in nutrient or decisions on surplus fertilizer application and permit an economic evaluation of management alternative to soil fertility. In addition, improved awareness of ecological matters by farmers has enhance the significance of soil testing for providing both environmental management needs and plant nutrient requirements (Oldham *et al*., 2010). Excessive irrigation reduces nutrient uptake and root growth, diminish the root zone of much required oxygen, leading to the contamination of aquifer as well as potential root diseases (Holzapfel *et al*., 2009)

2.13.1 Physical Properties of Soil

The physical properties of soil determine the intensity of biological operations that can be maintained by the soil and their adaptability to cultivation. The physical properties of soil also basically determine the capacity of delivering soil air and water to plants. Several soil physical properties varies with alterations in the land utilization methods and its management, for example; land cultivation intensity, nature of land under agriculture and the instrument employed, rendering the soil less permeable and more vulnerable to runoff and erosion losses (Sanchez, 1976).

2.13.2 Soil Chemical Properties

Soil chemical properties are the most significant among the factors that determines microbes and plants nutrient requirements. The chemical reactions that happen in the soil influence procedures that lead to the fertility and development buildup of the soil. Minerals inherited from the soil parent materials after a while release chemical elements that undergo different soil transformations and changes (Tilahun, 2007). The chemical properties of soils are total nitrogen, soil pH, available potassium, soil organic matter, exchangeable cations and available phosphorus. The pH scale ranges from 0-14, with 7 being neutral. Values less than 7 are acidic while those greater than 7 are alkaline. Most crops grow best with a soil pH between 6 (slightly acidic) and 7.5 (slightly alkaline) (Dinkins and Jones, 2013).

2.13.3 Soil Texture

Soil texture determines the quantity of chemical and physical soils properties and also influences water retention and infiltration, tillage, nutrients absorption, soil aeration, microbial activities and practices of irrigation (Foth, 1990; Gupta, 2004). The increase in stickiness of moisture content to mold depends on clay and silt content in the soil and also the extent to which the particles of clay are joined together into stable granules and the organic matter content (White, 1997)

2.13.4 Exchangeable Potassium, Sodium, Calcium and Magnesium

Potassium is the third most significant element subsequently to sodium and phosphorus that limit the productivity of plants. Its activity in the soil is primarily controlled by soil mineral weathering and cation exchange properties rather than by microbiological processes. Unlike K, Na and P causes no off-site ecological issues when it is no more in the soil structure. Potassium is not harmful and does not cause eutrophication in aquatic systems (Brady and Weil, 2002). According to Umass Extension (2015), plants lacking potassium are not capable to use water and nitrogen efficiently and are more susceptible to disease.

CHAPTER 3: STUDY AREAS AND METHODOLOGY

3.1 Akumadan Irrigation Scheme

The scheme was commissioned in 1976 and involved the cultivation of tomatoes on an irrigable area of 80 ha (net). The full potential area for the project is however 1000 ha. Akumadan Irrigation Scheme (AIS) is located in the Ashanti Region. It is about 100 km from Kumasi on the main Kumasi – Tamale road. Tomatoes produced at AIS were initially intended to feed the Wenchi Tomato factory. Two major crops are cultivated in the project, tomato in the dry season and maize in the wet season. The pump house accommodates two diesel pumps units of 85 hp and twelve (12) electric pumps of which each four (4) units 100hp, 55hp and 45hp.

3.2 Subinja Irrigations Scheme

The construction of the scheme started in the year 1974 to 1976. In 2006, the Government of Ghana funded the rehabilitation of Subinja Irrigation Scheme (SIA). Under the rehabilitation, four new electric pumps, laterals, mains lines and expansion works on the weir were carried out. The scheme is located in the Brong-Ahafo Region of Ghana and about 20 km from Wenchi.

The full potential area for the project is however 121 ha and the irrigable area of 60 ha, but the present average area under irrigation is about 18 ha. The topography of the scheme is gentle sloping and operating under sprinkler irrigation. The source of water is from river subin. The scheme has a new and old pump house; housing two diesel pumps and four electric pumps of 34 hp each.

There are two main seasons (wet and dry); the wet season has the major and minor season which falls within May to August and September to December respectively. Dry season ranges from December to April. The crops grown during the wet periods are maize, cowpea, garden eggs and watermelon. That of the dry season crops includes garden eggs, pepper, okra, watermelon, cowpea etc. The mean annual rainfall of Subinja in the transitional zone falls within 1253 mm. The highest rainfall is between Septembers to October.

The mean annual temperature is 26 ^{o}C with no much variation. The relative humidity is 75.1%, wind speed 133 km/day, average sunshine 6.2 hours per day and solar radiation 4.53 mm/day. Vegetation is semi-deciduous forest, woodlands and some grasses.

3.3 Crops Research Institute Irrigation Scheme

Crop Research Institute (CRI) is one of the research stations in Ghana mandated to develop and disseminate environmentally sound technologies, comprising improved high yielding, good quality pest and disease resistance varieties, improved crop management and post-harvest practices.

Crops Research Institute is located at Fumesua, 30km away from Kumasi, in the Ejisu-Juabeng District of the Ashanti Region of Ghana. The topography at the site and its surrounding areas is undulating with gentle slopes. The average elevation is 295m taken from GPS readings and corroborated from 1:25,000 topographic map of Ghana.

Supplementary irrigation is currently being applied to sections of the fields covering an area of 23 ha. The general goal of the irrigation project was to enhance crop improvement and technology development capacity of Crops Research Institute. This is to improve food security and livelihoods of smallholder and commercial farmers in Ghana.

3.4 Reason for the Selection of Study Areas

Akumadan, Subinja and CRI Irrigation Schemes were selected because the three irrigation schemes have the same irrigation system (sprinkler irrigation), cultivates the same crops (tomatoes, maize, cowpea etc) but there are differences in their irrigation management practises, soil properties and also crops yields. In addition, the three schemes lie within the transition zone of Ghana.

3.5 Research Methodology

The data used for the research was acquired through the following: Desk study, literature reviews, questionnaire administration, focus group discussion, interviews with key stakeholders, soil sampling (physical and chemical properties) to ascertain the soils relationship to crops yield.

3.5.1 Sources of Data Collection

Both primary and secondary sources of data were used in the analysis.

3.5.2 Primary Data Collection

Primary data was employed using formal and informal survey methods. Designed questionnaire were used to obtain information from the farmers. Farmers‟ cooperative societies, farm managers and technicians were interacted with to obtain information. A focus group discussion was held with community representatives especially concentrating on the water management indicators. Soils were sampled from all the three study areas for analysis of soil nutrients.

3.5.3 Secondary Data Collection

Crops yield data from the various research areas were assessed and analyzed. In addition to that, information was accessed from journals and newspapers. Specifically, documents and reports from SIS, AIS and CRI-IS on the operation, management and crop yields of the scheme were obtained and information used for the research.

3.5.4 Method of Data Collection

Questionnaires were administrated to seventy five respondents at the various study areas and focus group discussions were also conducted. The managers at AIS and SIS were interacted with in relation to the management practices within the schemes.

3.5.5 Soil Sampling

Soil samples were taken from the three study areas (SIS, AIS and CRI-IS) to cover the entire irrigation schemes at a depth of 30cm to determine the soil physical properties like soil type, percentages of clay, sand and loam, soil bulk density and chemical properties like soil pH, soil organic matter, total nitrogen, exchangeable bases (potassium, sodium, calcium and magnesium). Each study area comprise of four (4) blocks. Eleven (11) cores were taken from each of the 12 blocks, which amounted to 132 cores. According to Peters and Laboski (2013), research have shown that taking 10 to 20 cores provides a more representative sample of the area than when samples are made up of fewer cores. The W-shape sampling pattern was used to collect the soil sample.

3.5.6 Soil pH

Soil pH was measured in a 1:1 soil-water ratio using a glass electrode (H19017 Microprocessor) pH meter. Approximately 25 g of soil were weighed into a 50 ml polythene beaker and 25 ml of distilled water was added to the soil. The soil-water solution was stirred thoroughly and allowed to stand for 30 minutes. After calibrating the pH meter with buffers of pH 4.01 and 7.00, the pH was read by immersing the electrode into the upper part of the soil solution and the pH value recorded.

3.5.7 Soil Organic Carbon

The procedure involves a wet combustion of the organic matter with a mixture of potassium dichromate and sulphuric acid. After the reaction, the excess dichromate is titrated against ferrous sulphate. Approximately 1.0 g of air-dried soil was weighed into a clean and dry 250 ml Erlenmeyer flask. A reference sample and a blank were included. Ten ml 0.1667*M* potassium dichromate ($K_2Cr_2O_7$) solution was accurately dispensed into the flask using the custom laboratory dispenser. The flask was swirled gently so that the sample was made wet. Then using an automatic pipette, 20 ml of concentrated sulphuric acid (H_2SO_4) was dispensed rapidly into the soil suspension and swirled vigorously for 1 minute and allowed to stand on a porcelain sheet for about 30 minutes, after which 100 ml of distilled water was added and mixed well.

