UNIVERSITY FOR DEVELOPMENT STUDIES

PERFORMANCE ASSESSMENT OF IRRIGATION SCHEMES IN NORTHERN GHANA USING COMPARATIVE PERFORMANCE INDICATORS

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THOMAS APUSIGA ADONGO (BSc. Agriculture Technology)

(UDS/MSWC/0017/13)

A THESIS SUBMITTED TO THE DEPARTMENT OF AGRICULTURAL MECHANISATION AND IRRIGATION TECHNOLOGY, FACULTY OF AGRICULTURE IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTER OF PHILOSOPHY DEGREE IN SOIL AND WATER CONSERVATION AND MANAGEMENT

2015

DECLARATION

DECLARATION BY CANDIDATE

I hereby declare that this thesis is the result of my own original work and that no part of it has been presented for a degree in this university or elsewhere. The work of others, which served as sources of information for this study, has been duly acknowledged in the form of references.

Thomas Apusiga Adongo ---------------------------------- ------------------------------

(UDS/MSWC/0017/13) Signature Date

DECLARATION BY SUPERVISORS

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

Ing. Dr. Felix K. Abagale ------------------------------ ---------------------------------

(Principal Supervisor) Signature Date

Ing. Prof. G. Kranjac-Berisavljevic --------------------------- --------------------------------

(Co- Supervisor) Signature Date

ABSTRACT

The study assessed the performance of irrigation schemes in Northern Ghana using comparative performance indicators. It was carried out in Tono, Vea, Doba, Libga, Bontanga and Golinga irrigation schemes in the Upper East and Northern Regions of Ghana. The performance for the years of 2010 - 2014 were evaluated using selected comparative indicators, classified into five (5) groups, namely; water delivery, physical structures, financial, environmental condition and agricultural production performance. The problems of the schemes were also identified. Field measurements, laboratory analysis, interviews and literature review were used for data collection. The study revealed that the flow lengths of the main canals at the Tono, Vea, Doba and Libga irrigation schemes have reduced due to low reservoir water levels and infrastructural deficiencies. The developed irrigable area in Tono, Vea and Doba was under-utilised with irrigation rates ranging from 8 – 54 % while that of Libga, Bontanga and Golinga was put to full capacity use with irrigation rates ranging from 91 – 100 %. Irrigation service charges recovery was poor in the Vea, Libga and Bontanga schemes with recovery efficiency ranging from 19 – 52 % whereas the recovery was good in the Tono, Doba and Golinga schemes with efficiency ranging from 75 – 96 %. The irrigation schemes were not financially self-sufficient as they recorded low rates of 1.3 – 59 %. The Doba, Vea and Tono schemes recorded low sustainability of irrigated area indices 0 – 49 % whereas the Libga, Bontanga and Golinga recorded high indices of 95 - 100 %. Most of the irrigation infrastructure in the Tono, Vea, Doba and Libga schemes were in very poor working condition with high poor structure indices of 30 – 96 %. The road networks of the Tono, Libga, Bontanga and Golinga schemes were in good working condition as they recorded roads passability efficiency of 96 – 100 % whereas that of Vea scheme were severely eroded leaving gullies. Salinity and sodicity were observed as problems in the Libga scheme. The production of vegetables in all the irrigation schemes had drastically declined in recent years due to nematodes infestation. Irrigated farming at the upstream of reservoirs and destruction of reservoir protection vegetation were observed in all the schemes. Farmers in the irrigation schemes have responded to some of the constraints and problems by adaptation, improvisation, maintenance and abandonment. The Tono, Doba, Vea, and Libga irrigation schemes needed to be rehabilitated to improve performance.

DEDICATION

To my beloved mother, Theresa Adompoka Adongo. May your soul rest in perfect peace.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF ACRONYMS AND ABBREVIATIONS

BOCOPMU	Bontanga Co-operative Production, Processing and Marketing Union
DIFA	Doba Irrigation Farmers Association
DMC	Dam-site Management Committee
DS	Downstream
EC	Electrical Conductivity
EEC	European Economic Community
EISCR	Efficiency of Irrigation Service Charges Recovery
ESP	Exchangeable Sodium Percentage
FAO	Food and Agriculture Organisation
FBOs	Farmers Based Organisations
FSRs	Financial Self-sufficiency Rates
GIDA	Ghana Irrigation Development Authority
GOCIFS	Golinga Co-operative Irrigation Farming Society
GoG	Government of Ghana
GPS	Global Positioning System
GH¢	Ghana Cedi
ha	Hectare
ICOUR	Irrigation Company of Upper Region
IDC	Irrigation Development Center
IFAD	International Fund for Agricultural Development
IIMI	International Irrigation Management Institute
ISC	Irrigation Service Charges
ITFC	International Tamale Fruit Company
km	Kilometre
LACOSREP	Land Conservation and Smallholder Rehabilitation Project
LIFA	Libga Irrigation Farmers Association
M	Metre
MiDA	Millennium Development Authority
MoFA	Ministry of Food and Agriculture
MOM	Management, Operation and Maintenance
MS	Midstream
NRCS	National Resources Conservation Service
PIM	Participatory Irrigation Management
PSI	Poor Structure Index
t/ha	Tonnes per hectare
US	Upstream

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CHAPTER ONE

INTRODUCTION

1.1 Background

Water is a valuable resource for agricultural production. Scarcity and misuse of water resources pose serious and growing threats to life and sustainable development. As water is a limiting factor to agriculture in most parts of the world, increasing yields and sustaining food production depends mainly on irrigation. Therefore, development and protection of water resources, such as irrigation dams are crucial (Degirmenci *et al.*, 2003). Takeshi and Abdelhadi (2003) projected that within the next two decades, many countries in the world are expected to face insufficient water availability to satisfy their agricultural, domestic, industrial and environmental water demands. The world population is projected to grow by about 30 % by the year 2025, reaching 8 billion people. Dorsan *et al.* (2004) stated that the development and maintenance of artificial water resources such as irrigation dams is crucial to secure and maintain food security for the fast increasing population in the world. Irrigation is essential for world food production (Tellefson and Hogg, 2007). Similarly, Behailu *et al.* (2005) remarked that the struggle to secure food security in Africa should be assisted by increasing production through irrigated agriculture.

Africa has promoted irrigated agriculture as a means of ensuring food security as well as improving the standards of living of the rural people for many years (Hillel, 1997). Various studies have shown that irrigation schemes improve food security and livelihoods of rural farmers in Africa (You *et al.*, 2010; Oni *et al.*, 2011; Chazovachii, 2012). However, despite their important role in improving livelihoods of rural communities in Africa, irrigation schemes have had low performance; generally, they had less than 50 % efficiency due to poor infrastructure, limited farmer participation in the management of water, ineffective extension and mechanisation services and lack of reliable markets (Backeberg *et al.*, 1996; Arcus, 2004). World Bank study in 2008 indicated that about 30 % of the irrigation infrastructure assets in sub-Saharan Africa need revitalization and rehabilitation because they no longer perform well due to a combination of infrastructural, socio-economic, institutional and governance problems (Briceno-Garmendia *et al.*, 2008; Mwendera and Chilona, 2013).

Modern irrigated agriculture started in Ghana in 1960s and as at 2007, about 33,800 ha of Ghana's land was under irrigation (Namara *et al.*, 2011). Kyei-Baffour and Ofori (2006) argued that Ghana cannot achieve economic growth and poverty reduction targets without significant improvement in the agricultural sector, so extensification and intensification of irrigation is the key to achieving this goal. However, Miyoshi and Nagayo (2006) and Namara *et al*. (2011) indicated that the twenty-two (22) public irrigation schemes which are being managed by Ghana Irrigation Development Authority (GIDA) and Irrigation Company of Upper Regions (ICOUR) and the numerous small reservoir schemes which are managed by Water Users Associations (WUAs) are battling with several problems, mainly infrastructural and administrative and therefore cannot perform to their fullest potentials, despite their promise as engines of agricultural growth. The current irrigated area of 5,745 ha in all the schemes is far below the initial command area of 8,192 ha when the schemes were completed.

Considering the huge investment costs that come with the development of irrigation schemes and the crucial roles they play in food security, employment generation, among many others in human livelihoods, many researchers and authors, including Ijir (1994), Bos (1997), Molden *et al.* (1998), Sener *et al.* (2007), among others have developed and used several performance indicators to evaluate irrigation systems performance worldwide.

Bos (1997) mentioned that the most significant purpose of irrigation performance evaluation is to provide continuous information flow to project management to assess whether or not performance is sufficient. It allows management to determine the required measures to reach desired performance levels. It also facilitates the determination of possible problems and thus, improves the performance of irrigation schemes. Molden *et al.* (1998) also catalogued a variety of reasons for performance evaluation of irrigation schemes which included improving system operations, assessing progress against goals, assessing the general health of a system, diagnosing restrictions and comparing the performance of a system with others or with the same system over time. To achieve these, comparative performance indicators should be used.

Sener *et al.* (2007) remarked that due to the high cost of developing new irrigation schemes in recent years, it is more preferable to continuously assess the performance of the existing irrigation schemes to improve their performance than developing new ones. The authors reiterated that performance evaluation of irrigation schemes helps in the identification of the problems of the schemes. This will help the scheme managers to develop new strategies and ways of solving the problems to ensure higher performance in future. Similarly, Cakmak *et al.* (2009) pointed out that performance evaluation studies have gained significance since the early 2000s because it is the most practical tool to assess the success and failure of any irrigation scheme. Unlike in the developed countries, performance evaluation studies of irrigation schemes are not sufficient in the developing countries both in the aspects of their number and content. Through performance evaluation, reasons for low performances can be determined and related measures taken to improving overall system performance.

Using comparative performance indicators, several irrigation schemes worldwide have been successfully evaluated and the causes for the good or poor performances of the schemes identified and discussed. The performances of 18 irrigation schemes in 11 different countries in Africa were evaluated using the nine comparative indicators developed by the International Water Management Institute (Molden *et al.*, 1998). Furthermore, the performance of 29 irrigation schemes in the province of Antalya, Turkey (Sayin *et al.*, 2013), 3 small-scale irrigation schemes in the Tekeze Basin in Ethiopia (Behailu *et al.*, 2005) and Wurno Irrigation Scheme in Nigeria (Ijir, 1994) were evaluated with comparative performance indicators.

1.2 Problem Statement and Justification

In many parts of Africa, food security and poverty is a major cause of concern. In view of this, pragmatic and prudent measures are being taken to remedy the "chronic" food crisis and poverty. The construction of small-scale, medium-scale as well as large-scale irrigation schemes is a step to bring the food shortages and poverty under control. Ghana Irrigation Development Authority and Japan International Cooperation Agency (GIDA and JICA) (1996) stated that most irrigation schemes are performing below average, while the others have failed completely. Similarly, Sayin *et al.* (2013) reported that many of the irrigation schemes, especially the state-managed ones experience many drawbacks and cannot perform to expectation.

Namara *et al.* (2011) reported that majority of the public irrigation schemes in Ghana are faced with significant managerial, socio-economic, technical, environmental problems among many others and these setbacks hinder their performances. Irrigation has even been abandoned at some schemes including Amate Irrigation Scheme (Eastern Region), Kikam Irrigation Scheme (Western Region), Akumadan Irrigation Scheme (Ashanti Region) and Anum Valley Irrigation Scheme (Ashanti Region) due to malfunctioning of major infrastructures (Namara *et al.*, 2011).

In 2014, the Chiefs and Elders of the Bolgatanga Traditional Area made a clarion call on the Government of Ghana, to rehabilitate the Vea Irrigation Scheme to rescue it from total collapse. They indicated that since the dam was fully constructed in the 1980, it has never seen any major rehabilitation and all the facilities are in poor state. The canals and laterals networks are all in deplorable conditions and as a result, many farmers have abandoned their fields (News Ghana, 2014).

Though several authors have researched into the socio-economic impact of many irrigation schemes in Northern Ghana, there is scarce information on comparative performance assessment on them. It is important that the performance of the irrigation schemes is evaluated to keep track of whether or not the objectives of their construction are being achieved. From performance assessment, reasons for low performances can be determined and related measures taken to improving overall system performance. This study was therefore aimed at keeping track of whether or not the objectives of the construction of the six (6) selected irrigation schemes in northern Ghana are being achieved as well as making available literature on comparative performance assessment indicators and the conditions of the infrastructure of the irrigation schemes.

1.3 Objectives of the Study

Main Objective: The main objective of the study was to assess the performance of six (6) irrigation schemes in Northern Ghana using comparative performance indicators.

Specific Objectives: The specific objectives were:

- To assess the performance levels of the irrigation schemes in relation to water delivery, physical and financial structures, production levels and environmental state.
- To compare the performance levels of the selected irrigation schemes.
- To identify the problems of the irrigation schemes which affect efficient performance.

1.4 Hypotheses of the Study

- **H_o1:** The performance levels of the irrigation schemes in relation to water delivery, physical and financial structures, and crop production are poor.
- **H_A1**: The performance levels of the irrigation schemes in relation to water delivery, physical and financial structures, and crop production are good.
- **H_o2**: The performance level of one irrigation scheme is not significantly different from the other.
- **H_A2**: The performance level of one irrigation scheme is significantly different from the other.
- **H_o3**: The irrigation schemes are faced with technical, financial, managerial and environmental problems.
- **H_A3**: The irrigation schemes are not faced with technical, financial, managerial and environmental problems.