Ten ml of ortho-phosphoric acid and 1 ml of diphenylamine indicator was added and titrated by adding 1.0*M* ferrous sulphate from a burette until the solution turned dark green at end-point from an initial purple colour. About 0.5 ml 0.1667*M* $K_2Cr_2O_7$ was added to restore excess $K_2Cr_2O_7$ and the titration completed by adding $FeSO_4$ dropwise to attain a stable end-point. The volume of $FeSO_4$ solution used was recorded and % C calculated.

3.5.8 Total Nitrogen

Approximately 0.2 g of soil was weighed into a Kjeldahl digestion flask and 5 ml distilled water added. After 30 minutes a tablet of selenium and 5 ml of concentrated H_2SO_4 were added to the soil and the flask placed on a Kjeldahl digestion apparatus and heated initially gently and later vigorously for at least 3 hours. The flask was removed after a clear mixture was obtained and then allowed to cool. About 40 ml of distilled water was added to the digested material and transferred into 100 ml distillation tube. 20 ml of 40 % NaOH was also added to the solution and then distilled using the Tecator Kjeltec distiller. The digested material was distilled for 4 minutes and the distillate received into a flask containing 20 ml of 4 % boric acid
(H_3BO_3) prepared with PT5 (bromocresol green) indicator producing approximately 75 ml of the distillate. The colour change was from pink to green after distillation, after which the content of the flask was titrated with 0.02*M* HCl from a burette. At the end-point when the solution changed from weak green to pink the volume of 0.02*M* HCl used was recorded and % N calculated. A blank distillation and titration was also carried out to take care of traces of nitrogen in the reagents as well as the water used.

3.5.9 Available Phosphorus

Approximately 5 g of soil was weighed into 100 ml extraction bottle and 35 ml of extracting solution of Bray‟s no. 1 (0.03*M* NH_4F in 0.025*M* HCl) was added. The bottle was placed in a reciprocal shaker and shaken for 10 minutes after which the content was filtered through Whatman no.42 filter paper. The resulting clear solution was collected into a 100 ml volumetric flask. An aliquot of about 5 ml of the clear supernatant solution was pipetted into 25 ml test tube and 10ml colouring reagent (ammonium paramolybdate) was added as well as a pinch of ascorbic acid and then mixed very well. The mixture was allowed to stand for 15 minutes to develop a blue colour to its maximum. The colour was measured photometrically using a spectronic 21D spectrophotometer at 660 nm wavelengths. Available phosphorus was extrapolated from the absorbance read. A standard series of 0, 1.2, 2.4, 3.6, 4.8 and 6 mg P/l was prepared from a 12 mg/l stock solution by diluting 0, 10, 20, 30, 40 and 50 ml of 12 mg P/l in 100 ml volumetric flask and made to volume with distilled water. Aliquots of 0, 1, 2, 4, 5 and 6 ml of the 100 mg P/l of the standard solution were put in 100 ml volumetric flasks and made to the 100 ml mark with distilled water.

3.5.10 Determination of Available Potassium

Available potassium extracted using the Bray‟s no. 1 solution was determined directly using the Gallenkamp flame analyzer. Available potassium concentration was determined from the standard curve. Potassium standard solutions were prepared with the following concentrations: 0, 10, 20, 30, and 50 µg K / ml of solution. The emission values were read on the flame analyser. A standard curve was obtained by plotting emission values against their respective concentrations.

3.5.11 Determination of Calcium and Magnesium

For the determination of the calcium plus magnesium, a 25 ml of the extract was transferred into an Erlenmeyer flask. A 1.0 ml portion of hydroxylamine hydrochloride, 1.0 ml of 2.0 per cent potassium cyanide buffer (from a burette), 1.0 ml of 2.0 per cent potassium ferrocyanide, 10.0 ml ethanolamine buffer and 0.2 ml Eriochrome Black T solution were added. The solution was titrated with 0.01*N* EDTA (ethylene diamine tetraacetic acid) to a pure turquoise blue colour. The titre value was recorded. The titre value for calcium was subtracted from this value to get the titre value for magnesium.

3.5.12 Exchangeable Potassium and Sodium Determination

Potassium and sodium in the percolate were determined by flame photometry. A standard series of potassium and sodium were prepared by diluting both 1000 mg/l potassium and sodium solutions to 100 mg/l. This was done by taking a 25 ml portion of each into one 250 ml volumetric flask and made to volume with water. Portions of 0, 5, 10, 15 and 20 ml of the 100 mg/l standard solution were put into 200 ml volumetric flasks respectively. One hundred milliliters of 1.0*N* NH_4OAc solution was added to each flask and made to volume with distilled water. The standard series obtained was 0, 2.5, 5.0, 7.5, 10.0 mg/l for potassium and sodium. Potassium and sodium were measured directly in the percolate by flame photometry at wavelengths of 766.5 and 589.0 nm respectively.

3.5.13 Soil Physical Analysis

The soil texture was determined by the Hydrometer method. Approximately 40 g of soil was weighed into 250 ml beaker and oven dried at 105 ^{0}C overnight. The sample was removed from the oven and then placed in a desiccator to cool, after, which it was weighed and the oven dry weight taken. A 100 ml of dispersing agent commonly known as Calgon (Sodium Bicarbonate and Sodium Hexa-metaphosphate) was

measured and added to the soil. It was then placed on a hot plate and heated until the first sign of boiling was observed. The content in the beaker was washed completely into a shaking cup and then fitted to a shaking machine and shaken for 5 minutes. The sample was sieved through a 50 microns sieve mesh into a 1.0 L cylinder. The sand portion was separated by this method while the silt and clay went through the sieve into the cylinder. The sand portion was dried and further separated using graded sieves of varying sizes into coarse, medium and fine sand. These were weighed and their weights taken.

The 1.0 L cylinder containing the dispersed sample was placed on a vibration less bench and then filled to the mark. It was covered with a watch glass and allowed to stand overnight. The Hydrometer method was used to determine the silt and the clay contents. The cylinder with its content was agitated to allow the particles to be in suspension, it was then placed on the bench and hydrometer readings taken at 30 seconds, 4 minutes, 1 hour, 4 hours and 24 hours intervals. At each hydrometer reading the temperature was also taken. Coarse silt, medium silt, fine silt and clay portions were then calculated graphically. The various portions were expressed in percentage and using the textural triangle the texture was determined.

3.5.14 Method of Data Analysis

The data collected through questionnaires were analyzed descriptively using Statistical Package for Social Science (SPSS), formulation of data into graphics and tables

CHAPTER 4: RESULTS AND DISCUSSIONS

4.1 Social and Economic Profile of the Study Areas

The background of the various farmers influences their adoption to technology and management behaviour. SIS and AIS have majority of farmers being indigenous people, whiles CRI-IS are mixed origin. From the study 32% and 44% of the farmers from SIS and AIS have alternative livelihood because of the risk associated with farming in terms of disease outbreak, lack of funds and low crop yield returns. Management of the irrigation scheme is affected by poor organization of farmer association and lack of funds for the purchase of inputs such as fertilizers, weedicides/ herbicides, payment of electricity bills etc. Transportation of crops yield from the farm to the market is not much of a problem since the road network leading to the farm is quite good at all the three study areas.

4.2 Educational Level of Farmers

The educational levels of farmers from the three study areas are shown in Figure 4-1. Out of 75 respondents from the three study areas; majority of the respondents with basic education are from SIS and AIS, 44% and 39% respectively. The research also reveal 28%, 33% and 7% of the respondents at SIS, AIS and CRI-IS respectively had secondary or technical education. CRI-IS had 93% respondents with tertiary education while 20% and 23% for SIS and AIS respectively.

From the study, the low level of education at SIS and AIS is the cause of poor record keeping on cropping activities and lack of knowledge on the need to test the soil before and after the cropping season so as to ascertain the fertility levels of the soil.

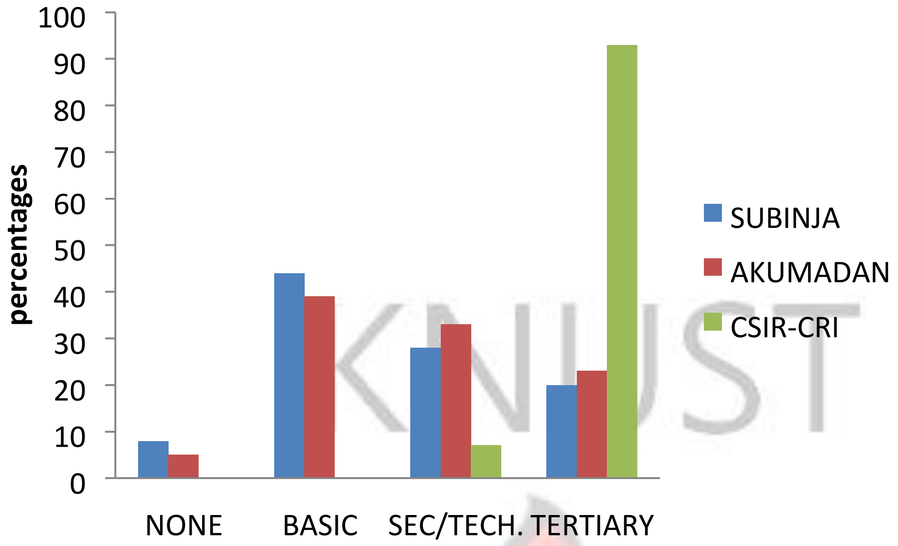

Figure 4-1: Educational Levels of Farmers

4.3 Management and Institutional Issues of the Schemes

Government led management of the irrigation schemes in Ghana (funds and personnel) had become difficult so a „„Participatory Irrigation Management"" was introduced whereby beneficiary farmers and stakeholder have the opportunity to manage the irrigation systems. Appendix G shows the supposed institutional arrangement at SIS and AIS but unfortunately, the institutional arrangement is not fully implemented due to lack of funding from the government and insufficient

Irrigation Service Charges. Staffs of GIDA and the executives of farmers" cooperative society jointly manage SIS and AIS. Figure 4-2 shows the management and institutional arrangement currently at Subinja and Akumandan irrigation schemes.

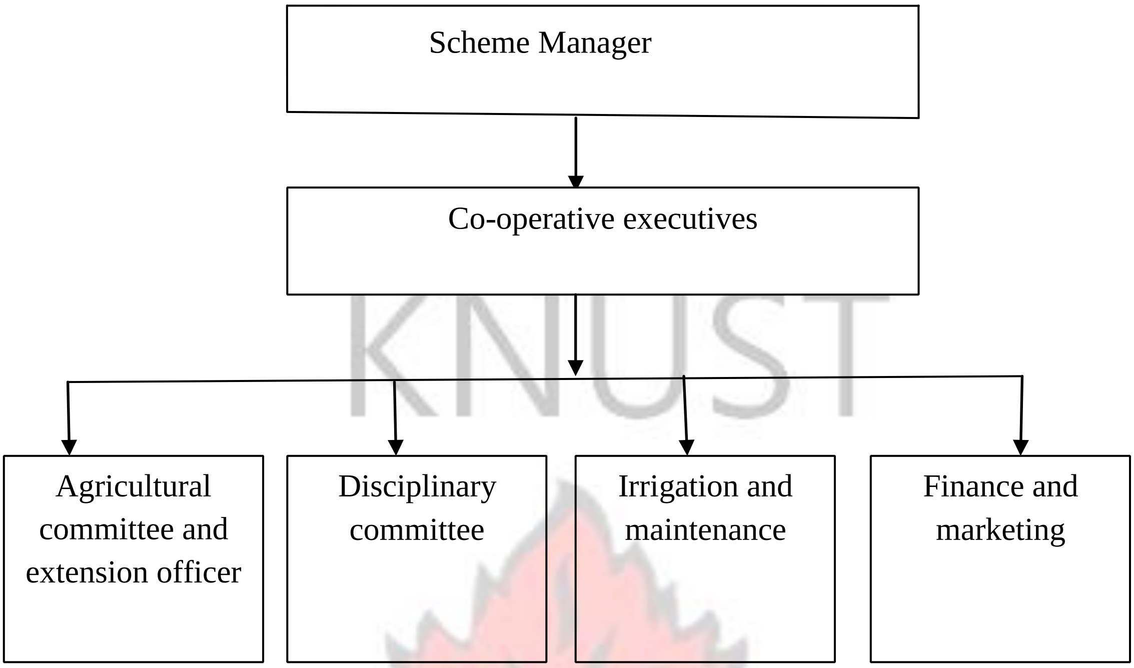

Figure 4-2: Schematic Diagram of Co-operative Society at Subinja and Akumandan Irrigation Schemes

4.3.1 Scheme Manager

The manager is mandated to implement policies and decisions taken by GIDA with the help of his/her assistant(s) who should be a member of the farmers‟ co-operative society. They must organize training, workshops, field visits and give a listening ear to the farmers. These activities are usually not carried out because of inadequate funds to organize such programmes regularly.

4.3.2 Farmers‟ Co-operative Society

The registered farmers within the co-operative society are numbering 33 and 84 at SIS and AIS, respectively. The farmers‟ co-operative society organizes communal labour to undertake maintenance works in and around the pump station, valves and hydrants.

The co-operatives society organizes vehicles during the harvesting season to commute farm produce to the market, educate farmers on the rules and regulations governing the irrigation schemes. Trainings are organized by the farmers‟ co-operative society on spraying, mulching, irrigation maintenance, introduction of new crop variety, new technologies etc. Unfortunately, scheme managers and executives of the farmers‟ cooperative society find it difficult organizing farmers especially at SIS because the farmer‟s prioritize working on their crops and attending to other commitment than honouring farmers‟ co-operative meeting invitations. According to the farmers such co-operative meets waste their time and the same old issues are repeatedly discussed most of the times.

4.3.3 Agricultural Committee

Information gathered from the field survey reveals that the Agricultural committee consists of 3 members and works directly with one extension officer from the Ministry of Food and Agriculture who offers technical advice to the farmers. The responsibility of the committee is to identify farmers willing to cultivate crops during the beginning of the farming season, allocate fields to interested farmers for cultivation, enquiring about the cost of farm inputs and communicating same to the farmers. Finally the committee monitors and advice farmers on problems encountered during cultivation of crops and find lasting solution to such problem. This committee performs its work efficient and effectively at SIS and AIS.

4.3.4 Disciplinary Committee

Three (3) members form the disciplinary committee; they ensure that farmers have good working relationship during and after work. The committee helps think through issues emanating from GIDA and advice members of the co-operative society appropriately. This committee works well according to the respondents at AIS and SIS.

4.3.5 Irrigation and Maintenance Committee

Four (4) members of the co-operative society form the irrigation and maintenance committee of the scheme. This committee ensure that the irrigation facility is in good shape and working properly. They calculate the diesel or electricity cost and factors it into the general cost of irrigation for the cropping season. The committee also encourage members of the co-operative society to be more involving in communal works for the better running of the irrigation scheme.

4.3.6 Finance and Marketing Committee

The committee monitors the market prices of the produce under cultivation and communicate such information to the farmers. This gives the farmers fair idea of the market price of their crops yield and helps them sell their commodities without making a lost. The finance committee tries to seek for financial support from the financial institutions to boost cropping activities.

From the focus group discussion conducted with farmers at SIS and AIS, despite the efforts put in by the financial committee and individual farmers to secure loans from financial institutions, their efforts yielded no results. Market men/women insisted on buying farmers‟ produce at cheaper prices since the commodities (tomatoes) are perishable and if not sold out on time would be a total loss to the farmers.

4.4 Operation of Irrigation Facility

From the field interviews, the method of irrigation is through sprinkler system where laterals and sprinklers are move from one farm to the other. The study reveals that operation of irrigation facility (control of valves, laterals, sprinklers etc) was mostly carried out by individual farmers in need of irrigation service at SIS and AIS as shown in Table 5-1.

Table 4-1: Percentages of respondents that operate the irrigation facilities at various study areas during the interview.

Area of study	Operators	Percentage
SIS	25	100
AIS	23	88
CRI	6	24

From Table 4-1, out of the 25 respondents at each study area, SIS and AIS recorded 100% and 88%, respectively of farmers operating sprinklers and laterals by themselves, whilst at CRI-IS, 24% out of the 25 respondents said irrigation technicians operates the entire irrigation scheme. Since the irrigation technicians are well trained, crop protection is highly taken into consideration when fixing and moving laterals lines. The irrigation facility at SIS and AIS gets damage frequently because of poor handling of the equipment by farmers.

According to the respondents at SIS, due to low crops yield and lack of funds; payment of bills (Irrigation Service Charge, Electricity bills and Association dues) have been accumulated leading to the disconnection of electricity from the national grid to the pump station, therefore, resulting to the use of diesel pumps. For the irrigation schemes to be more effective at SIS and AIS, farmers must strengthen their co-operative society and pay all levies with respect to the use of irrigation facility before the cropping season starts. This would help in the smooth running of the irrigation schemes.

4.5 Irrigation Management Issues

From the interview, all accessories needed to operate and maintain the irrigation scheme at CRI-IS are provided by the management of the institute upon request from the head of the irrigation unit. SIS and AIS are different, the irrigation facility user fees charges are used for the maintenance and repair works.

At CRI-IS, the irrigation team consists of one scientist, two senior technicians and two farm assistants whereas at SIS and AIS, the managers are from GIDA and assisted by the various committees within the farmers‟ co-operative society manage the schemes. From Figure 4-3, 64%, 30% and 10% out of the 75 respondents at SIS, AIS and CRI-IS, respectively said poor irrigation management had contributed to low crops yield and even led to the disconnection of electricity from the national grid to the pump station at Subinja Irrigation Scheme.