1.5 Structure of the Thesis

The thesis is organised into five main chapters. Chapter One (1) presents an introduction to the study which comprises; background to the study, problem statement and justification, objectives of the study and hypotheses of the study. Chapter Two (2) provides a review of the relevant literature relating to definition of irrigation, objectives for irrigation development, trend of irrigation development in sub-Saharan Africa and Ghana, management of irrigation schemes in Ghana, performance assessment of irrigation schemes, performance levels of irrigation schemes in Africa and the impact of irrigation on soil quality. Chapter Three (3) outlines the materials and methods used in the study; description of study areas, data collection methods and comparative performance assessment indicators used in the study. The fourth Chapter presents the results and discussions and finally the fifth Chapter presents the conclusions and recommendations of the study.

CHAPTER TWO

LITERATURE REVIEW

2.1 Definition of Irrigation

Mutsvangwa and Doranalli (2006) defined irrigation as the ministering to the land through the artificial application of water to ensure double cropping as well as steady supply of water in areas where rainfall is unreliable. Irrigation farming is another way of improving agricultural production both in subsistence and commercial farming. According to Shirsath (2009), irrigation is the artificial application of water to the soil usually for assisting in growing crops. It is critical and a vital input to production process and pivotal to agricultural, social, and economic growth of nations. It has two primary objectives namely; to supply essential moisture for plant growth, which includes transport of essential nutrients, and to leach or dilute salts in soil.

2.2 Objectives of Irrigation Development

Ijir (1994) mentioned that in discussing irrigation performance criteria and indicators, it is worthwhile looking at the objectives set for irrigation development, as it is against these that performance should be measured. It is widely accepted that the issue of irrigation performance is closely linked to objectives. Therefore, in the process of understanding the behaviour of irrigation systems and assessing their performance it is necessary to have a clear idea of the objectives for which these projects were developed, and what they aim to achieve.

Table 2.1: Highlights of National Irrigation Objectives in some Commonwealth Countries

Country	Main Irrigation Objectives
India	- Reduce fluctuation in food crop production - Employment generation - Save foreign exchange and increase foreign exchange earnings - Income distribution
Indonesia*	- Increase food production - Support transmigration programme - Promote farmers participation and responsibility for operation and maintenance of tertiary system
Kenya	- Raise food production and reduce probability of crop failure - Earn foreign exchange and reduce imports - Employment generation - Equitable income distribution - Settlement programme
Malaysia	- National self-sufficiency in rice - Raising productivity and income of rural paddy farmers
Bangladesh	- Increase domestic food production and reduce import - Create employment - Flood control - Income redistribution
Nigeria	- Security of food production - Import substitution and foreign exchange earnings - Employment generation - Income distribution
Sri Lanka	- Self-sufficiency in food - Increased cropping intensity - Yield increases

**Not part of the Commonwealth, invited delegation.*

Source: (Commonwealth Secretariat, 1978; Ijir, 1994).

Keller (1990) summarised and categorised the above objectives for irrigation development (Table 2.1) into four, namely; for commercial production, for socio-political reasons, for environmental reasons, and for geo-strategic reasons. Kuscu *et al.* (2009) also mentioned that irrigation is of major importance in many countries in terms of agricultural production and food supply, employment generation, and provision of incomes for the rural people

2.3 Trend of Irrigation Development in Sub-Saharan Africa

The earliest attempts at irrigation development in the sub-Saharan Africa evolved from farmers' own adjustments to a tropical environment as seen in many small-scale indigenous systems in Nigeria, Burindi, Chad, Sudan, Ghana, Guinea, Sierra Leone, Senegal, Somalia, Mali, Madagascar, Niger, Tanzania, and Kenya. However, in recent times, the adoption of irrigation has tended to be in response to governmental initiatives. Irrigation development in Africa has been classified into two categories; formal and informal systems (FAO, 1986; Ijir, 1994).

According to FAO (1987), Courier (1990) and Ijir (1994), irrigation in Africa is not as well developed as in other parts of the world, due to a variety of reasons. Some of the most cited reasons are that the need for irrigation and irrigation potential do not often coincide; inadequate water supplies; difficult terrain; absence of irrigation traditions among small farmers; relatively lower population densities (compared to say Asia); and availability of alternative farming systems including rain-fed and livestock agriculture.

Carruthers *et al.* (1997) argued that the last 50 years have seen massive investments in large-scale public surface-irrigation infrastructure as part of a global effort to rapidly increase staple food production and avoid devastating famine. Investment in irrigation accelerated in the 1960s and 1970s, with area expansion in developing countries at 2.2 % per year, reaching 155 Mha in 1982. According to Rosegrant and Svendsen (1993), the unprecedented high food prices during the two food crises in the 1970s induced huge irrigation investments in developing countries.

Various studies conducted on the scale of development of irrigation in sub-Saharan Africa, gave different figures of irrigated areas. According to FAO (1995), the sub-region has an irrigation potential of approximately 42 Mha out of which, only 13.33 % (5.6 Mha) is actually irrigated. More recent data from FAO (2005) shows that actual irrigated area in the sub-region had increased by 1 Mha. This increases the fraction of actual irrigated land to 15.71 %. However, Shirsath (2009) reported that the annual growth rate of irrigation systems in sub-Saharan Africa, particularly large-scale public schemes, has rather decreased since the late 1970s and is currently 2 %, which is the slowest in the world.

2.4 Irrigation Development in Ghana

Records date irrigation to have begun about a century ago, even though serious irrigation efforts date back to the past 50 years. Irrigation development in Ghana has followed the global irrigation investment pattern, with a peak in 1970. However, the scale of overall development has remained low (Namara *et al.*, 2011). Of the gross estimated 2.9 million ha of potentially irrigable area, including valley bottoms and floodplains (Namara *et al.*, 2010), less than 2 % has been developed. Between 1960 and 1980, approximately 19,000 ha of irrigated land have been developed. As of 2007, the area under irrigation had expanded to 33,800 ha (Namara *et al*, 2011).

Namara *et al.* (2011) observed that irrigation systems can be classified into two types: conventional systems which are mainly initiated and developed by the Ghanaian government or various NGO's and emerging systems, which are initiated and developed by private entrepreneurs and farmers. Though little is officially known about emerging systems they are expanding at a rapid rate, mainly fuelled by access to relatively affordable pumping technologies and export markets for horticultural crops.

2.4.1 Classification of Irrigation Schemes in Ghana

The two common methods for categorising irrigation schemes in Ghana have been by organisational structure and size. Structural classifications usually distinguish between formal and informal systems. Formal systems are those developed and sometimes managed by the government, often with donor funding. In Ghana, most formal systems were developed between the late 1940s and 1970s. Informal systems are those developed and managed by communities or individuals. Informal schemes are often ignored in statistics and policy, but can account for the majority of irrigation in many countries, like in Ghana (IWMI, 2007). Size classifications usually divide irrigation schemes into small (up to 200 ha), medium (200 - 1,000 ha) and large (more than 1,000 ha) (Namara *et al.*, 2010).

2.4.2 Public Irrigation Schemes

Miyoshi and Nagayo (2006) and Namara *et al.* (2010) reported that Ghana's irrigation sector is often equated to public or communal surface irrigation schemes, particularly in the twenty-two (22) public irrigation schemes managed by the Ghana Irrigation Development Authority (GIDA) and Irrigation Company of Upper East Region (ICOUR). These 22 Pubic irrigation schemes of varying sizes have been developed across the entire country, covering a total developed irrigable area of 8,745 ha, but this area has been decreasing year after year due to infrastructural deficiencies. Namara *et al.* (2011) stated that public irrigation schemes of late, play an insignificant role in the overall agricultural economy of Ghana, despite substantial efforts to develop the sector since 1950s. Capacity under-utilization is a major problem in many existing irrigation facilities. Table 2.2 indicates the number of public irrigation schemes currently existing in Ghana across the regions.

Table 2.2: Public Irrigation Schemes (as of 30th June, 2003)

No.	District	Area of developed land (ha)	Area of irrigated land (ha)	Irrigation type	Target crops	Remarks
1	Ashaiman	155	56	Gravity	Rice /V	
2	Dawhenya	200	150	Gravity & P	Rice	
3	Kpong	2,786	616	Gravity	Rice/V	
4	Weija	220	0	Pump	Vegetables	Abandoned (2003)
5	Afife	880	880	Gravity	Rice	
6	Aveyime	60	0	Gravity & P	Rice	Abandoned (1998)
7	Kpando Torkor	40	6	Pump (P)	Vegetables	
8	Mankessim	17	17	Pump	Vegetables	
9	Okyereko	81	42	Gravity & P	Rice	
10	Subinja	60	6	Pump	Vegetables	
11	Tanoso	64	15	Pump	Vegetables	
12	Sata	34	15	Pump	Vegetables	
13	Akumadan	65	0	Pump	Vegetables	Abandoned
14	Anum Valley	89	0	Gravity & P	Rice	Abandoned
15	Amate	101	0	Pump	Rice	Abandoned
16	Dedeso	20	8	Pump	Vegetables	
17	Kikam	27	0	Gravity & P	Rice	Abandoned
18	Bontanga	450	390	Gravity	Rice & V	
19	Golinga	40	16	Gravity	Rice & V	
20	Libga	16	16	Gravity	Rice & V	
21	Tono	2,490	2,450	Gravity	Rice & V	
22	Vea	850	500	Gravity	Rice & V	
	Total	8,745	5,192			

(Source: Miyoshi and Nagayo, 2006) *P - Pump and V - Vegetables*

2.4.3 Small Reservoirs

According to Namara *et al.* (2010), small reservoirs are classified into two sub-groups namely, small dams and dugouts. The main distinguishing attributes are: size, priority of water use, structural details and their management system. Dugouts are smaller in surface area, the volume of water they impound and the number of beneficiaries are usually small. Unlike the small dams, dugouts have no intake structures, canals and laterals. Dugouts usually serve one to two villages, and are planned primarily for domestic and livestock with limited use for crop irrigation.

Numerous NGOs and donors, including International Fund for Agricultural Development (IFAD), Plan Ghana, Red Cross, Action Aid, Land Conservation and Smallholder Rehabilitation Project (LACOSREP I) and LACOSREP II have been involved in construction of small reservoirs and dugouts for irrigation and domestic water supply starting as far back as 1970s and 1980s. In 2008, GIDA and MoFA inventoried small reservoirs and dugouts for Ghana's ten administrative regions and 786 small reservoirs and 2,606 dugouts were identified with an estimated total of irrigated area of 6,116 ha, which is comparable to the area irrigated by the 22 public irrigation schemes (GIDA and MoFA, 2008).

According to Birner (2008), small reservoirs in the country are faced with significant physical, social and institutional problems. These include: breakage of canals, choking of canals with weeds, construction delayance, and lack of organisations for managing and sustaining the schemes. For instance, a Water User Association (WUA) could be identified for only 31 of the 126 small reservoirs visited in Upper East. For the 31 reservoirs that had a WUA, the participation of farmers in the design, construction and management of the infrastructure was limited. Table 2.3 presents a summary of small dams and dugouts across the 10 regions of Ghana.

Table 2.3: Summary of Small Dams and Dugouts in the 10 Regions of Ghana

No.	Region	Number of		Total No. of Small dams and dugouts	Cultivated Area (ha)
		Small Dams	Dugouts		
1	Greater Accra	35	218	253	120.0
2	Upper West	84	54	138	712.0
3	Upper East	149	129	278	895.0
4	Eastern	75	115	190	438.0
5	Volta	167	136	303	103.0
6	Central	23	265	288	342.0
7	Ashanti	22	219	241	677.0
8	Western	50	783	833	820.0
9	Brong-Ahafo	50	289	339	1,360.
10	Northern	131	398	529	649.0
	Total	786	2,606	3,392	6,116.0

Source: (GIDA and MoFA, 2008)

2.5 Management of Irrigation Schemes in Ghana

Ghana Irrigation Development Authority (GIDA) is a government organisation that comes under the jurisdiction of the Ministry of Food and Agriculture. It was established in 1977with the responsibility of surveying candidate sites for irrigation development, designing and constructing facilities, managing and maintaining irrigation-project schemes under further development, and disseminating farming technology among farmers (Miyoshi and Nagayo, 2006).

The Irrigation Company of Upper Region (ICOUR) was established in 1985 to manage the Tono and Vea Irrigation Schemes in the Upper East Region of Ghana. Initially the organisation was supported from internally generated sources of income with the income generated used for organisation and management of the schemes and paying staff salaries. Now, staff salaries as well as some operation and management costs are covered by Government of Ghana. Major repairs and maintenance are also financed by Government of Ghana (Namara *et al.*, 2011).

Since the establishment of GIDA, it has developed and managed Public irrigation systems utilising government subsidies and public funds to cover staff costs. However, as part of the government's policy of structural adjustments, GIDA reduced its staff from roughly 1,500 personnel (in the 1980s) to 739 in 1993, 441 in 1994, and 377 in 1995. As of 2004, only 304 employees remained. These included 121 head office staff (including Irrigation Development Center (IDC) staff), 73 staff members at the Regional Offices, and 110 staff members at the Site Offices (Miyoshi and Nagayo, 2006).

As a result of the dramatic reduction in GIDA's personnel and budget as part of the government's structural adjustments, early 1990 saw fundamental changes to the management framework of public irrigation schemes. The previous "Government-led Management" system had become difficult to maintain, and so "Participatory Irrigation Management (PIM)" was introduced, whereby beneficiary farmers and others could manage the irrigation facilities (Miyoshi and Nagayo, 2006). Since the introduction of the system of PIM in early 1990, operation and management of irrigation facilities in public irrigation schemes has been mostly conducted using funds collected from irrigation service charges paid by beneficiary farmers. Irrigation service charges are determined by factors such as the irrigated land area of each farmer, the irrigation type of the district in question (pump, gravity, etc), and the standard of the facilities. Therefore irrigation service charges per unit area (ha per season) differ by amounts ranging from tens to several hundred US dollars. For example in 2003, the irrigation service charge for the Dawhenya Irrigation scheme was $110/ha per year due to extensive pumping, while in the Afife and Ashaiman Irrigation schemes, which are served by gravity, the irrigation service charge was $22/ha per year (Miyoshi and Nagayo, 2006).

Currently, in Ghana, small reservoir projects are managed by the users of the facilities namely, Water Users Associations (WUA), ensuing government's policy of decentralisation, diversification and privatisation of the economy (Gyasi, 2005). For effective management and utilisation of the facilities, under LACOSREP I and II, management and ownership of the rehabilitated dams were transferred to the beneficiaries and that the formation or prior existence of a functional WUA was in fact a prerequisite for a given community to have its dam rehabilitated (MoFA and IFAD, 1998).

The advent of the WUA which is an eclectic organisation of user groups made up of gardeners, fishermen and livestock owners who have stakes in the dam infrastructure and their services have yielded good results in terms of management, operation and maintenance (Abaka-Yankson, 2009). The association collects a fixed sum (levy) from every participating farmer and uses it for repairs and maintenance of irrigation canals, dam walls, valves and spillways. Decisions on water distribution arrangements as well as the amount to levy for irrigation water for a particular season were jointly taken at a general meeting of the WUA (MOFA/IFAD, 1998). In the management of the small reservoirs, the Ghana Irrigation Development

Authority (GIDA) provides technical personnel to support the WUAs when the need arises (Mdemu, 2008). Elected representatives of the user groups constitute the Dam-site Management Committee (DMC), which is responsible for the management of the system (MOFA/IFAD, 1998).

The management functions of the WUAs were outlined by Abaka-Yankson (2009) as follows:

- Maintenance of the irrigation system (control structures, canals, laterals),
- Maintenance of dam infrastructure (dam wall, spillway and reservoir),
- Grassing of dam embankment and bunds against erosion,
- Protection of the catchment area to control erosion,
- Protection of crops from grazing animals,
- Responsibility for land allocation and water distribution,
- Collection of water levies and funds mobilisation,
- Record keeping,
- Formulation and enforcement of bye-laws and
- Conflict resolution.

2.6 Performance Assessment of Irrigation Schemes

Performance in the context of this study refers to the degree of attainment of the objectives, targets or expectations set for an irrigation scheme, or components of it. This is usually measured by evaluating a set of performance criteria or indicators (Ijir, 1994). In order to assess or actually evaluate the performance of irrigation schemes, there is the need for performance indicators. Evaluation is very essential for effective planning and management (Dorsan et *al.*, 2004). According to Schultz and De Wrachien (2002), performance assessment is an increasingly relevant concept in present-day irrigation and drainage systems. This is because the deterioration of a significant part of the large-scale systems developed in the second half of the 20^{th} century is very apparent. Also, performance indicators are measurable variables that describe the condition of a system and its changes over time and space. They enable the functioning of the system to be assessed against an agreed set of criteria.

2.6.1 Reasons for Performance Assessment

Small and Svendsen (1992) and Ijir (1994) outlined three (3) broad types of performance assessment of an irrigation scheme and they include: operational performance monitoring, accountability assessment, and intervention assessment. Ijir (1994) stated that there might be several cases for carrying out performance assessment of an irrigation scheme which might include:

- When we know something is wrong and we wish to find out what is causing it,
- When we want, as part of the management process, to know how we are doing so that we can improve it and,
- When a researcher, using the case study approach, seeks to understand the detailed workings of an irrigation scheme in order to draw generalised inferences.

Cakmak *et al.* (2004) and Kuscu *et al. (*2009) indicated that performance assessment enables verification of the degree to which targets and objectives are being realised. It also provides different stakeholders (system managers, farmers and policy makers) with a better understanding of how a system operates. It can help determine problems and identify ways and means of improving system performance. Also, Cakmak *et al.* (2009) stated that performance assessment is the most practical tool to assess the success of any changes in irrigation management. That is why performance evaluation studies have gained significance since the early 2000s. It is only by the performance evaluation that, the reasons for low performances can be determined, related measured taken and overall system performance can be improved. Performance evaluation also facilitates the determination of possible problems and thus improves the performance of irrigation schemes.

2.6.2 Performance Criteria and Indicators

Various researchers and authors have developed and used a number of performance indicators for studies of irrigation performance. Usually these indicators are related to some objectives or targets of the irrigation system. It is widely recognized that irrigation systems' general objectives have to be translated into specific criteria by which the performance can be evaluated (Ijir, 1994).

Ijir (1994) developed and used 18 comparative performance indicators to evaluate the performance of the Wurno Irrigation Scheme in Nigeria. The indicators are as follows:

1. Scheme development ratio = $\frac{Adev}{Ap}$ x 100 % --------------------------------- *Equation (2.1)*

Where:

Adev - Total area of the scheme actually developed and provided with irrigation facilities (ha) and,

Ap - Potential irrigable area within the scheme earmarked for development (ha)

2. Water availability index = $\frac{Wa}{Wd}$ x 100 % ------------------------------------- *Equation (2.2)*

Where:

Wa = Total amount of water available from the scheme water supply sources (m^3/y) and,

Wd = Scheme water needs to meet crop water requirements for the highest planned cropping intensity (m^3/y).

3. Efficiency of main system capacity = $\frac{Ca}{Cd}$ x 100 % ------------------------- *Equation (2.3)*

Where:

Ca - Actual limiting canal capacities at typical sections of the main system (m^3/s),

Cd - Designed canal capacities for same sections (m^3/s).

4. Scheme command area capacity = $\frac{Ac}{Adev}$ x 100 % -------------------------- *Equation (2.4)*

Where:

Ac - Scheme total area commanded by gravity flow (ha) and,

Adev - Total developed irrigable area (ha).

5. Extent of main system flow lengths = $\frac{La}{Ld}$ x 100 % ----------------------- *Equation (2.5)*

Where:

La - Actual length of canals sections still flowing (km) and,

Ld - Total length of main system canals constructed (km).

6. Structure condition index = $\frac{Ng}{N}$ x 100 % ------------------------------------ *Equation (2.6)*

Where:

Ng - Actual number of structures in good condition (safe, working normally and attaining design standards) and,

N - Total number of structures constructed within the system.

7. Environmental stability index = $\frac{Aaf}{Adev}$ x 100 % ------------------------------ *Equation (2.7)*

Where:

Aaf - Total scheme area not affected by environmental problems of waterlogging, salinity, erosion (ha) and,

Adev - Total developed irrigable area (ha).

8. Crop planting date indicator = $\frac{Np}{N}$ x 100 % ---------------------------------- *Equation (2.8)*

Where:

Np - Number of farmers planting within the recommended planting period for a specified crop in a season and,

N - Total number of farmers engaged in irrigated cultivation for the season.

9. Cropping intensity = $\sum_i^n \frac{Apn}{Adev}$ x 100 % --------------------------------------- *Equation (2.9)*

Where:

Apn - Total area planted for the season (ha),

Adev - Total developed irrigable scheme area (ha) and,

n - Number of cropping seasons per year.

10. Average crop yields = $\frac{Yi}{Ai}$ -- *Equation (2.10)*

Where:

Yi - Total seasonal production of crop i (tonnes) and,

Ai - Total area planted to

11. Manpower ratio = $\frac{N}{Adev}$ --- *Equation (2.11)*

Where:

N - Total manpower numbers for operation and maintenance of the system and, Adev - Total developed irrigable area (ha).

12. Manpower quality ratio = $\frac{Np}{N}$ x 100 % -------------------------------- *Equation (2.12)*

Where:

Np - Number of professional (graduate) and middle level personnel employed in the scheme and,

N - Total manpower numbers for operation and maintenance of the system.

13. Scheme financial autonomy factor = $\frac{Fs}{Fg}$ x 100 % ----------------------- *Equation (2.13)*

Where:

Fs - Amount of scheme income retained by the managing agency and,

Fg - Amount passed to central or provincial government.

14. Scheme financial self-sufficiency factor = $\frac{I}{C}$ x 100 % ------------------ *Equation (2.14)*

Where:

I - Total annual scheme income from water charges and diverse other revenue sources and,

C - Total annual operation and maintenance costs.

15. Maintenance budget ratio = $\frac{Mm}{Mt}$ x 100 % -------------------------------- *Equation (2.15)*

Where:

Mm - Amount of annual recurrent expenditure actually applied to maintenance of the scheme and,

Mt - Total annual recurrent operation and maintenance expenditure.

16. Irrigation service fees recovery rate = $\frac{Wc}{Wa}$ x 100 % --------------------- *Equation (2.16)*

Wc - Annual amount of water charges collected and, Wa - Total annual amount of water charges assessed.

17. Efficiency of roads passability = $\frac{Ra}{Rd}$ x 100 % ---------------------------- *Equation (2.17)*

Where:

Ra - Actual length of roads which has all year round accessibility (km) and,

Rd - Total length of scheme constructed roads (km).

18. Crop yield variation due to cultural practices.

Molden *et al.* (1998) used the International Water Management Institute's (IWMI) nine external and internal comparative indicators in their study. These indicators were developed with the objective of providing a means of comparing performance across irrigation schemes. To make it practicable, the indicators were applied on 18 irrigation schemes and the results showed large differences in performance among the schemes. These indicators include:

1. Output per cropped area ($\frac{\$}{ha}$) = $\frac{Production}{Irrigated\ cropped\ area}$ ------------------- *Equation (2.18)*

2. Output per unit command ($\frac{\$}{ha}$) = $\frac{Production}{Command\ area}$ -------------------------- *Equation (2.19)*

3. Output per unit irrigation supply ($\frac{\$}{m^3}$) = $\frac{Production}{Diverted\ irrigation\ supply}$ ------ *Equation (2.20)*

4. Output per unit water consumed ($\frac{\$}{m^3}$) = $\frac{Production}{Volume\ of\ water\ consumed\ by\ crop}$ --- *Eqn (2.21)*

5. Relative water supply = $\frac{Total\ water\ supply}{Crop\ demand}$ --------------------------------- *Equation (2.22)*

6. Relative irrigation supply = $\frac{Irrigation\ supply}{Irrigation\ demand}$ ---------------------------- *Equation (2.23)*

7. Water delivery capacity (%) = $\frac{Canal\ capacity\ to\ deliver\ water\ at\ system\ head}{Peak\ consumptive\ demand}$ ---*Eqn (2.24)*

8. Gross return on investment (%) = $\frac{Standardized\ gross\ value\ of\ production\ (SGVP)}{Cost\ of\ irrigation\ infrastructure}$ *Eqn (2.25)*

9. Financial self-sufficiency (%) = $\frac{Revenue\ from\ irrigation}{Total\ operation\ and\ maintenance\ expenditure}$ -- *Eqn (2.26)*

2.6.3 Classification of Comparative Performance Indicators

In assessing the performance of irrigation schemes using comparative indicators, most authors and researchers classify these into agricultural production level, financial, water delivery, physical structures and environmental state as presented in Table 2.4 (Sener *et al.*, 2007; Cakmak *et al.*, 2009).

Table 2.4: Summary of Irrigation Performance Assessment Indicators Commonly Used on Each Classification

Class of Irrigation Performance	**Author(s)**	**Irrigation Performance Assessment Indicators commonly used**
Agricultural Production Performance	Molden *et al.* (1998), Sener *et al.* (2007), Cakmak *et al.* (2009)	Output per unit of land cropped, output per unit of command area, output per unit of irrigation supply, and output per unit of water consumed
Financial and Economic Performance	Ijir (1994), Molden *et al.* (1998), Sener *et al.* (2007), Kuscu *et al.* (2009)	Financial autonomy factor, scheme financial self-sufficiency factor, maintenance budget ratio, irrigation service fees recovery rate, manpower number ratio and manpower quality ratio, gross return on investment, cost recovery ratio, operating cost per unit area and total cost per person employed on water
Water Delivery and Use Performance	Ijir (1994), Molden *et al.* (1998), Behailu *et al.* (2005), Sener *et al.* (2007)	Water availability index, efficiency of main system capacity, relative water supply, relative irrigation supply, water delivery capacity, conveyance efficiency and application efficiency, total annual water per command area and total annual water per irrigated area
Physical Structures performance	Sener *et al.* (2007),	Irrigation rate (ratio) and sustainability of irrigated land
Environmental Performance	Ijir (1994), Sener *et al.* (2007)	Environmental stability index, electrical conductivity (salinity), sodium absorption ratio (sodicity) and waterlogging

Source: (Ijir, 1994; Molden *et al.*, 1998; Behailu *et al.*, 2005; Sener *et al.*, 2007; Cakmak *et al.*, 2009; Kuscu *et al.*, 2009)

2.7 Performance Levels of Irrigation Schemes in Africa

It is widely recognised that irrigation development has the potential for increasing food production and attaining food self-sufficiency in many countries. However, there is an increasing realisation that the majority of the irrigation systems in the developing world, particularly Africa, perform below their potentials; some have simply failed (Ijir, 1994). Similarly, Courier (1990), Adams (1991) and Ijir (1994) also lamented that the performance of formal large scale smallholder irrigation schemes that have been developed operated and maintained by government agencies in Africa has been widely criticised by many authors over poor performance. They added that the experience of large-scale irrigation development in Africa over the past 30 - 40 years has been disappointing.

An evaluation by Van Steekelenburg and Zijistra (1985) of a number of smallholder irrigation projects in Africa funded by the European Economic Community (EEC) also found faults with many large scale irrigation schemes, and concluded that:"In irrigation projects in sub-Saharan Africa, it would appear that the larger the projects are, and the higher the level of their technology, the poorer is their performance." Plusquellec *et al.* (1990) stated that this low performance of irrigation projects in sub-Saharan Africa has been found to be similar to projects in other parts of the developing world. Even in Asia, where irrigation is generally more successful, there are still large opportunities for improvement.