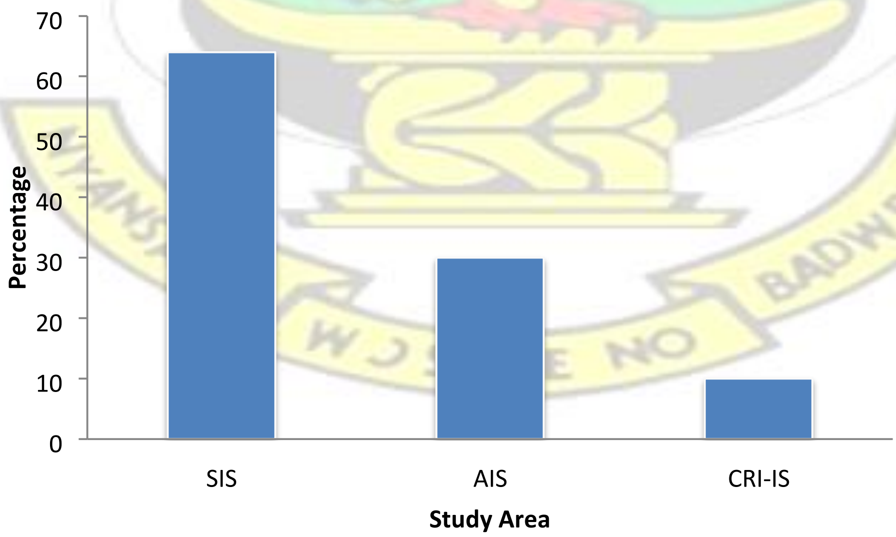

Figure 4-3: Poor Irrigation Management

4.6 Inputs

Interviews conducted at the three study areas show that 97.5% of the respondents believe that obtaining farm inputs from the market is not a problem, if only the funds are available. As shown in Figure 4-4, 64%, 72% and 60% of the respondents at SIS, AIS and CRI-IS respectively said farm inputs are expensive so Government and donor organizations should subsidise farm inputs such as fertilizer, weedicides, herbicides, seeds, electricity bill and diesel cost etc to make crops cultivation less expensive. The farmers also appeal to retailers of the various companies dealing in farm inputs to deliver the agricultural inputs directly to their farms.

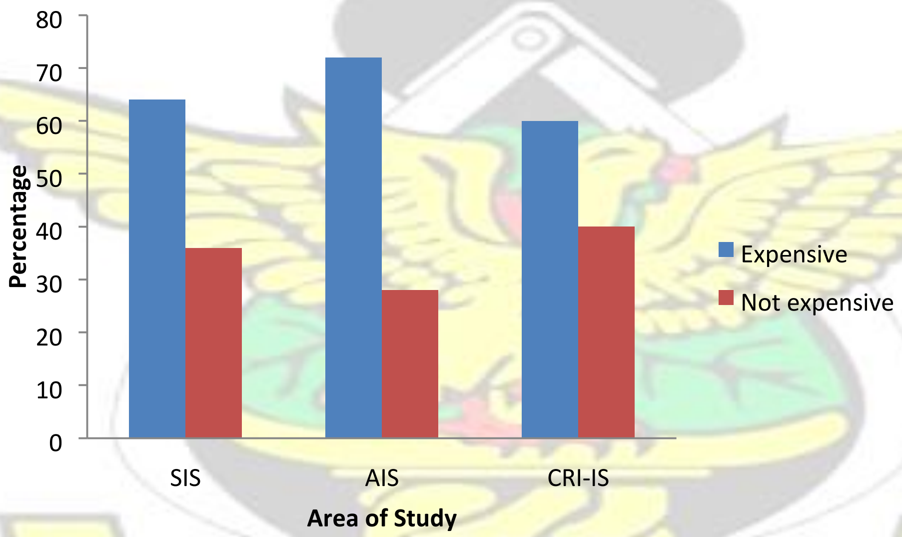

Figure 4-4: Responds to Cost of Farm Inputs

4.7 Credits Facilities

From the 25 respondents at each of the study area, access to credit facility has been a major problem. From Figure 4-5, 70.6% and 92% of the respondents at SIS and AIS, respectively said obtaining financial assistance from the financial institutions is not forth coming because they (financial institutions) are aware of the risks involved in farming and also lack of appropriate collateral and documentation of cropping activities makes it difficult to support farmers. This is in accordance with the report of Irrigation Agriculture (2000) which states that as long as the essential farming support systems remain unimproved, sustained advancement of irrigated agriculture would not be achieved. Even if the credit facility is available, interest rate is high. The rate at Agriculture Development Bank stands at 31.5% as revealed in an interview with management of the bank. Due to the high interest rate, farmers who are able to meet the loan requirement conditions often default in the loan repayment schedule.

At CRI-IS funds are provided by donors (WAAPP, AGRA, DONATA etc) and the Government of Ghana for research work. Figure 4-5 shows the level of unavailability of credit facility at Subinja and Akumadan Irrigation Schemes.

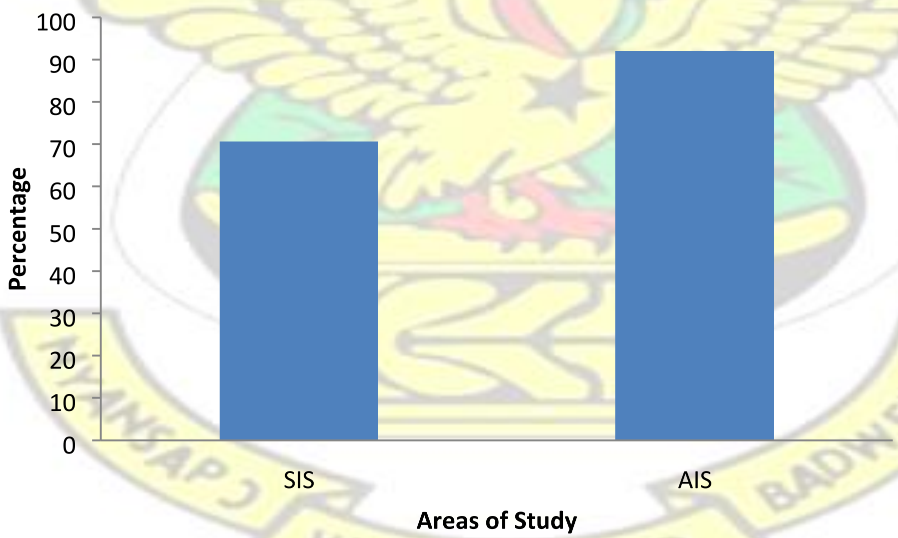

Figure 4-5: Lack of Credit Facility at SIS and AIS

4.8 Training in Irrigation Management

From Figure 4-6, 76.5%, 69%, 25% of the respondents at SIS, AIS and CRI-IS respectively have had one or two trainings in irrigation management. CRI-IS recorded the lowest level of irrigation management training (25%) because the institute have established irrigation unit which is responsible for all irrigation activities.

Despite the high (76.5%) percentage of irrigation management training at SIS, farmers do not implement the knowledge acquired because they believe the procedures of better irrigation management practices learnt are time consuming. In addition to that, lack of funds to carry out such activities is a major problem limiting the implementation of the acquired knowledge.

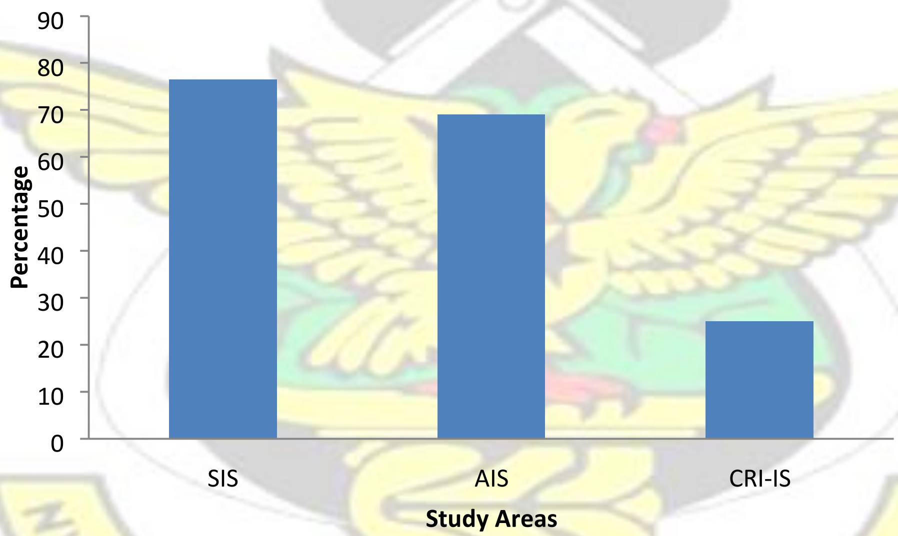

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Figure 4-6: Training in Irrigation Management

4.9 Present Farm Practices

All farmers and researchers from the three study areas had fair knowledge on the agronomic practices such as fertilizer application, planting in rows, spraying of chemicals (fungicides and insecticides), timely weeding etc. According to the farmers, agronomic knowledge was acquired through workshops/trainings, friends and also farming for many years (experience).

4.10 Crops Grown Under Irrigation

The research revealed that each study area grow different types of crops under irrigation. The types of crops cultivated are cowpea, tomatoes, maize, garden eggs, pepper, okra etc. CRI- Irrigation Scheme researches into root and tuber crops (yam, cocoyam, cassava, and sweet potatoes), cereals (rice and maize), legumes (groundnut, cowpea, soybeans) and vegetables.

4.10.1 Average Yield at Akumadan Irrigation Scheme

Akumadan irrigation scheme is mainly noted for the cultivation of tomatoes. Tomatoes recorded a yield value of 10.4 Mt/ha as against the expected yield of 20 Mt/ha in the year 2013. In the same year, 30.0 ha were expected to be cultivated but the actual cultivated land area was 25.0 for tomatoes. The study also revealed that; cowpea, pepper and maize had an actual yield of 1.2 Mt/ha, 2.6 Mt/ha and 3.2 Mt/ha respectively. Figure 4-7 shows the actual and expected crops yield at Akumanda Irrigation Scheme.