Ijir (1994) remarked that the management of irrigation systems in Africa and elsewhere has proved more difficult than foreseen. Deficiencies in system design and management, combined with poor operation and maintenance have resulted in lower than expected irrigation benefits in terms of area irrigated, the levels of yield and production achieved, and return on investments. These deficiencies have also led in many instances to social inequalities and extensive areas of irrigated lands being degraded by waterlogging and salinisation. Hence, there is an urgent need to study the performance of particular irrigation systems. Cakmak *et al.* (2009) also reported that performances of many irrigation schemes in the world, especially those in the developing countries are significantly below their potential due to a number of shortcomings, including poor design, construction, operation and maintenance culture. The authors concluded that performance assessment on irrigation schemes should be carried out periodically to identify the causes for low or high performance of the schemes and offer suggested solutions if there are problems.

2.8 The Impact of Irrigation on Soil Quality

According to Doran *et al.* (1994) and Adeboye *et al.* (2011), soil quality is the capacity of a soil to function within ecosystem boundaries to sustain biological productivity, maintain environmental quality and promote plant and animal health and thus has a profound effect on the health and productivity of a given ecosystem and the environment related to it. Bardak-Meyers (1996) indicated that the installation and operation of an irrigation scheme can cause changes in the quantity and quality of the soil within the irrigable area. The author continued to argue that, despite the increased food production, diversification and associated economic benefits, the sustainability of irrigation is questioned due to its sometimes detrimental effects on the soil (waterlogging, soil salinity, sodicity, nutrient deficiency, alkalinity and groundwater contamination).

Irrigation development, while contributing to the economic well-being of many countries, has potential negative effects on the soil (Pereira *et al*., 1996). Binns *et al*. (2003) also remarked that the continuous use of developed irrigable lands throughout the year for both irrigation and rain-fed conditions could trigger fertility depletion, salinity and sodicity which may affect the quality of the soil. Poor quality of irrigation water affects both soil quality and crop production adversely (Bello, 2001).

2.8.1 Soil Salinity and Sodicity

Regardless of the source, irrigation water contains some dissolved salts (Michael, 1985). The concentration and proportion of dissolved salts among other things determine the suitability of water for irrigation (Ajayi *et al.*, 1990; Adamu, 2013). According to Tellefson and Hogg (2007), the long term effect of irrigation on soil physico-chemical properties as they relate to soil productivity require quantification. Horneck *et al.* (2007) stated that salinity in soil can originate from soil parent material; from irrigation water, from fertilizers or other soil amendments. Waskom *et al.* (2010) indicated that accumulation of salts can result in three soil conditions, namely saline, saline-sodic and sodic soils. According to Senon *et al.* (2012), soil salinity is the presence of high levels of soluble salts in soils. That is, saline soils contain excess soluble salts that reduce the growth of most crops. These soluble salts contain cations such as sodium (Na^+), potassium (K^+), calcium (Ca^{2+}) and magnesium (Mg^{2+}) along with the anions chloride (Cl^-), sulphate (SO_4^{2-}), nitrate (NO_3^-), bicarbonate (HCO_3^-) and carbonate (CO_3^{2-}). Soils may become saline as a result of land use, including the use of irrigation water with high levels of salt. Irrigating from salt-impacted wells or saline industrial water may lead to the formation of saline soils.

However, soil sodicity refers to the presence of a high proportion of sodium ions relative to other cations in the soil. It is caused by high sodium levels in soils at concentrations greater than 15 % of the cation exchange capacity. Sodic soils tend to have poor structure with physical properties such as poor water infiltration and air exchange, which can reduce plant growth (Senon *et al.*, 2012). Charm and Murphy (2000) defined sodicity as the relative predominance of exchangeable sodium compared to other exchangeable cations, mainly calcium, magnesium, potassium, hydrogen and aluminium and is expressed as ESP (exchangeable sodium percentage). The sodium adsorption ratio (SAR) is another expression of sodicity that refers to the ratio of adsorbed sodium and the sum of calcium and magnesium. Soil salinity is a characteristic of soils relating to their content of water-soluble salts and expressed mostly as ECe (electrical conductivity of saturation paste extract) and is measured as dS m^{-1}. According to Singh *et al.* (2007), the amount of Na in the soils predicts the sodicity danger of the soil.

Horneck *et al.* (2007) reported that saline soils commonly have visible salt deposits on the surface and are sometimes called “white alkali” soils whereas sodic soils often have a black colour and are called “black alkali” or “slick spots” while saline-sodic soils are high in sodium and other salts. They typically have electrical conductivity (EC) greater than 4 dS/m (mmhos/cm), SAR greater than 13, and/or ESP greater than 15. Liu and Hanlon (2012) defined soil pH as a measure of soil acidity or basicity.

pH ranges from 0 - 14. A pH of 7.0 is defined as neutral, while a pH of less than 7.0 is described as acidic and a pH of greater than 7.0 is described as basic. It is one of the most important soil chemical properties that affects nutrient bioavailability and microbial activity. pH determines the solubility and bioavailability of nutrients essential for crop production.

2.8.2 Effects of Soil Salinity and Sodicity on Plants

Salinity is a serious threat to agriculture in arid and semiarid regions (Rao and Sharma, 1995; Salehi *et al.*, 2008). Approximately 932 million ha of farmlands worldwide are degraded due to salinity and sodicity. Of this area, salinity affects 23 % of arable land while saline-sodic soils affect a further 10 % (Szabolcs, 1989; Wong *et al.*, 2006). The deleterious effects of salinity and sodicity on soil physic-chemical properties are well known, and ultimately cause declines in plant growth (Wong *et al.*, 2004). Accumulation of excessive salt in irrigated soils can reduce crop yields, reduce the effectiveness of irrigation, ruin soil structure, and affect other soil properties. Salinity and sodicity are the major variables that affect crop and soil productivity (Horneck *et al.*, 2007). Salinity reduces water availability for plant use. High salt levels hinder water absorption, inducing physiological drought in the plant. The soil may contain adequate water, but plant roots are unable to absorb the water due to osmotic pressure. This is referred to as the osmotic or water-deficit effect of salinity. Plants are generally most sensitive to salinity during germination and early growth (Senon *et al.*, 2012).

The second effect of salinity is shown when excessive amounts of salt enter the plant in the transpiration stream and injure leaf cells, which further reduces growth. This is called the salt-specific or ion-excess effect of salinity (Greenway and Munns, 1980). Symptoms may include restricted root growth, marginal or leaf tip burning/browning, inhibited flowering and reduced crop yields. Tate (1995) and Salehi *et al.* (2008) reported that increasing salt concentration may have a detrimental effect on soil microbials as a result of direct toxicity as well as through osmotic stress.

Soil sodicity can lead to reduced flow of water through the soil – which limits leaching and can cause salt to accumulate over time and the development of saline subsoils. It can also lead to dispersion in the soil surface, causing crusting and sealing which then impedes water infiltration. Furthermore, soil sodicity can lead to dispersion in the subsoil, accelerating erosion, which can cause the appearance of gullies and tunnels. It can also lead to dense, cloddy and structureless soils as it destroys aggregation. In short, the main problems caused by soil sodicity are reduced infiltration, reduced hydraulic conductivity, and surface crusting (Warrence *et al.,* 2003). Too much sodium causes problems related to soil structure. As sodium percentage increases, so does the risk of dispersion of soil aggregates (Horneck *et al.*, 2007)

2.8.3 Visual Diagnosis of Salt-Affected Soils

Waskom *et al.* (2010) outlined some physical observations or symptoms which may be helpful in diagnosing salt-related soil problems (Table 2.5).

Table 2.5: Physical Symptoms for Diagnosing Salt-Related Soil Problems

Salt-affected Soil	Symptoms
Saline	White crust on soil surface; water-stressed plants; leaf tip burn
Sodic	Poor drainage; black powdery residue on soil surface
Saline-sodic	Grey-coloured soil; plants showing water stress

Source: (Waskom *et al.*, 2010)

Also, Warrence *et al.* (2003) gave some common indicators or signs of sodicity. They include: poor vegetation or crop growth, poor water infiltration, surface crusting, dense or hard soil, prismatic or columnar structure in the subsoil, soapy feel when wetting and working up for soil textures, pH > 8.5, cloudy water in puddles and shallow rooting depth.

2.8.4 Soil Salinity and Sodicity Measurements

Irrigation water, groundwater and soils in the irrigable area of irrigation schemes should be monitored for salinity and sodicity because these two negative environmental impact have to be known to avoid the damage to sensitive crops and groundwater fluctuation (Sener *et al.*, 2007). Salinisation monitoring should be done probably every year (Eswaran and Kapur, 1998). Senon *et al.* (2012) indicated that the typical laboratory methods for measuring the levels of soil salinity and sodicity include the determination of electrical conductivity, total soluble salts (TSS), sodium absorption ratio (SAR) and exchangeable sodium percentage (ESP). The United States Department of Agriculture, Natural Resources Conservation Service (USDA-NRCS, 2003) provided a classification system for salt-affected soils using the saturated paste extraction as presented in Table 2.6.

Table 2.6: Classification of Salt-affected Soils by the United States Department of Agriculture, Natural Resources Conservation Service (2003)

Class	EC mmhos/cm	SAR	ESP	Typical Soil Structural Condition
Normal	< 4	< 13	< 15	Flocculated
Saline	> 4	< 13	< 15	Flocculated
Sodic	< 4	> 13	> 15	Dispersed
Saline-sodic	> 4	> 13	> 15	Flocculated

Source: (Horneck *et al.*, 2007)

Horneck *et al.* (2007) continued to explain that sodic soils are high in exchangeable sodium compared to calcium and magnesium. In these soils, EC is less than 4 dS/m and often less than 2 dS/m. Soil pH usually is greater than 8.5 and can be as high as 10 or even 11 in extreme cases. Saline-sodic soils are high in sodium and other salts. They typically have EC greater than 4 dS/m (mmhos/cm), SAR greater than 13, and/or ESP greater than 15. Soil pH can be above or below 8.5.

Table 2.7: Interpretation of Electrical Conductivity (EC) from Saturated Paste Extract

Electrical conductivity (mmhos/cm)	Salt Rank	Interpretation
0 – 2	Low	Very little chance of injury on all plants
2 – 4	Moderate	Moderate Sensitive plants and seedlings of others may show injury
4 – 8	High	High most non-salt tolerant plants will show injury; salt-sensitive plants will show severe injury
8 – 16	Excessive	Excessive salt-tolerant plants will grow; most others show severe injury
16+	Very excessive	Excessive very few plants will tolerate and grow

Source: (Lamond and Whitney, 1992)

2.8.5 Reclamation of Salt-affected Soils

Correcting a salt-affected soil involves identifying the kind and amount of salt, leaching, chemical treatment, or a combination of both. When a salinity problem is identified, it is recommended that corrective steps be taken immediately. Prompt action will give a better chance of reclaiming the affected soil, will be less expensive and pose lower risk to plant damage (Senon *et al.*, 2012).

Leaching: Application of good quality irrigation water in the correct amounts will remove excess salts from soils that are well structured and have good internal drainage.

Excess salts should be leached below the root zone so that the EC of the soil solution becomes lower than the crop's critical threshold. The University of Georgia (2009) recommends leaching techniques to remove salts from the root zone when EC is > 1.25 mmhos/cm at a soil-to-water ratio of 1:2. The depth of low-salt water needed to dissolve and leach any large quantities of salts from the soil is presented in Table 2.8. A general rule of thumb is that 15 cm of water will remove about 50 % of the salt, 30 cm will remove 80 % of the salt and 60 cm will remove 90 % of the salt. For soils with poor drainage, it is recommended to break root-restrictive hardpans or clay pans by deep tillage to allow water to penetrate and leach the salts. It may be necessary to install tile drains to remove salt-laden drainage water and move it below the root zone by rainfall or irrigation water (Senon *et al.*, 2012).

Table 2.8: Estimated Leaching Requirements to Remove Salts in Soil

Depth of Salt-free Water Required (cm)	Reduction Rate of Salt Content in Soil (%)
15	50
30	80
60	90

Source: (Senon *et al.*, 2012)

Chemical Treatment: When a soil has an SAR value of above 13 (or ESP greater than 15), it contains excess sodium that makes it a sodic soil. Excess sodium can cause soil dispersion, which prevents the formation of soil aggregates, resulting in surface sealing or crusting. Dispersion of the soil by excess sodium reduces water infiltration and movement through the soil, and also causes poor aeration. Good aeration and water movement are both essential to unrestricted growth of plant roots. To eliminate surface sealing, the soil should be treated with calcium to remove sodium. One of the most commonly used calcium sources for correcting sodium-contaminated soil is gypsum (calcium sulphate, $CaSO_4.2H_2\ O$). Gypsum is incorporated into the soil, followed by application of salt-free irrigation water. The amount of calcium to apply depends on the quantity of sodium in the soil (Senon *et al.*, 2012).

CHAPTER THREE

MATERIALS AND METHODS

3.1 Description of Study Areas

The study was carried out at the Tono, Vea and Doba Irrigation Schemes in the Upper East Region and the Libga, Golinga and Bontanga Irrigation Schemes in the Northern Region of Ghana in 2015.

3.1.1 Tono Irrigation Scheme

The Tono Irrigation Scheme is one of the two irrigation schemes under the management of Irrigation Company of Upper Region (ICOUR). The scheme is located at Tono near Navrongo in the Kassena-Nankana Municipality of Upper East Region of Ghana. It lies between latitude N 10° 84' and longitude W 1° 10'. The construction of the project was started in 1975 and was fully completed in 1985 by the Government of Ghana (GoG). The main canals were rehabilitated in 2008 by GoG. The scheme has a potential irrigable area of 3,860 ha, with a developed area of 2,490 ha while the undeveloped area was 1,370 ha. The predominant soil type in the lowland irrigable area is clay loam, while in the uplands it is sandy loam. The source of water is from the River Tono. The major crops grown include rice (*Oryza sativa*), tomatoes (*Lycopersicon esculentum)* and onion (*Allium cepa*) whereas cowpea (*Vigna unguiculata*), okra (*Hibiscus esculentus)* and roselle (*Hibiscus sabdariffa)* are the minor crops. The mode of water delivery from the reservoir is by gravity. The beneficiary communities include: Bonia, Wuru, Yogbania, Yigbwania, Korania, Gaani, Biu and Chuchuliga (ICOUR-Tono, 2015).

3.1.2 Vea Irrigation Scheme

The Vea Irrigation Scheme is also one of the two irrigation schemes under the management of Irrigation Company of Upper Region (ICOUR). The scheme is situated at Vea in the Bongo District of Upper East Region of Ghana and lies between latitude N 10° 86' and longitude W 0° 84'. The construction of the scheme was started in 1965 and fully completed in 1980 by the Government of Ghana. It has not received any rehabilitation since completion. The dam was constructed on River Yarigatanga. It has a potential irrigable area of 1,197 ha and the developed area of 850 ha while the undeveloped area is 347 ha. The lowlands irrigable area (53.7 %) comprises heavy clay soils and the uplands irrigable area (44.7 %) is composed mostly of sandy loam. The major crops grown include rice (*Oryza sativa*), tomatoes (*Lycopersicon esculentum)* and onion (*Allium cepa*) whiles cowpea (*Vigna unguiculata*), okra (*Hibiscus esculentus),* roselle (*Hibiscus sabdariffa)* and pepper (*Capsicum frutescens)* are the minor crops. Water delivery to farmers' fields is by gravity. The beneficiary communities include: Vea, Gowrie, Bongo Nyariga, Bolga Nyariga, Zaare, Yikine and Sumbrungu (ICOUR – Vea, 2015).

3.1.3 Doba Irrigation Scheme

The Doba Irrigation Scheme is located at Doba in the Kassena-Nankana Municipality of the Upper East Region of Ghana and lies between latitude N 10° 86' and longitude W 1° 04'. It is situated along the Navrongo – Bolga road. The dam was constructed in 1956 by the Government of Ghana for irrigation, livestock watering and domestic usage. The developed irrigable area is 7 ha. The predominant soil type in the irrigable area is sandy loam. The mode of irrigation is gravity and the major crops cultivated include tomato (*Lycopersicon esculentum*), pepper (*Capsicum frutescens),* roselle (*Hibiscus sabdariffa)* and okra (*Hibiscus esculentus*). The average landholding per farmer is 0.06 ha. The scheme is currently under rehabilitation by MoFA (GIDA - Bolga, 2015).

3.1.4 Libga Irrigation Scheme

The Libga Irrigation Scheme is located in the Savelugu District of the Northern Region of Ghana, 26 km away from Tamale. It lies between latitude N 9° 59' and longitude W 0° 85'. The construction of the scheme started in 1969 and completed in 1980 by the Government of Ghana. It is one of the irrigation schemes under the management of Ghana Irrigation Development Authority (GIDA). The scheme has a potential irrigable area of 40 ha but only 16 ha was developed and irrigated. The predominant soil type in the uplands irrigable area is sandy loam, whereas in the lowlands area it is clay loam. The source of its water is the River Perusua. The major crops cultivated on the scheme are roselle (*Hibiscus sabdariffa)* and vegetable jute (*Corchorus olitorius)*. The minor crops grown are rice (*Oryza sativa*), okra (*Hibiscus esculentus*), onion (*Allium cepa*) and pepper (*Capsicum frutescens*). The mode of water delivery from the reservoir is by gravity. The climate is the Guinea Savannah type. The beneficiary communities include: Libga, Zazzi, Nyoglo, Kanshegu, Behenayili and Savelugu (GIDA – Tamale, 2015).

3.1.5 Bontanga Irrigation Scheme

The Bontanga Irrigation Scheme is the largest irrigation scheme in the Northern Region under the management of GIDA. It is located in Bontanga in the Kumbungu District, 34 km northwest of Tamale, the regional capital. It lies between latitude N 9° 57' and longitude W 1° 02'. The constructional work of the scheme was started in the 1980 and completed in 1986 by the Government of Ghana. It was constructed to provide employment for the youth in the catchment area and to enable farmers in the catchment to have access to all year round crop production. Test cropping was done in 1985 and 1986, with actual crop production starting in 1987. It has a potential irrigable area of 800 ha and the developed area of 495 ha. The predominant soil type in the irrigable area is sandy loam. The dam was constructed on the River Bontanga, a tributary of White Volta. The scheme consists of an earthen dam that delivers water to the field by gravity and incorporated in the embankment are two (2) off-takes and a spillway, which is set to control the top water level in the reservoir. The major crop grown is rice (*Oryza sativa*). The minor crops include onion (*Allium cepa*), tomatoes (*Lycopersicon esculentum*), okra (*Hibiscus esculentus*) and pepper (*Capsicum frutescens*) (GIDA - Tamale, 2015).

3.1.6 Golinga Irrigation Scheme

The Golinga Irrigation Scheme is one of the irrigation schemes under the management of GIDA and is located in the Tolon District of the Northern Region of Ghana. It is 14.5 km away from Tamale, the regional capital and lies on latitude N 9° 4' and longitude W 1° 0'. The construction of the scheme was started in 1971 and completed in 1974 by the Government of Ghana. The embankment, spillway, canals, laterals and road networks were rehabilitated in 2011/2012 by the Millennium Development Authority (MiDA). The River Kornin is the source of its water. It has a potential irrigable area of 100 ha. The developed irrigable area covers 40 ha. The predominant soil type in the irrigable area is sandy loam. Mode of water delivery is by gravity. The major crops cultivated on the scheme are roselle (*Hibiscus sabdariffa)* and vegetable jute (*Corchorus olitorius)*. The minor crops grown are rice (*Oryza sativa*), okra (*Hibiscus esculentus*), onion (*Allium cepa*) and pepper (*Capsicum frutescens*). The climate in the area can be described as tropical semi-arid and vegetation type belongs to the Guinea Savannah type. The beneficiary communities of the scheme include: Golinga, Gbulahagu, Galinkpegu, Tuunayili and Naha (GIDA- Tamale, 2015).

3.1.7 Climatic and Vegetation Characteristics of the Upper East Region

The Upper East Region is located on the north east corner of Ghana. It lies between latitudes 10° 30' North and longitudes 1° 30' West within the White Volta River Basin. The region covers a land surface area of 8,860 km^2 (Mdemu *et al.*, 2008).

The climate of the region is influenced by the movement of harmattan and monsoon winds, which controls the climate of the West African sub-region. The Upper East Region is characterised by mono-modal rainy season starting between April and May and lasting until the end of September or beginning of October. Rainfall is erratic and spatially variable. Average annual rainfall ranges between 700 mm to 1,010 mm per year with peak rainfall occurring in late August or early September. Annual evapotranspiration is generally twice the annual precipitation and therefore, water storage reservoirs provide an important source of water supply during the dry season (Mdemu *et al.*, 2008).

Temperatures in the region are consistently high (23 - 39.1 °C). Relative humidity is high during rainy season and low during the dry season. The largest part of the region belongs to the Guinea Savannah Agro Ecological Zone, that is, an ecological association in which tall grasses are dominant and sparse trees are also present. Also, small part of the region belongs to the Sudan Savannah Agro Ecological Zone (Mdemu *et al.*, 2008).

3.1.8 Climatic and Vegetation Characteristics of the Northern Region

Northern Region is characterised by one rainy season (unimodal) with total annual rainfall of about 1,000 - 1,300 mm (Kranjac-Berisavljevic, 1999). The rainy season is about 140 - 190 days in duration. The rainy season is from May to October in a normal year, with peak rainfall occurring in August and September. The other months (November – May) are very dry, leaving domestic and agricultural sectors to struggle for the scanty water resources available in the region (Kranjac-Berisavljevic, 1999).

Temperatures in this region are consistently high with an annual average of 29 °C. The estimated reference evapotranspiration (ET_o) in the region is above 1,600 mm/y (Kranjac-Berisavljevic, 1999; Abdul-Ganiyu, 2011). Relative humidity is generally low during the dry season, when average values are below 50 %; while temperatures and wind velocities are generally higher in the dry season. This necessitated the construction of irrigation schemes in the region to store runoff water in earth dams to ensure water availability for irrigation of cereals and vegetable crops for the long period of the dry season (Abdul-Ganiyu *et al.*, 2015). The region belongs to the Guinea Savannah Agro Ecological Zone - tall grasses are dominant with sparse trees (Adu and Stobbs, 1995).

3.2 Data Collection Methods

3.2.1 Desk Study

Desk study was done during which literature including journals, articles, thesis and reports on irrigation schemes worldwide as well as work done on irrigation schemes in the Northern Ghana were reviewed. Documents on the schemes were also obtained from the various schemes' offices and Ghana Irrigation Development Authority (GIDA) at Tamale and Bolgatanga.

3.2.2 Interviews

Using a semi-structured questionnaire (Appendix D_1 and Appendix D_2) and informal interviews, a total of one hundred and twenty (120) irrigation farmers and six (6) key informants were interviewed in all the irrigation schemes. Twenty (20) farmers were randomly interviewed on each scheme.

Plate 3.1: Interview Session with Irrigation Farmers

3.2.3 Direct Observation and Field Measurements

Observations were made during field measurements around the irrigation schemes. At the same time, visual assessments were made on the conditions of physical structures (canals, laterals, drains, control structures, intake structures, weeds, sediments, and seepage), farmers' operations and irrigation practices with relevant photographs taken and presented in this work. Observations were done to ascertain the general nature and condition of the soils; their spatial variability as well as physical properties associated with soil erosion, waterlogging, salinity and sodicity.

Measurements were also carried out on the field during the study because of the difficulty in obtaining some data such as dimensions of main canals, flow velocity and sediment volume in main canals, yield of roselle and vegetable jute.

3.2.3.1 Measurement of Flow Velocity and Main Canals Dimensions for Discharge Determination

Flow Velocity: Flow velocity was carried out in the main canals of the Bontanga, Libga, Golinga and Doba irrigation schemes to determine their discharges since there was no data on discharges, due to lack of flow measurement structures. The float method was used for the flow velocity measurement in the schemes. The canals are trapezoidal on all the schemes and their dimensions were measured with a tape measure. Other measured parameters included the length of travel of float (*l*) and the time of travel of float (*t*). A reduction factor of 0.8 (JICA, 2004) was used to convert the surface velocity to mean velocity.

Mean flow velocity, v (m/s) = 0.8 x $\frac{L\ (m)}{t\ \ (s)}$ ------------------------------------ *Equation (3.1)*

Main Canal Dimension: The bottom width (b), top width (a) and maximum depth (h) of the canals were measured with a measuring tape. These dimensions were used for calculating the cross-sectional area of flow.

Cross-sectional area of flow, A = $(\frac{a+b}{2})$ x h ---------------------------------- *Equation (3.2)*

Where:

A - Cross-sectional area of flow (m^2),

a - Top width of canal (m),

b - Bottom width of canal (m) and,

h - Depth of water in canal (m).

The discharge (Q) was calculated using the flow continuity equation:

Discharge, Q (m^3/s) = v (m/s) x A (m^2) --------------------------------------- *Equation (3.3)*

Plate 3.2: Measurement of Flow Velocity in Main Canal by Float Method

3.2.3.2 Measurement of Sediment Volume in Main Canals

The volume of sediments in the main canals of each scheme was estimated using the profile method. Depending upon the length of each canal, several profiles were dug in the canals to the bottom concrete lining to determine the depth of sediments deposited in them as illustrated in Plate 3.3. The top width in contact with the sediments and the bottom width of the canals were also measured with a tape measure as illustrated in Plate 3.4. The depth of sediments, bottom width and the top width of the canals in contact with the sediments were measured to calculate the average cross-sectional area of the sediments deposited in the canals. All the canals were trapezoidal in shape.

The volume of sediments in each main canal was then estimated using the relationship:

Volume of sediments (VS) = Average cross-sectional area of sediments deposited (m^2) x Length of canal (m) -- *Equation (3.4)*

Plate 3.3: Profile Digging and Measurement of Depth of Sediments in a Main Canal

Plate 3.4: Measurement of Top Width in Contact with Sediments and Bottom Width in a Main Canal

3.2.3.3 Soil Physical and Chemical Properties of Irrigable Areas

The irrigable areas of the schemes were divided into three zones namely; upstream, midstream and downstream for the soil sampling. Composite soil samples (0 – 30 cm depth) were taken in each stream. Three (3) samples were taken on each irrigation scheme except Libga where five (5) samples were taken to determine the severity of the salinity problem. A total of twenty (20) soil samples were taken from the six (6) schemes at the point locations presented in Table 3.1. The samples were analysed at the Savannah Agricultural Research Institute Soil Science Laboratory in Nyankpala for pH, electrical conductivity (salinity), exchangeable sodium percentage (sodicity) and texture. pH was determined using 1:2.5 H_2O dilution method. The levels of salinity were determined by measuring the electrical conductivity (EC) of a solution extracted from a soil wetted to a saturation paste **(**Senon *et al.,* 2012). The exchangeable sodium percentage (ESP) procedure was used to determine the levels of sodicity in the soils (Senon *et al.,* 2012). Plate 3.5 illustrates soil sampling with an auger in the field.