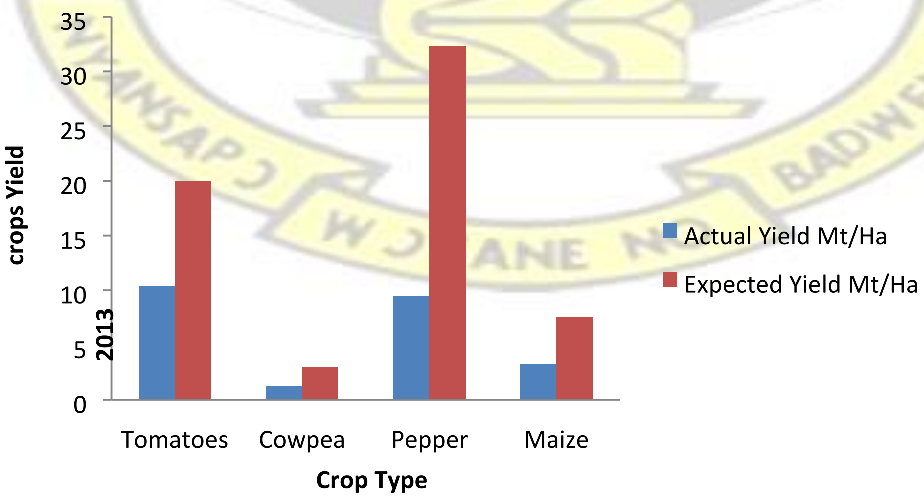

Figure 4-7: Average Crop Yield at Akumadan Irrigation Scheme

4.10.2 Average Yield at Subinja Irrigation Scheme

The average crops yield for maize, cowpea, tomatoes and pepper at Subinja Irrigation Scheme are 2.8 Mt/ha, 1.1 Mt/ha, 7.8 Mt/ha and 8.3 Mt/ha respectively. Figure 4-8 shows the actual and expected crops yield in the year 2013.

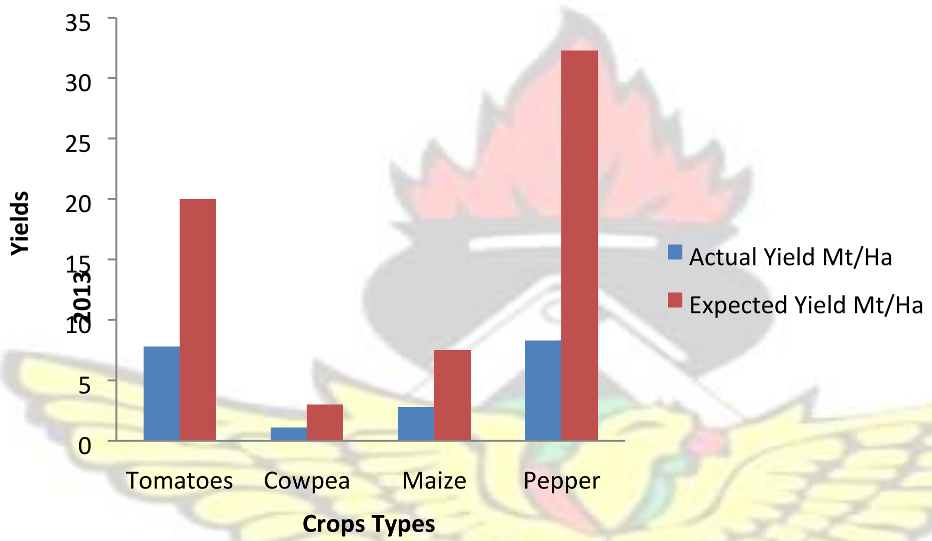

Figure 4-8: Average Crop Yield at Subinja Irrigation Scheme

4.10.3 Average Yield at CRI-Irrigation Scheme

CRI-IS recorded 15 Mt/ha, 2.7 Mt/ha, 6.2 Mt/ha and 16.7 Mt/ha for tomatoes, cowpea, maize and pepper, respectively. Figure 4-9 shows the actual and expected crops yield in the year 2013.

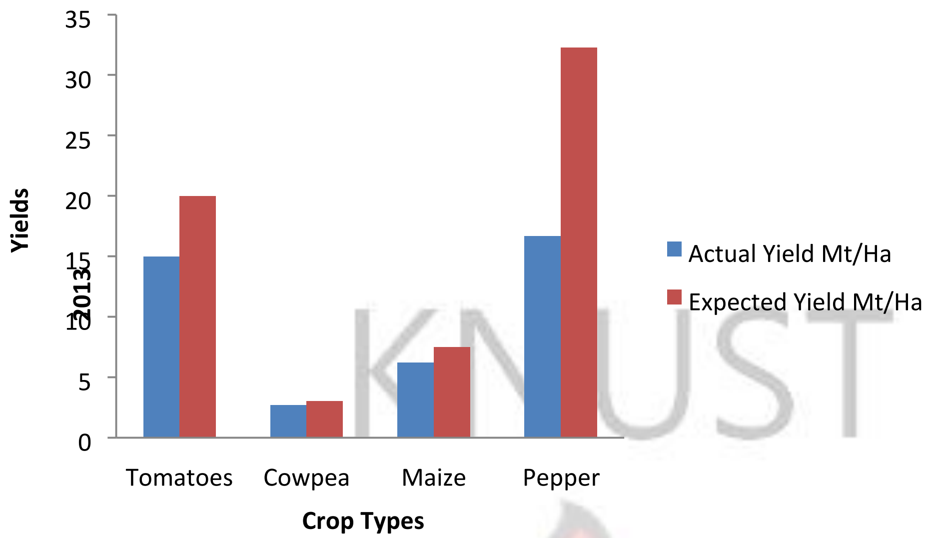

Figure 4-9: Average Crops Yield at CRI- Irrigation Scheme

4.10.4 Comparison of Average Crops Yields at AIS, SIS and CRI-IS

From Table 4-2, crops at CRI-IS performed better than AIS and SIS in terms of crops yield because irrigation is managed well, improved crops varieties are used and agronomic practices are strictly followed. AIS recorded slightly higher values in crops yield than that of SIS because the irrigation facility at SIS is not functioning as it is required because of the mismanagement of the scheme.

Table 4-2: Average crops yields (Mt/ha) at various study areas

Crops	Area of study		
	CRI-IS	SIS	AIS
Tomatoes	15	7.8	10.4
Cowpea	2.7	1.1	1.2
Maize	6.2	2.8	3.2
Pepper	16.7	8.3	9.5

4.11 Soil Analysis Responds

The soil needs to be analysed at least once in every three years, the Table 4-2 below shows the percentage of farmers that analyse the soils before and after cropping.

Table 4-3: Responds to laboratory soil analysis before and after the cropping season at least once in every three years at the various study areas.

Study Area	Response	Percentage (%)
SIS	Yes	5.9
	No	94.1
AIS	No	100
CRI-IS	Yes	72.7
	No	27.3

From Table 4-3; 94.1%, 100% and 27.3% of the respondents at SIS, AIS and CRI-IS respectively don‟t analysis the nutrient level of the soil before and after the cropping season. This according to the farmers is attributed to lack of funds and the essence of soil nutrient analysis especially at SIS and AIS.

4.12 Soils Samples

The laboratory results of soil samples from 12 fields of the various study areas; SIS, AIS and CRI-IS are shown in Appendix H. Since soil provides nutrients for plants growth and development, it is necessary to assess the nutrient levels of various soils at various study areas in relation to the crops yield. The assessment of nutrient levels in the soil informs the farmer of the right amount of nitrogen, phosphate, potassium, ammonium etc required in the soil for better crop yield and the type of crops to cultivate on a particular soil.

4.12.1 Soil pH

The soil pH and significant difference in means within the various study areas are discussed from Table 4-4 and Table 4-5 below.

Table 4-4: Shows the soil pH at various blocks within the study areas.

Study Area	Block1	Block2	Block3	Block4
SIS	5.78	5.78	5.37	5.22
AIS	5.28	5.16	5.61	5.95
CRI-IS	6.09	6.04	5.93	5.60

Table 4-5: Shows the significant difference in means of soil pH within the various study areas.

Study Areas	Mean
AIS	5.5 [a]
SIS	5.55 [a]
CRI-IS	5.915 [a]
LSD (0.05)	**0.62**

The significant difference is denoted by „„a""

a) Subinja Irrigation Scheme

The average pH values for SIS at Block 1and 2 is 5.78 (medium acidity). At Block 3 and 4 the pH values ranges 5.37-5.22 (strongly acid). Under acidic conditions, most micronutrients such as manganese (Mn), boron (B), copper (Cu) and zinc (Zn) are more soluble and therefore more available to plants (Umass Extension, 2015).

b) Akumadan Irrigation Scheme

From Table 4-4, the pH values at Block 1 and 2 are 5.23 and 5.16 respectively (strongly acidic) and Block 3 and 4 are 5.61 and 5.95 respectively (moderately acidic). According to Umass Extension (2015), when the soil is acidic, the availability of nitrogen, phosphorus, and potassium is reduced, and there are usually low amounts of calcium and magnesium in the soil.

c) CRI-Irrigation Scheme

With reference to Table 4-4; Block 1, 2, 3 and 4 shows pH values of 6.09, 6.04, 5.93 and 5.60, respectively (moderately acidic). According to Hardy *et al*. 2013, the pH value alone does not determine how much lime is required but is used in combination with exchangeable acidity in determining lime rates. Tillage depth influences the quantity of lime required to increase soil pH and can also affect the time required for pH to increase. Greater quantities of lime are generally required to increase soil pH as tillage depth increases, because a greater volume of soil is effectively being treated.