Plate 3.5: Field Soil Sampling Using Auger

Table 3.1: Soil Sampling Points in the Irrigable Areas of the Schemes

Scheme	Location	Latitude (°)	Longitude (°)	Altitude (m)
Tono	US	N 10.86916	W 001.13835	176
	MS	N 10.80809	W 001.12694	161
	DS	N 10.74831	W 001.12641	154
Vea	US	N 10.86426	W 000.85694	185
	MS	N 10.84960	W 000.84960	183
	DS	N 10.83937	W 000.87577	179
Doba	US	N 10.86419	W 001.03518	172
	MS	N 10.86157	W 001.03495	171
	DS	N10.85978	W 001.03577	171
Libga	US	N 09.59627	W 000.85387	149
	MS	N 09.59811	W 000.85392	147
	DS	N 09.60071	W 000.85520	144
Bontanga	US	N 09.57848	W 001.02898	128
	MS	N 09.59785	W 001.03280	125
	DS	N 09.61747	W 001.03376	120
Golinga	US	N 09.35713	W 000.95148	148
	MS	N 09.35306	W 000.95006	143
	DS	N 09.35079	W 000.94925	137

US – Upstream, MS – Midstream and DS – Downstream

3.2.3.4 Estimation of Crop Yields

Crop yields per unit area irrigated were obtained from farmers and the scheme managers. However, yields of leafy vegetables mainly roselle (*Hibiscus sabdariffa)* and 'vegetable jute' (*Corchorus olitorius)* in tonnes per unit area cropped were obtained using the *in-situ* crop cutting method (Tanton, 1987; Ijir, 1994). This method was carried out on a sample of randomly selected farms at Libga and Golinga for the determination of yields of the crops at harvest time (Plates 3.6).

 

Plate 3.6: Determination of Vegetables Yield in the Field

3.3 Comparative Performance Indicators

The performance of the schemes were assessed using the following selected comparative indicators classified into five groups namely; water delivery, physical structures, financial, environmental state and crop production performance criteria. In this study, the approach recommended by the International Programme for Technology and Research in Irrigation and Drainage (IPTRID) for performance evaluation in irrigation and drainage sector was used (Malano and Burton, 2001; Cakmak *et al.*, 2009).

3.3.1 Water Delivery Performance

Two types of indicators were used to evaluate water delivery performance of the schemes.

3.3.1.1 Total Irrigation Water Supply per Hectare per Season

As given by Cakmak *et al.* (2009), total irrigation water supply per hectare per season was determined using the equation:

TIWSHS = $\frac{Tawd}{Ia}$ -- *Equation (3.5)*

Where:

TIWSHS - Total irrigation water supply per hectare per season (m^3/ha),

Tawd -Total annual water delivery (m^3) and *Ia* - Irrigated area (ha)

3.3.1.2 Extent of Main Canal Flow Lengths

According to Ijir (1994), the extent of main canal flow lengths is calculated as;

Extent of main canal flow lengths = $\frac{La}{Lt}$ x 100 % ----------------------------- *Equation (3.6)*

Where:

La - Actual total length of main canals sections still flowing (km) and,

Lt - Total length of main system canals constructed (km)

3.3.2 Physical Performance

Physical indicators are related to the changing or losing of irrigated land in the developed area due to reasons including poor conveyance and distribution structures. Four (4) performance indicators were used to evaluate the physical performances of the schemes.

3.3.2.1 Irrigation Rate (IR)

According to Sener *et al.* (2007), Kuscu *et al.* (2009) and Cakmak *et al.* (2009), irrigation rate of an irrigation scheme is defined as the ratio of irrigated area to the total developed irrigable area of the scheme. Irrigation rate can be referred to as irrigable land utilization efficiency (Bekisoglu, 1994).

Irrigation Rate = $\frac{Actual\ Irrigated\ area\ (ha)}{Total\ developed\ irrigable\ area\ (ha)}$ x 100 % ----------------- *Equation (3.7)*

3.3.2.2 Sustainability of Irrigated Area Index (SIAI)

Sustainability of irrigated area is defined as the ratio of the current irrigated area to the initial irrigated area when the scheme was fully completed (Bos, 1997; Sener *et al.*, 2007).

$$\text{SIAI} = \frac{Current\ irrigated\ area\ (ha)}{Initial\ irrigated\ area\ when\ the\ scheme\ was\ fully\ completed\ (ha)} \text{ x } 100\ \% \text{ ---------- } \textit{(3.8)}$$

3.3.2.3 Poor Structure Index of Irrigation Schemes (PSIIS)

Poor structure index of the irrigation schemes was calculated using the equation (Bos, 1997):

$$\text{Poor structure index of irrigation schemes} = \frac{Np}{Ns} \text{ x } 100\ \% \text{ -------------------- } \textit{Equation (3.9)}$$

Where:

Np - Number of structures in poor condition (not functioning adequately, at the risk of failure) and,

Ns - Total number of structures constructed within the scheme.

The structures include conveyance, regulatory and flow measurement structures. The conveyance structures for this indicator include canals and laterals. The regulatory structures include offtake valves, weirs in canals, check structures in canals and laterals, and gates of check structures and laterals. The flow measuring structures include Parshall and Cutthroat flumes.

3.3.2.4 Efficiency of Roads Network Passability

According to Ijir (1994), efficiency of irrigation schemes road network passability is determined as:

Efficiency of roads network passability = $\frac{Ra}{Rd}$ x 100 % -------------------- *Equation (3.10).*

Where:

Ra - Actual length of roads which has all year round accessibility (km) and,

Rd - Total length of roads constructed within scheme (km).

3.3.3 Environmental Performance Using Environmental Stability Index

Environmental stability index was used to evaluate the environmental performance of the schemes. Irrigated area not affected by negative environmental problems such as salinity, erosion or waterlogging was used in the calculation of the index (Ijir, 1994).

Environmental stability index = $\frac{Tna}{Tdia}$ x 100 % ------------------------------ *Equation (3.11)*

Where:

Tna - Total scheme area not affected by environmental problems of waterlogging, salinity or erosion (ha) and,

Tdia - Total developed irrigable area (ha)

3.3.4 Economic Performance

The following indicators were used in the evaluation of the economic performance of the irrigation schemes:

3.3.4.1 Efficiency of Irrigation Service Charges Recovery

According to Ijir (1994) and Sener *et al.* (2007), efficiency of irrigation service charges recovery is calculated as: EISR= $\frac{Ctaisc}{Etaisc}$ x 100 % --------------------------- *Equation (3.12)*

Where:

EISR - Efficiency of irrigation service charges recovery (%)

Ctaisc - Collected total annual irrigation service charges (GH¢) and

Etaisc - Expected total annual irrigation service charges (GH¢).

3.3.4.2 Scheme Financial Autonomy Factor

According to Ijir (1994), scheme financial autonomy factor is determined as:

SFAF = $\frac{Fs}{Fg}$ x 100 % -- *Equation (3.13)*

Where:

SFAF - Scheme financial autonomy factor

Fs - Amount of scheme income retained by the irrigation scheme management (GH¢),

Fg - Amount passed to central government (GH¢).

3.3.4.3 Financial Self-Sufficiency Factor

Financial self-sufficiency factors of the schemes were computed using the equation given by Ijir (1994) and Kuscu *et al.* (2009).

FSF = $\frac{\boldsymbol{Tai}}{\boldsymbol{Taome}}$ x 100 % -- *Equation (3.14)*

Where:

FSF - Financial self-sufficiency factor (%)

Tai - Total annual scheme income from water charges and diverse other revenue sources (GH¢) and,

Taome - Total annual operation and maintenance expenditure of the scheme (GH¢).

3.3.5 Production Performance Criteria

Average irrigated area (ha) per crop and average yield (t/ha) per crop were used to evaluate the production performance of the schemes.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Engineering Characteristics of the Irrigation Schemes

4.1.1 Tono Irrigation Scheme

The engineering characteristics of the studied scheme are presented in Table 4.1

Table 4.1: Engineering Characteristics of the Tono Irrigation Scheme

	Engineering Characteristics	
Year of construction/ Rehabilitation	Year construction started	1975
	Year construction completed	1985
	Year of rehabilitation	2008
Dam/Reservoir	Maximum height of embankment	18.59 m
	Length of embankment	3.5 km
	Catchment area	650 km^2
	Surface area of reservoir at full supply level	1,619 ha
	Live storage capacity	83 x 10^6 m^3
	Dead storage capacity	10 x 10^6 m^3
	Dead storage level	172.47 m
Offtake	Maximum emergency discharge	8.4 m^3/s
	Design discharge for canal	3.7 m^3/s
Spillway	Spillway capacity	496 m^3/s
	Crest (spill) level	179.22 m
	Maximum design depth on crest	2.47 m
	Design flood level	181.69 m
Pump station	Capacity	0.52 m^3/s
	Lift required	15.24 m
	Water horse power	105 hp
Canals	Total length of main canals (2)	42 km
Laterals	Total length of laterals (82)	56 km
Sub-laterals	Total length of sub-laterals	110 km
Flumes	Number of measuring devices (parshal flumes) on the main canals	1
Nigh storage reservoirs	Number of night storage reservoirs	7
Irrigable area	Potential irrigable area	3,860 ha
	Developed irrigable area	2,490 ha
	Undeveloped irrigable area	1,370 ha
Water delivery	Mode of water delivery from reservoir	Gravity
Road network	Total length of road network	120 km

Source: (ICOUR-Tono, 2015)

4.1.2 Vea Irrigation Scheme

The engineering characteristics of the scheme are presented in Table 4.2

Table 4.2: Engineering Characteristics of the Vea Irrigation Scheme

Engineering Characteristics		
Year of construction/ Rehabilitation	Year construction started	1965
	Year construction completed	1980
	Year of rehabilitation	-
Dam/Reservoir	Maximum height of embankment	13.4 m
	Length of embankment	1.6 km
	Maximum width at base of embankment	71.6 m
	Maximum water surface level	189.80 m
	Catchment area	136 km^2
	Surface area of reservoir at full supply level	385 ha
	Length of reservoir at full supply level	5 km
	Maximum storage capacity	$17 \times 10^6 m^3$
	Live storage capacity	$16 \times 10^6 m^3$
	Dead storage capacity	$1 \times 10^6 m^3$
	Dead storage level	179.64 m
Offtake	Design discharge of right bank canal	1.26 m^3/s
	Design discharge of left bank canal	1.07 m^3/s
Spillway	Spillway capacity	105.56 m^3/s
	Crest (spill) level	189.80 m
Canals	Total length of main canals (2)	26.5 km
Laterals	Total number of laterals	60
Control gates	Total number of control gates	62
Flumes	Number of measuring devices (parshal flumes and cut-throat) on the main canals	2
Nigh storage reservoirs	Number of night storage reservoirs	1
Irrigable area	Potential irrigable area	1,197 ha
	Developed irrigable area	859 ha
	Undeveloped irrigable area	347 ha
Water delivery	Mode of water delivery from reservoir	Gravity
Road network	Total length of road network	39 km

Source: (ICOUR-Vea, 2015)

4.1.3 Doba Irrigation Scheme

The engineering characteristics of the scheme are presented in Table 4.3.

Table 4.3: Engineering Characteristics of the Doba Irrigation Scheme

Engineering Characteristics		
Year of construction/ Rehabilitation	Year of construction	1956
	Year (s) of rehabilitation	2015
Dam/Reservoir	Length of embankment	510 m
	Maximum height of embankment	3.9 m
	Catchment area	0.65 km^2
	Surface area of reservoir at full supply level	8.8 ha
	Maximum storage capacity	17,040 m^3
Spillway	Width of the earth spillway	13.80 m
Offtake valve	Total number of offtake valves	1
Canal	Length of canal	0.6 m
Laterals	Total number of laterals	10
Irrigable area	Potential irrigable area	12 ha
	Developed irrigable area	7 ha
	Undeveloped irrigable area	5 ha
Water delivery	Mode of water delivery from reservoir	Gravity

Source: (GIDA-Bolgatanga, 2015)

4.1.4 Libga Irrigation Scheme

The engineering characteristics of the scheme are presented in Table 4.4.

Table 4.4: Engineering Characteristics of the Libga Irrigation Scheme

Engineering Characteristics		
Year of construction/ Rehabilitation	Year construction started	1969
	Year construction completed	1980
	Year (s) of rehabilitation	1984, 2005 and 2008
Dam/Reservoir	Maximum height of embankment	5 m
	Length of embankment	0.65 km
	Catchment area	165 km^2
	Maximum storage capacity	597,575 m^3
	Dead storage capacity	17,407 m^3
Offtake	Number of offtake valves	1
Spillway	Width of the concrete lined spillway	50 m
Canals/Laterals	Number of main canals	1
	Length of main canal	1.3 km
	Discharge of main canal	0.4 m^3/s
	Total number of laterals	8
	Total length of laterals	1.6 km
Flumes	Number of measuring devices (parshall and cut-throat flumes) on the main canals	2
Nigh storage reservoirs	Number of night storage reservoirs	0
Irrigable areas	Potential irrigable area	40 ha
	Developed irrigable area	16 ha
	Undeveloped irrigable area	24 ha
Water delivery	Mode of water delivery from reservoir	Gravity
Road network	Total length of road network	1 km

Source: (GIDA-Tamale, 2015)

4.1.5 Bontanga Irrigation Scheme

The engineering characteristics of the scheme are presented in Table 4.5.

Table 4.5: Engineering Characteristics of the Bontanga Irrigation Scheme

Engineering Characteristics		
Year of construction/ Rehabilitation	Year construction started	1980
	Year construction completed	1986
	Year (s) of rehabilitation	2011 - 2012
Dam/Reservoir	Maximum height of embankment	12 m
	Length of embankment	1.9 km
	Maximum width of embankment	65 m
	Catchment area	165 km^2
	Length of reservoir at full supply level	8 km
	Flooded area of reservoir at fully supply level	770 ha
	Minimum storage capacity (dead storage)	5×10^6 m^3
	Elevation of dead storage	1.52 m
	Maximum storage capacity	25×10^6 m^3
	Useful storage capacity (live storage)	20×10^6 m^3
Canals/Laterals	Design discharge of right bank main canal (RBC)	1.5 m^3/s
	Total length of RBC	5.5 km
	Total number of laterals on RBC	14
	Total irrigable area on RBC	191 ha
	Design discharge of left bank main canal (LBC)	1.5 m^3/s
	Total length of LBC	6 km
	Total number of laterals on LBC	14
	Total irrigable area on LBC	376 ha
	Total length of lateral network	17.5 km
Distribution facilities	Type of valve at reservoir	Penstroke
	Flow measuring devices (Parshall flumes)	2
	Total number of weirs constructed	13
Drop inlet spillway	Crest elevation	5.8 m
	Maximum discharge capacity	85 m^3/s
Emergency spillway	Crest elevation	5.9 m
	Maximum discharge capacity	103 m^3/s
Night reservoir	Number of night storage reservoirs	0
Irrigable areas	Potential irrigable area	800 ha
	Developed irrigable area	495 ha
	Undeveloped irrigable area	305 ha
Water delivery	Mode of water delivery	Gravity
	Total length of road network	30.7 km

Source: (GIDA-Tamale, 2015)

4.1.6 Principal Engineering Characteristics of the Golinga Irrigation Scheme

The engineering characteristics of the scheme are presented in Table 4.6

Table 4.6: Engineering Characteristics of the Golinga Irrigation Scheme

Engineering Characteristics		
Year of construction/ Rehabilitation	Year construction started	1971
	Year construction completed	1976
	Year (s) of rehabilitation	2011 - 2012
Dam/Reservoir	Maximum height of embankment	4.5 m
	Length of embankment	0.7 km
	Catchment area	124 km^2
	Minimum storage capacity (dead storage)	149,400 m^3
	Useful storage capacity (live storage)	5×10^6 m^3
Canals/Laterals	Discharge of right bank main canal (RBC)	0.2 m^3/s
	Total length of RBC	1.1 km
	Total number of laterals on RBC	5
	Discharge of left bank main canal (LBC)	0.3 m^3/s
	Total length of LBC	1.2 km
	Total number of laterals on LBC	7
	Total length of lateral network	3.3 km
Spillway Structure	Width of spillway	80 m
	Height of spillway	1.65 m
Irrigable areas	Potential irrigable area	100 ha
	Developed irrigable area	40 ha
	Undeveloped irrigable area	60 ha
Water delivery	Mode of water delivery	Gravity
	Total length of road network	5.6 km

Source: (GIDA-Tamale, 2015)

4.2 Management and Administration of the Irrigation Schemes

4.2.1 Organisational Structure and Responsibilities

Administratively, the Tono and Vea Irrigation Schemes are managed by ICOUR who reports directly to the Chief Director at MoFA, Accra. ICOUR is responsible for the management, operation and maintenance of the above mentioned schemes through the scheme managers. ICOUR is under Government subvention.

Responsibility for the direct management and day to day operations and maintenance of the schemes rests with the Project Managers and the Project Irrigation Engineering staff. Releasing water into the main canals, minor construction, repairs and routine maintenance of the irrigation facilities are carried out by the project irrigation engineers, water bailiffs, maintenance supervisor, works supervisor, carpenter and mason. However, major works including desilting of main canals are awarded contract to the farmers within the schemes or outside contractors through negotiations. Apart from the offices of the project manager and project irrigation engineer, there exist the offices of project extension/agronomy, project equipment and business administration (Appendix B_1).

The Doba Irrigation Scheme is managed by a Water User Association known as the Doba Irrigation Farmers Association. The structure of the WUA include; Chairperson, Secretary, Treasurer, Organiser and Water bailiff.

The Libga, Bontanga and Golinga irrigation schemes are managed by Ghana Irrigation Development Authority (GIDA). The organisational structure of GIDA is presented in Appendix B_2. On all the three schemes, there are no irrigation engineers, or water bailiffs. Some farmers have voluntarily taken the responsibilities of water bailiffs on the schemes.

4.2.2 Manpower on the Studied Schemes

One of the important factors that affect the performance of irrigation schemes is the manpower that is responsible for management, operation and maintenance (MOM). According to Carter *et al.* (1986), there has been no consensus on a specific staffing levels for operation and maintenance of irrigation schemes in literature but the ideal irrigation area that could be controlled by an irrigation staff is in the range of 3.8 -75.7 ha.

The actual MOM staffing levels (full-time) on the studied irrigation schemes as at January, 2014 and unit irrigated area per manpower are presented in Table 4.7.

Table 4.7: Actual Management, Operation and Maintenance Staffing Levels (Full-time) in the Irrigation Schemes as at January, 2014

Scheme	Manpower (No. of Staff)*	Average Irrigated Area (ha) (2010 - 2014)*	Average Unit Irrigated Area per MOM Manpower (ha/staff) **
Tono	12	1158.8	96.6
Vea	5	107.2	21.4
Doba	5 (WUAE, NFT)	1.5	0.3
Libga	1	15	15
Bontanga	3	427.2	142.4
Golinga	1	31.8	31.8

MOM - Management, Operation and Maintenance, WUAE – Water Users Association Executives, NFT – Not Full-Time

(Source: * - Project Records, 2015 and ** - Desk Computation, 2015)

As shown in Table 4.7, the average unit irrigated area (ha) controlled by an irrigation staff in Vea (21.4 ha/staff), Libga (15 ha/staff) and Golinga (31.8 ha/staff) indicate that the manpower numbers in the schemes are at adequate levels since they are within the ideal manpower numbers of 3.8 -75.7 ha/staff (Carter *et al.* (1986), whereas the 96.6 ha/staff recorded in the Tono scheme and the 142.4 ha/staff in the Bontanga scheme indicate understaffing. Understaffing could affect efficient and effective monitoring of fields which could result in low performance. In a similar study, Nalbantoglu and Cakmak (2007) recorded understaffing manpower values in the range of 88.4 -151.5 ha/staff. Cakmak *et al.* (2004) determined the unit irrigated area per staff member in Batman-Silvan, Devegecidi, Derik-Kumluca, Nusaybin- Cagdas and Cinar-Goksu irrigation systems for the period of 1996 - 2000 to be in a range of 113.6 - 588.2 ha/staff member. Considering the average irrigated area (1.5 ha) in Doba scheme over the past five years (2010 – 2014), the scheme is overstaffed with 0.3 ha/staff. The scheme is managed by WUA executives (not full-time staff). Averagely, the unit irrigated area controlled by ICOUR irrigation staff is 59 ha while that of GIDA is 63 ha.

4.2.3 Farmers Participation in the Management of the Irrigation Schemes

There are no Water Users Associations (WUAs) in the Tono and Vea irrigation schemes. However, Village Committees (VCs) were established in all the Project Villages in 1989 to ensure that farmers are actively involved in the management and maintenance of the irrigation schemes. The VCs took over from ICOUR all tenancy agreements held by individual farmers. The VCs are responsible for:

- The allocation of land to interested individual farmers in each season and,
- Organising the irrigation farmers in their respective villages for cleaning of laterals, field drains and field bunds.

The village committee groups are currently being transformed gradually into Farmer Based Organisations (FBOs) along irrigation laterals.

ICOUR is responsible for:

- Delivery of water to irrigable fields,
- Collection of irrigation service charges (ISC),
- The cleaning of the main canals and,
- Maintaining and repairing canals and lateral gates.

The Doba, Libga, Bontanga and Golinga Irrigation Schemes have Water Users Associations (WUAs). These associations actively participate in the management, operation and maintenance of the schemes. There are established communication channels between the farmers and irrigation staff as a result of the formation of WUAs. The WUA in Doba is called 'Doba Irrigation Farmers Association' (DIFA) with a membership of 110 comprising 24 females and 86 males, whereas the WUA in Libga is known as 'Libga Irrigation Farmers Association' (LIFA) with a membership of 65 comprising 10 females and 55 males. The WUA in Bontanga is called the 'Bontanga Co-operative Production, Processing and Marketing Union' (BOCOPMU) and is made up of 10 FBOs with a membership of 528 comprising 100 females and 428 males, while the WUA in Golinga is known as 'Golinga Co-operative Irrigation Farming Society' (GOCIFS) with a membership of 190 comprising 38 females and 152 males.

The core responsibilities of the WUAs on the schemes include:

- Cleaning of canals, laterals and drains,
- Allocation of plots and collection of irrigation service charges,
- Water distribution,
- Minor repairs/maintenance of the irrigation facilities and dam infrastructure,
- Record keeping,
- Farm gate price negotiations,
- Formulation and enforcement of bye-laws and
- Conflict resolution.

4.3 Socio-Economic Conditions of Farmers in the Irrigation Schemes

4.3.1 Characteristics of Farmers in the Irrigation Schemes

The majority of the farmers across all the schemes live in the villages around the schemes. Apart from the Tono irrigation scheme, where some lands are reserved for contract farmers, the use of the land is virtually restricted to the local inhabitants in the other five (5) schemes.

The official farmers' registers revealed the following plot holders in the various schemes: Tono (1,772), Vea (600), Doba (110), Libga (65), Bontanga (528) and Golinga (190). The majority (78 %) of these farmers do not have any other occupation. The few others were either engaged in teaching, petty trading, fishing or craft works alongside farming.

Gender Distribution: The gender distribution of plot holders in the various schemes is presented in Figure 4.1.

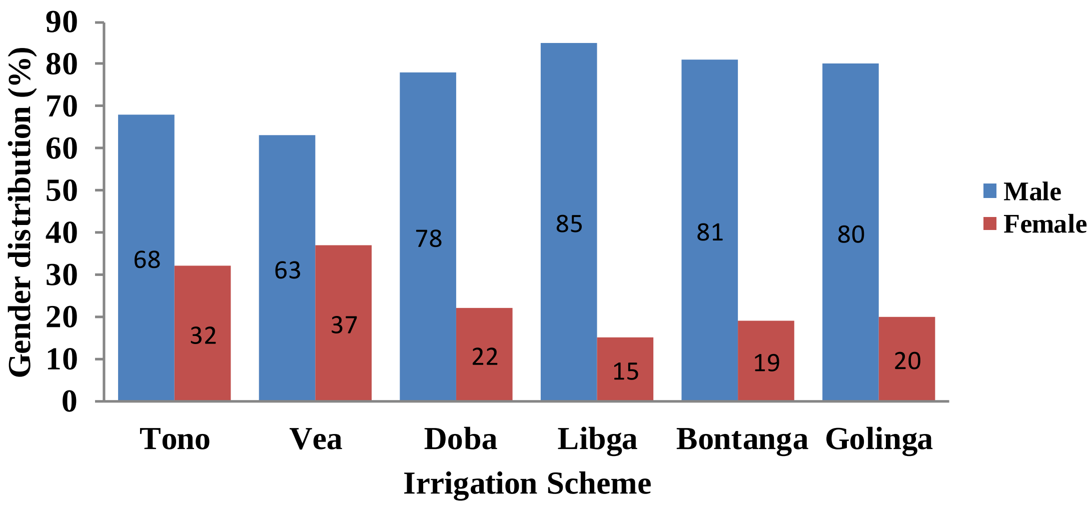

Figure 4.1: Gender Distribution of Plot Holders in the Irrigation Schemes

Generally, females have low representation across all the schemes and majority of the females were working on the schemes either for their husbands or as hired labour. This could negatively affect food production and food security because studies have shown that when women farmers have access to the same resources as men, they are more productive than men farmers. Saito (1994) reported that in Kenya the average gross value of output per ha from female-managed irrigated plots was usually 22 % higher than malemanaged plots with the same resources. FAO (2007) reported that in most developing countries, rural women are the mainstay of small-scale agriculture, farm labour, and day-to-day family subsistence, so as to alleviate rural poverty and improve food security; women have to be actively involved in irrigated agriculture.

Age Distribution: Table 4.8 presents the percentage age distribution of the farmers in the irrigation schemes. From the table, it is realised that about 95.7 % of the farmers in the irrigation schemes are within the economically active working age group (21 – 60 years) with majority of them being youthful (21 – 50 years). This indicates that the youth have been keen on taking to irrigated farming. The high youthful engagement in irrigated farming across all the irrigation schemes have the potential to increase food production and drastically reduce food insecurity especially in the northern parts of Ghana if enough irrigation facilities are provided. This also suggests that the advent of the irrigation schemes could significantly reduce the migration of the youth from northern Ghana to southern Ghana during dry seasons to seek non-existent or menial jobs.

Table 4.8: Age Distribution of Farmers in the Irrigation Schemes (%)

Scheme	21- 30 years	31- 40 years	41- 50 years	51 - 60 years	> 60 years
Tono	20.0	36.3	24.6	12.0	7.1
Vea	13.5	42.0	32.2	7.3	5.0
Doba	23.0	37.7	27.1	10.2	2.0
Libga	11.1	40.2	33.5	9.0	5.2
Bontanga	17.0	38.3	27.2	13.1	4.4
Golinga	14.6	37.0	33.0	14.3	2.1

(Source: Tono, Vea, Doba, Libga, Bontanga and Golinga Records, 2015)

Education Levels of Farmers: Across all the irrigation schemes, over 70 % of the farmers have not had formal education as presented in Figure 4.2. This high level of farmers with no formal education in the schemes negatively affects agricultural production as some of them are not willing to use modern agricultural techniques. Majority of illiterate farmers cannot access credit to finance their farming activities. According to Appleton and Balihuta (1996), formal education may affect agricultural productivity in a number of different ways including; enabling farmers to access credit to finance their farming activities, ability to follow written instructions for chemical inputs and other aspects of modern farm technology and ability to calculate correct dosages to attain desirable yields.