The soil pH values at SIS, AIS and CRI-IS were significantly not different ($p \leq 0.05$) as shown in Table 4-5 but lime must be applied to increase the pH values as reported by Osei *et. al.,* (2014); Dinkins and Jones (2013), majority of crops cultivated with soil pH ranging from 6 -7.0 grows better.

4.12.2 Organic Carbon

The soil organic carbon and its significant difference in means at the various study areas are indicated in Table 4-6 and Table 4-7

Table 4-6: Shows soil organic carbon at the study areas

Study Area	Block1	Block2	Block3	Block4
SIS	0.74	0.76	1.01	0.70
AIS	1.35	1.48	1.87	1.91
CRI-IS	1.00	1.39	0.92	1.44

Table 4-7: Shows the significant difference in means of soil organic carbon within the various study areas.

Study Area	Mean
SIS	0.802 [a]
CRI-IS	1.188 [a b]
AIS	1.652 [c]
LSD (0.05)	**0.412**

The significant difference is denoted by „„a"", „„b"" and „„c""

a) Subinja Irrigation Scheme

From Table 4-6; the average organic carbon values obtain at Block 1, 2 and 4 were 0.74%, 0.76% and 0.7% respectively which is low when compared to the standards of Charman and Roper (2000). Block 3 recorded organic carbon of 1.01% which is moderate with reference to Appendix B.

b) Akumadan Irrigation Scheme

At AIS, the 1.35% and 1.48% organic carbon recorded were moderate for Block 1 and 2 but that of Block 3 and 4 were 1.87% and 1.91% (high) respectively as shown in Table 4-6.

c) CRI-Irrigation Scheme

The organic carbon shown in Table 4-6 reveals that, Block 1, 2 and 4 had values of

1.00%, 1.39%, and 1.44% respectively were moderate. Block 3 recorded 0.92% (low). There were significant difference between AIS and SIS likewise AIS and CRI-IS but SIS and CRI-IS had no significant difference in organic carbon. According to the analysis, on average there were significant ($p \leq 0.05$) differences in organic carbon at the various study areas. These differences could be attributed to the farming practices use at the various study areas. This agrees with the findings of Blakemore *et. Al.*, (1987) that organic carbon within a soil is dependent on farming practices and climatic conditions.

4.12.3 Total Nitrogen

The total nitrogen content in the soil at the various study areas are shown in Table 4-8 and the significant difference of total nitrogen are also indicated in Table 4-9.

Table 4-8: Shows soil total nitrogen at various study areas.

Study Area	Block 1	Block 2	Block 3	Block 4
SIS	0.05	0.07	0.09	0.04
AIS	0.11	0.13	0.18	0.15
CRI-IS	0.08	0.13	0.07	0.14

Table 4-9: Shows the significant difference in means of soil total nitrogen within the various study areas.

Study Area	Mean
SIS	0.0625^{a}
CRI-IS	$0.1050^{a b}$
AIS	0.1425^{b}
LSD (0.05)	**0.05309**

The significant difference is denoted by „„a"" and „„b""

a) Subinja Irrigation Scheme

From the soil analysis in Table 4-8, SIS average values for total nitrogen were 0.05%, 0.07%, 0.09% and 0.04% for Block 1, 2, 3 and 4 respectively. The values above imply that the total nitrogen levels at the irrigation scheme are low. There were no significance difference in total nitrogen between SIS and CRI but for SIS and AIS there were significance differences in there means.

b) Akumadan Irrigation Scheme

Results in Table 4-8 shows that, the total nitrogen levels for Block 1and 2 were low with values of 0.11% and 0.13% respectively but Block 3 and 4 recorded 0.18% and 0.15% respectively (medium). AIS and CRI-IS had no significance difference between the mean values of total nitrogen but there were significance difference in the mean values at AIS and SIS.

c) CRI-Irrigation Scheme

From Table 4-8, Block 1, 2 3 and 4 values were 0.08%, 0.13%, 0.07% and 0.14% respectively. This implies low total nitrogen in soils. Soils at the three study areas had been cultivated for more than 40 years and are low in total nitrogen levels this is in accordance with Wakene, (2001). He reported that, agricultural land cultivated for over 40 years depletes in total nitrogen by 30%. On a whole, there were no significant ($p \leq 0.05$) differences in total nitrogen at various study areas.

4.12.4 Available Potassium (K)

Plants require potassium ion for protein synthesis and for the opening and closing of the stomata. Table 4-10 and Table 4-11 shows the available potassium at the study areas and significant difference of potassium within study areas respectively.

Table 4-10: Shows the available potassium (K) at the three study areas.

Study Area	Block 1	Block 2	Block 3	Block 4
SIS	33.2	38.61	31.03	27.78
AIS	91.65	67.11	90.21	75.53
CRI-IS	64.23	43.66	48.35	50.52

Table 4-11: Shows the significant difference in means of available potassium (K) within the various study areas.

Study Area	Mean
SIS	0.135[a]
CRI-IS	0.243 [a]
AIS	0.453 [b]
LSD (0.05)	**0.1403**

The significant difference is denoted by „„a"" and „„b""

a) **Subinja Irrigation Scheme**

The average values of potassium (K) for Block 1, 2, 3 and 4 were 33.2 ppm, 38.61ppm, 31.03ppm and 27.78 ppm respectively from Table 4-10. These values are generally low according to Michigan State University (2012) as indicated in Appendix D. There were no significant differences in the means of SIS and CRI-IS but there was significant difference in the means of SIS and AIS.

b) **Akumadan Irrigation Scheme**

From the results of the soil analysis in Table 4-10, Block 1 and 3, had potassium values of 91.65ppm and 90.21ppm respectively (medium). Block 2 and 4 were 67.11ppm and 75.53ppm respectively was considered low with reference to Appendix C

c) CRI- Irrigation Scheme

From Table 4-10, the average values of Block 1, 2, 3and 4 were 64.23ppm, 43.66ppm, 48.35ppm and 50.52ppm respectively are considered low. Plants deficient in potassium are unable to utilize nitrogen and water efficiently and are more susceptible to diseases (Umass Extension, 2015).

4.12.5 Available Phosphorous (P)

Adequate phosphorous availability for plant stimulates early plant growth and hastens maturity (Busman *et al*., 2002). Table 4-12 shows the available phosphorous at the various study areas.

Table 4-12: Shows the available phosphorous (P) at the various study areas.

Study Area	Block 1	Block 2	Block 3	Block 4
SIS	40.18	28.30	16.66	14.19
AIS	14.67	43.29	4.38	30.30
CRI-IS	147.49	171.41	9.89	49.19

Table 4-13: Shows the significant difference in means of available phosphorous (P) within the various study areas.

Study Area	Mean
AIS	23.16[a]
SIS	24.83[a]
CSIR-CRI	94.50 [c]

LSD (0.05)	69.7

The significant difference is denoted by „„„a‟‟‟ and „„„c‟‟‟

a) Subinja Irrigation Scheme

From Table 4-12, average values of phosphorous (P) at Block 1 and 2 are 40.18ppm and 28.30ppm respectively are high according to Brays (P) rating in Appendix E. Block 3 and 4 were 16.66ppm and 14.19ppm respectively considered as moderate.

There were no significant differences in means at AIS and SIS likewise SIS and CRIIS as shown in Table 4-13.

b) Akumadan Irrigation Scheme

From Table 4-12, Block 1 recorded 14.67ppm (moderate), whilst Block 3 was 4.38ppm (very low). Block 2 and 4 had 43.29ppm and 30.30ppm respectively which are very high when compared to the standards in Appendix E. There were no significant difference in means at AIS and SIS but there were significant difference in means at AIS and CRI-IS as shown in Table 5-13. This may influence the crops yields at AIS and CRI-IS.

c) CRI- Irrigation Scheme

From Table 4-12; Block 1, 2 and 4 recorded 147.49ppm, 171.41ppm and 49.19ppm respectively. This implies high levels of phosphorus in the soil. Block 3 was 9.89ppm representing low level of phosphorus. There were significant difference in means at AIS and CRI-IS but no significant differences were observed in means at SIS and

CRI-IS.

4.12.6 Soil Texture

Soil texture determines the rate of water infiltration and also the availability of water to the plant. Table 4-14 shows the soil texture at various study areas.

Table 4-14: Soil texture at the various study areas

Study area	Texture
SIS BK 1	Sandy Loam
SIS BK 2	Sandy Loam
SIS BK 3	Sandy Loam
SIS BK 4	Sandy Loam
AIS BK 1	Sandy Loam
AIS BK 2	Sandy Clay Loam
AIS BK 3	Sandy Clay Loam
AIS BK 4	Sandy Clay Loam
CRI-IS BK 1	Sandy Loam
CRI-IS BK 2	Sandy Loam
CRI-IS BK 3	Sandy Loam
CRI-IS BK 4	Sandy Loam

From Table 4-14; soil texture at SIS and CRI-IS are sandy loam and that of AIS are sandy clay loam with the exception of AIS Bk 1 which is sandy loam. According to FOA, (1990) the basic infiltration rate for sandy loam and sandy clay loam are within the range 20-30 and 5-10 mm/hour respectively. Sandy loam soils can hold significant amount of water and nutrients for plants growth. Crops cultivated in sandy loam soils require frequent irrigation than that of sandy clay loam because of the high infiltration rate of sandy loam soils. A well-drained sandy loam soil is good for the cultivation of vegetable as reported by Osei *et al*., (2014). From the soil laboratory analysis, the entire soil nutrients at the three study areas are good for crops cultivation but needs an improvement.

4.13 Irrigation of Crops

The hours of irrigation determines the amount of water available to the plant at a particular time. Table 4-15 shows the percentage of respondents in relation to hours of irrigation.

Table 4-15: Shows hours of irrigation

Hours	Percent (%)
1 hour	21.4
2 hours	23.8
3 hours	23.8
4 hours	26.2

From the study, out of 75 respondents at SIS, AIS and CRI-IS; 95.2% of farmers irrigates their crops twice in a week depending on the climatic and soil conditions. The irrigation last between 1-4 hours base on the type of crops and its water requirement. Respondents irrigate their crops within 1-4 hour twice in a week mainly because of the soil texture which is largely sandy loam. Unfortunately, 4.8% of the respondents at SIS are not able to irrigate their crops twice a week because of high cost fuel prices.

4.14 Maintenance of the Irrigation Facility

According to the farmers at SIS and AIS, the irrigation facility (laterals, sprinklers, pumps, hydrants etc) are maintain in collaboration with GIDA and support from farmers co-operative societies. From observation and the questionnaires administrated; 95% of respondents from AIS, SIS and CRI-IS said laterals and sprinklers are not sufficient, making irrigation of crops tedious.

Funds from Irrigation Service Charge (ISC) are used for repair works at AIS and SIS. Unfortunately such repair works takes a longer time to be carried out due to insufficient funds from Irrigation Service Charge and the Government of Ghana. The irrigation unit at CRI-IS takes responsibility of the maintenance of the irrigation facility and also obtains funds from the institute for any repair works.

The study revealed that 65% out of the 75 respondents at CRI-IS, SIS and AIS fail to provide fire belts around the irrigation facilities (hydrants, laterals, sprinklers etc) before burning or during the dry seasons. Fire outbreaks have destroyed some of the irrigation facilities at all the three locations.

From Table 4-16; there were significant ($p \leq 0.05$) difference in means of the maintenance of irrigation facility at CRI-IS, AIS and SIS. AIS and SIS had no significant ($p \leq 0.05$) difference in means of the maintenance of irrigation facility because they had the same maintenance culture.

Table 4-16: Significant difference in means on maintenance of irrigation facility at the various study areas.

Area of study			Significant	
I	J	I-J		
			0.017	SIS
	AIS 0.375 CRI-IS -0.325 0.053			
AIS	SIS	-0.375 0	0.017 CRI-IS	-0.7
CRI-IS	SIS	0.325	0.053	
	AIS	0.7	0	

`

4.15 Challenges during Irrigation

From the study, 84.3% of the respondents at SIS, AIS and CRI-IS said non-uniformity of water on crops had been the greatest challenge in respect to irrigation. According to

Marco *et al*. (1989), wind can distort the sprinkler distribution pattern that both the water and chemicals are applied non-uniformly. To solve the problem of nonuniformity, it is advisable to irrigate early in the morning or late afternoon when the wind speed is low.

The irrigation reservoir at CSIR-CRI, AIS and SIS are all silted and needs to be drudged. Even in the case of SIS and AIS aquatic weeds are covering the entire surface of the reservoir.

4.16 Source of Water and Types of Pumps

The research revealed that, SIS, AIS and CRI-IS had their water source from rivers which feeds the reservoir. At SIS, there are four electric pumps units (34 Hp each) and two (old) diesel pumps. Akumadan Irrigation Scheme had twelve (12) electric pumps (100 Hp, 55 Hp and 45 Hp) and one diesel pump is mounted. CRI-IS had five pumps, four (45 Hp) electric pumps and one (7.5 Hp) pump.

4.17 Billing of Irrigation Facility Usage

Information gathered at the study areas revealed that, irrigation usage is charged base on Irrigation Service Charges, Electricity bill or fuel cost and number of hectares (ha) under cultivation. Billing for irrigation facility usage differs from one irrigation scheme to the other and price ranges from GH¢540-1000/ha depending on the frequency of the irrigation facility usage.

CHAPTER 5: CONCLUSION AND RECOMMENDATION

5.1 Conclusions

The main objective of this study is to determine the impact of management of irrigation schemes on food productivity.

The results obtained from this study showed that the main concern of the farmers at Subinja and Akumanda Irrigation Schemes are lack of maintenance of the irrigation facilities and access to credit facility from the financial institutions. Poor records keeping and the absent of soil nutrient testing before and after planting season was due to low levels of education at Subinja and Akumanda Irrigation Schemes. Untimely and inadequate irrigation resulted in low crops yields at SIS and AIS whilst crops yields at CRI-IS were high because of timely irrigation and better irrigation management structure.

5.2 Recommendations

- Farmers‟ co-operative societies at SIS must be well organized to take up the full responsibility of the scheme. This will help avoid future disconnection of electricity to the pump station and increase crops yield.

- Information flow between (farmers and GIDA) and (irrigation technicians and researchers) and vice-versa needs to be improved for better management of the irrigation schemes.

- Crops rotation must be practiced to improve the soil fertility and also soil analysis should be carried out before and after planting season at least every two-three years.

- Irrigation must be carried out early in the morning or late afternoon to avoid high wind speed leading to non-uniformity watering of crops.

- The reservoirs at all the three locations (SIS, AIS and CRI-IS) for irrigation must be dredged as soon possible to increase the water storage capacity.

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APPENDICES

Appendix A: Soil pH

Ratings	pH
very strongly alkaline strongly	> 9.0
alkaline	9.0 - 8.5
moderately alkaline mildly	8.4 - 7.9
alkaline	7.8 - 7.4
Neutral slightly	7.3 - 6.6
acid	6.5 - 6.1
moderately acid	6.0 - 5.6
strongly acid very	5.5 - 5.1
strongly acid	5.0 - 4.5

Source: Bruce and Rayment (1982)

Appendix B: Organic carbon content

Rating	% of Organic Carbon Content
Very high	>3
High	1.8 - 3
Moderate	1 - 1.8
Low	0.6 – 1
Very low	0.4 - 0.6
Extremely low	< 0.4

.

Source: Emerson (1991); Charman and Roper (2000

Appendix C: Total Nitrogen

Rating	Nitrogen (% by weight)
very low	< 0.05
Low	0.05 - 0.15
Medium	0.15 - 0.25
High	0.25 - 0.50
very high	> 0.5

Source: Bruce and Rayment (1982)

Appendix D: Potassium

Rating	Potassium (ppm)
very low	<30
Medium	80-150
High very	150
high	>150

Source: Michigan State University (2012)

Appendix E: Phosphorus

Rating	Phosphorus (mg P/kg soil)
very low	< 5
low	5.-10
Moderate	10.-17
High	17.-25
very high	> 25

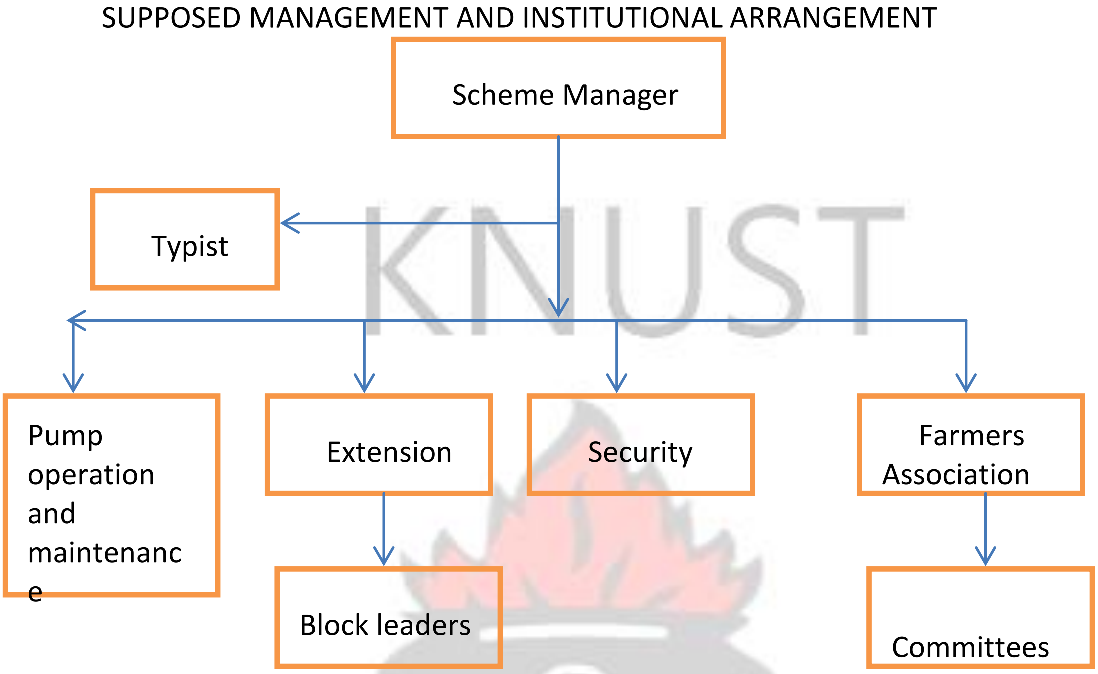
Source: Holford and Cullis (1985).

Appendix F: Exchangeable cations

Cation	Very low	Low	Moderate	High	Very high
Na	0 - 0.1	0.1 - 0.3	0.3 - 0.7	0.7 - 2	> 2
K	0 - 0.2	0.2 - 0.3	0.3 - 0.7	0.7 - 2	> 2
Ca	0 – 2	2 - 5	5 - 10	10-20	> 20
Mg	0 - 0.3	0.3 - 1	1 - 3	3 - 8	> 8

Source: Metson (1961).

Appendix G: Supposed management and institutional arrangement



Appendix H: Soil analysis

Study Blocks	PH	% O.C	% O.M	% N	Bray's Available		Exchangeable Cations				Particle-Size Analysis			
					ppm P	ppm K	Ca	Mg	Na	K	% Sand	% Silt	% Clay	Texture
SIS BK 1	5.78	0.74	1.28	0.05	40.18	33.2	1.34	0.4	0.06	0.12	73.16	12.92	13.92	Sandy Loam
SIS BK 2	5.83	0.76	1.31	0.07	28.30	38.61	1.34	0.4	0.08	0.14	79.16	6.92	13.92	Sandy Loam
SIS BK 3	5.37	1.01	1.75	0.09	16.66	31.03	2.14 1.2	1.07	0.07	0.15	71.16	8.92	19.92	Sandy Loam
SIS BK 4	5.22	0.70	1.21	0.04	14.19	27.78	4.94	0.93	0.07	0.13	73.16	8.92	17.92	Sandy Loam
AIS BK 1	5.28	1.35	2.32	0.11	14.67	91.65	4.01	2.27	0.26	0.42	67.16	14.92	17.92	Sandy Loam
AIS BK 2	5.16	1.48	2.56	0.13	43.29	67.11	8.81	1.87	0.18	0.35	53.16	22.92	23.92	Sandy Clay Loam
AIS BK 3	5.61	1.87	3.23	0.18	4.38	90.21	6.68	2.67	0.13	0.64	59.16	18.92	21.92	Sandy Clay Loam
AIS BK 4	5.95	1.91	3.30	0.15	30.30	75.53	3.47	1.87	0.19	0.4	61.16	16.92	21.92	Sandy Clay Loam
CRI-IS 1	6.09	1.00	1.72	0.08	147.49	64.23	2.67	1.34	0.17	0.32	79.16	6.92	13.92	Sandy Loam
CRI-IS 2	6.04	1.39	2.39	0.13	171.41	43.66	2.14	1.07 0.8	0.08	0.19	75.16	8.92	15.92	Sandy Loam
CRI-IS 3	5.93	0.92	1.58	0.07	9.89	48.35	2.14	0.53	0.06	0.22	71.16	8.92	19.92	Sandy Loam
CRI-IS 4	5.60	1.44	2.49	0.14	49.19	50.52			0.07	0.24	71.16	8.92	19.92	Sandy Loam

QUESTIONAIRE FOR IRRIGATION USERS The questions are for research purpose only, therefore, be rest assured that your answers are anonymous and confidential.

PART ONE

BACKGROUND INFORMATION CIRCLE THE APPLICABLE ANSWER

1. AGE:

   1) 10- 20 2) 21-30 3) 31-40 4) 41- 50 5) 51-60 6) 61 and above

2. Gender: 1) Male 2) Female

3. Occupation: 1) Farmer 2) Researcher 3) Irrigation Manager 4) Technician

4. Area of study: 1) Wenchi 2) Akomadan 3) CSIR-Crops Research Institute, Fumesua

PART TWO

1. Type of irrigation system used?

   1) Sprinkler irrigation 2) Drip irrigation 3) Open flooded

   4) Others (specify)....................................

2. Do you irrigate daily? 1) Yes 2) No

3. How many hours do you irrigate the crops?

   1) One hour 2) Two hours 3) Three hours 4) Four hours 5) Five hours 6) Six hours

   7) Seven hours 8) Eight hours

4. Do you maintain the irrigation facility regularly? 1) Yes 2) No 5. How often do you maintain the irrigation facility?

   1) Once a month 2) Twice in a month 3) Once a year 4) Twice in a year

   5) Three times in a year

6. In the use of irrigation for crop growth, are there any challenges you have encountered or envisage? 1) Yes 2) No

7. If yes, could you mention the challenges? ---

-

....

8. In which way have you resolve these challenges? ....

....

....

....

9. Have you had any specialized training on irrigation? 1) Yes 2) No

10. How long have you practised irrigation? ....

11. Were the beneficiaries of the irrigation scheme consulted before the installation of the irrigation facility? 1) Yes 2) No

12. If yes, what was your contribution towards the establishment of the irrigation scheme?

....

....

....

PART THREE

13. What type of farming system do you practice?

    1) Mono-cropping 2) Mixed cropping 3) No tillage 4) Crop rotation

    5) Others (specify) …………………

14. What types of crops are grown on your field?

    1) Maize 2) Okra 3) Tomatoes 4) Cowpea 5) Cassava 6) Groundnut

    7) Others (specify).....................................

15. What is the irrigable farm size (Ha) for sprinkler irrigation? ……………………..

16. What is the irrigable farm size (Ha) for drip irrigation? ……………………………
17. What types of crops are grown under irrigation?

1) Maize 2) Okra 3) Tomatoes 4) Cowpea 5) Cassava 6) Groundnut

7) Others (specify).....................................

18. What quantity of produce harvested under irrigation?

Crops	**Quantity (sac, basket, etc)**
Maize	
Okra	
Tomatoes	
Cowpea	
Groundnut	
Cassava	
Others (specify)	

19. Do you carry out soil analysis before or after planting? 1) Yes 2) No

20. If yes, how often? ....

21. If no, why? ....

22. What type of fertilizer do you use to fertilize your crops?

1) NKP 2) Urea 3) Ammonia 4) Others (specify)........................

23. What method of fertilizer application is practiced?

1) Side dressing 2) Broadcasting 3) Ring application
4) Others (specify) ……………….

24. What type of weedicides/herbicides do you use?

1) Roundup 2) Sanphosate 3) Kondem 4) Sinosate

5) Others (specify)..........................

25. Are you able to irrigate all your irrigable farm land? 1) Yes 2) No

26. If no, why?

1) Shortage of water

2) Overhead cost of irrigation is expensive

3) Poor quality of irrigation facility

4) Poor maintenance of irrigation facility

5) Others (specify)..

27. What benefit have you obtained from the irrigation scheme?

1) Increase in productivity

2) Enhance employment during dry season

3) Aid in the growth of different crops

4) Others (specify) …………………………………….

Rank the following important factors which affect your crop output (yield).
1 = excellent 2= very good 3= good 4= Bad

Factors	Rank	Extent of the problem		
		Severe	Not severe	Considerable
Land				
Water				
Labour				
Credit facility				
Weeds control				
Fertilizer				
Transportation				
Market				
Storage				
Inadequate technical know how				

Labour availability, land preparation and crop management

Activity	Farmer	Hired Labour	Spouse	Children	Others
Land preparation					
Planting/ transplanting					
Irrigating					
Weeding					
Agro-chemical					
Harvesting					
Storing					
Others (specify)					

If hired labour, complete the following.

Activity	number of persons	Number of days	Cost/person/day (GH ¢)	Total cost
Land preparation				
Planting/ transplanting				
Irrigating				
Weeding				
Agro-chemical				
Harvesting				
Storing				
Others (specify)				

PART FOUR

28. Where is the source of water for irrigation?

1) Lake 2) River/ stream 3) Ground water

4). Others (specify)..

29. What type of water delivery system is used to convey the water onto the farm?

1) Electricity powered motor pumps
2) Diesel powered motor pumps
3) Diversion using gravity
4) Others (specify)..

30. In case of electricity outage how is irrigation carried out?

1) The use of generator to power the motor
2) Solar panel system to power the motor
3) Others (specify) …………………………….

31. In the case of fuel shortage or fuel price increase how is irrigation carried out?

……………………………………………………………………………………

32. Who operate the irrigation facility?

1) IDA
2) Irrigation technicians
3) Individual farmers
4) Others (specify) ……………………………………………

33. Is there a mechanism for pricing the irrigation facility usage? 1) Yes 2) No

34. If yes, what mechanism is used?

....

....

35. If yes to question 33, what is the price per season per Ha charged for the use of irrigation facility? ....
36. Who maintains the irrigation facility? (weeding, controlling laterals, etc)
    1) IDA
    2) Technicians
    3) Individual farmers
    4) Others (specify)..

Thank you.