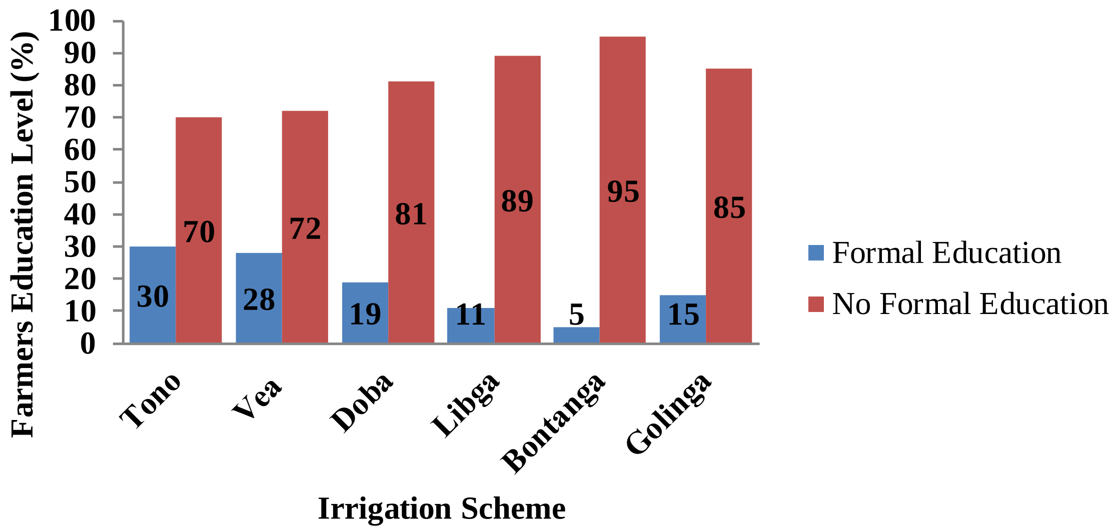

Figure 4.2: Education Levels of Farmers in the Irrigation Schemes

4.3.2 Land Allocation and Landholdings

Land Allocation: For the Tono and Vea irrigation schemes, land allocation was done by the various Village Committees while payment of irrigation service charges was done to the project. However, contract farmers acquired their land allocation from the project office.

At Doba irrigation scheme, the WUA executives were responsible for land allocations and collection of the irrigation service charges.

At Libga, Bontanga and Golinga irrigation schemes, land allocation and collection of irrigation services were done by the lateral leaders who form part of the WUAs executives. Unlike Tono and Vea irrigation schemes where some plots were reserved for research purposes, there were no plots reserved for research purposes in the Doba, Libga, Bontanga and Golinga irrigation schemes.

Landholdings: Table 4.9 presents farmers' landholdings in the irrigation schemes.

Table 4.9: Percentage Distribution of Farmers' Landholding in the Schemes

Scheme	< 0.1 ha	0.1 ha	0.2 ha	0.4 ha	0.6 ha	0.8 ha	1 ha
Tono	-	-	8	42	10	25	15
Vea	-	-	21	39	22	11	7
Doba	100	-	-	-	-	-	-
Libga	-	44	19	37	-	-	-
Bontanga	-	-	4	25	8	57	6
Golinga	-	26	53	21	-	-	-

(Source: Tono, Vea, Doba, Libga, Bontanga and Golinga Records, 2015)

As shown in Table 4.9, the farmers' landholdings in the Tono, Vea and Bontanga irrigation schemes were in a range of 0.2 - 1 ha. One of the operation rules of the schemes is that the maximum landholding per farmer is 1 ha. This is to allow many farmers to have access to land for dry season farming in the schemes. The average landholding size is 0.6 ha. The crops grown were rice, tomatoes, okra, cowpea, roselle, pepper and onion. In Wurno irrigation scheme in Nigeria, farmers landholdings were in a range of 0.4 - 12 ha with an average landholding of 1.6 ha per farmer (Ijir, 1994).

At the Doba irrigation scheme, all the farmers held less than 0.1 ha each done to the small developed irrigable area (7 ha). The average landholding size on the scheme was 0.06 ha. Cowpea, roselle, tomato, okra, pepper and onion were the crops grown in the scheme. At the Libga and Golinga irrigation schemes, farmers' landholdings were in a range of 0.1 - 0.4 ha due to the small developed irrigable area in each scheme. The developed irrigable area in Libga was 16 ha while that of Golinga was 40 ha. Roselle, vegetable jute, rice, cowpea, okra, pepper and tomatoes were the crops cultivated in the scheme.

4.3.3 Labour and Power Sources of Farming Operations on the Irrigation Schemes

Fifteen percent (15 %) of farmers interviewed mentioned labour as a constraint to production in the schemes. The majority of the farmers utilised family labour. They used hired labour only as a supplement to family labour for the intensive tasks such as weeding, harvesting and threshing. It is only the contract farmers who depended entirely on hired labour. These reasons were cited in the Tono, Vea and Bontanga schemes where farmers have up to 0.8 ha or more.

Besides human labour, the other sources of power were animals, tractors and power tillers. Across all the irrigation schemes, animals such as cattle and donkeys were used for ploughing, ridging, transporting materials to the fields and produce from the farm to markets or home.

The irrigation schemes had no tractors of their own. The tractor land preparation services which were provided by the Tono, Vea and Bontanga irrigation schemes to farmers had been phased out completely due to non-functional tractors. As a result, farmers have no option than to depend on tractor services from private sources. Some farmers even cultivated with hand implements such as hoes and machetes. This is a major constraint to timely land preparation, especially for poor farmers who find it most difficult to access the available tractors. Ijir (1994) reported that the Wurno irrigiation scheme in Nigeria and the farmers in the scheme had no tractors of their own and as a result depended on tractors from other Government Agencies and private sources for services including ploughing, harrowing and transportation of inputs and produce.

4.4 Comparative Performance Indicators of the Irrigation Schemes

4.4.1 Water Delivery Performance

The following indicators were used to assess the water delivery performance of the irrigation schemes.

4.4.1.1 Extent of Main Canals Flow

This measure demonstrates the practical limitations of the irrigation systems in supplying water as required. As existing irrigation systems deteriorate, it becomes impossible to get canal water to flow in certain areas especially the tail-ends. Thus, this index reveals the extent of constraint imposed by the inability of the canals to flow in some parts of the developed irrigable area. The extent of main canals flow lengths of the schemes are presented in Table 4.10.

Table 4.10: Extent of Main Canals Flow Lengths

Scheme	* Total length of main canals constructed within the scheme (km)	Actual total length of main canals sections still flowing (km) *	Extent of main canals flow lengths (%) **
Tono	42	31.1	74
Vea	26.5	4.7	18
Doba	0.6	0	0
Libga	1.30	1.15	89
Bontanga	11.5	11.5	100
Golinga	2.3	2.3	100

(Source: * - Project Records, 2015 and ** - Desk Computation, 2015)

At Tono, the low reservoir water levels in recent times and the very poor state of the laterals have reduced the canals flow length to 74 % of the 42 km canal. At Vea, only 18 % of the 26.5 km long main canals still flow. The remaining 82 % of the canals' length was no longer being used. This is due to the breaches and siltation of the canals and laterals and the defunct off-take valves on the left bank canal. Consequently, the fields along the canal were not cropped in the 2015. At Doba, the entire length of the main canal (0.6 km) has not been flowing since 2013 as a result of low reservoir water levels. Also, 11 % of the 1.30 km long main canal at Libga could no longer flow, mainly due to poor construction of the canal. As a result, 1 ha out of the total 16 ha developed irrigable area was left uncultivated during dry seasons since 2008.

However, the main canals and laterals of Bontanga and Golinga schemes were in good state and flow properly to the tail-ends, attaining 100 % flow length. This is due to the rehabilitation carried out in 2011-2012. According to Ijir (1994), the notional normal value for extent of main canals flow length is 100 %. However, the author reported that nearly half (45 %) of the total length of the main canals of the Wurno Irrigation Scheme in Nigeria could no longer flow due to breaches and siltation of the canals network.

4.4.1.2 Estimated Total Irrigation Water Supply per Hectare per Season

The estimated total irrigation water supplied per hectare per season for the irrigation schemes for 2010 – 2014 are presented in Table 4.11.

Tono, Vea and Bontanga Schemes: At Tono, Vea and Bontanga irrigation schemes, where rice, onion, tomatoes and okra are the major crops grown, total irrigation water supplied of 27,360 - 31,697 m^3/ha, 94,194 - 97,907 m^3/ha and 29,363 - 37,767 m^3/ha were respectively recorded. Kuscu *et al.* (2009) reported that in the tropics, when total irrigation water supply in a range of 24,440 – 93,980 m^3/ha is diverted to fields where the predominant crops are rice and tomatoes, it indicates that sufficient amount of water is supplied to the irrigable area. Therefore, the results obtained for the Tono and Bontanga irrigation schemes were within the range except Vea which exceeded the range found by Kuscu *et al*. (2009), indicating that excess amount of water was delivered to the irrigable area which could lead to waterlogging. This might be attributed to the poor state of the canals and laterals; because of seepage more water was delivered to enable it reach the tail-end farmers.

Table 4.11: Estimated Total Irrigation Water Supply per Irrigated Area per Season (m^3/ha)

Indicator	**Estimated total irrigation water supply (10^6 m^3) - December to May** *				
Year	2010	2011	2012	2013	2014
Tono	37.83	32.93	36.69	41.27	18.62
Vea	11.68	6.71	8.42	9.64	14.78
Doba	-	-	-	-	-
Libga	0.32	0.29	0.38	0.26	0.21
Bontanga	15.56	12.45	12.45	15.56	15.56
Golinga	0.71	1.04	1.04	1.56	1.51
Irrigated area (ha) *					
Year	2010	2011	2012	2013	2014
Tono	1325	1189	1341	1302	637
Vea	124	71	86	100	155
Doba	-	-	-	-	-
Libga	15	15	15	15	15
Bontanga	412	420	424	431	449
Golinga	20	27	32	40	40
Total irrigation water supply per irrigated area per season (m^3/ha) **					
Year	2010	2011	2012	2013	2014
Tono	28,551	27,696	27,360	31,697	29,231
Vea	94,194	94,507	97,907	96,400	95,355
Doba	-	-	-	-	-
Libga	21,333	19,333	25,333	18,000	14,667
Bontanga	37,767	29,643	29,363	36,102	34,655
Golinga	35,500	38,519	32,500	39,000	37,760

(Source: * – Project Records, 2015 and ** – Desk Computation, 2015)

Libga and Golinga Schemes: As presented in Table 4.11, the estimated total irrigation water supply per irrigated area recorded for the Libga irrigation scheme was in the range 14,667 - 25,333 m^3/ha while Golinga scheme recorded 32,500 – 39,000 m^3/ha. Roselle and vegetable jute are the major crops grown in the schemes. According to Cakmak *et al.* (2009), a water delivery of 8,586 -13,611 m^3/ha is ideal for vegetable production on irrigation schemes which experience high evapotranspiration with soil conditions being silty loam or sandy loam. However, the results from the study indicate that excess amount of water was delivered to the irrigable areas of the schemes thus causing waterlogging conditions in some parts of the irrigable areas. This might be attributed to poor water control by farmers and management of the schemes.

At Doba, the total irrigation water supply per irrigated area could not be determined as there was no irrigation due to low reservoir water level. Also, there were no available records on the dam's water delivery.

4.4.2 Physical Structures Performance

The physical structures performance indicators are related to the changing or losing of irrigated land in the developed area due to poor conveyance and distribution structures. Three (3) performance indicators namely; irrigation rate, sustainability of irrigated area index, poor structure index and efficiency of roads passability were used to evaluate the physical performances of the schemes over the past five years (2010 - 2014).

4.4.2.1 Irrigation Rate

Irrigation rate is the percentage of the total developed irrigable area of an irrigation scheme being irrigated in a season or a year. It is also called irrigable land utilisation efficiency. The results of irrigation rates for the various schemes are presented in Table 4.12.

Table 4.12: Irrigation Rates

Indicator	Actual Irrigated Area (ha) *					DIA	Irrigation Rate (%) **				
Year	**2010**	**2011**	**2012**	**2013**	**2014**	**(ha)**	**2010**	**2011**	**2012**	**2013**	**2014**
Tono	1325	1189	1341	1302	637	2490	53	48	54	52	26
Vea	124	71	86	100	155	850	15	8	10	12	18
Doba	2.5	1.5	2	1.5	0	7	36	21	29	21	0
Libga	15	15	15	15	15	16	94	94	94	94	94
Bontanga	412	420	424	431	449	495	83	85	86	87	91
Golinga	20	27	32	40	40	40	50	58	63	100	100

DIA - Developed Irrigable Area*

(Source: * - Project Records, 2015 and ** - Desk Computation, 2015)

Tono Irrigation scheme: The irrigation rates for the scheme were found to be in the range of 26 – 54 % during the years of 2010 – 2014. The rates recorded in 2010, 2012 and 2013 suggest that barely half of the scheme's developed irrigable area was irrigated each year, whereas the rates recorded in 2011 and 2014 indicated that considerably less than half of the developed area were irrigated in those years. These lower rates of irrigation were attributed to the poor state of the laterals, low reservoir water levels and reduced flow lengths of the canals. These rates are similar to the results obtained by Cakmak *et al.* (2009) which ranged from 44 – 55 % in the Asartepe Irrigation Scheme in Turkey for the period of 2001 - 2004.

Vea Irrigation Scheme: The irrigation rates for the scheme for the period of 2010 - 2014 were found to be very low, ranging from 8 – 18 % as in Table 4.12. These low irrigation rates were caused by:

- Defunct left bank canal off-take valves,
- Breached, weedy and silted canals and laterals,
- Waterlogging of irrigable area due to spillage from canals and laterals,
- Reduced main canals flow lengths and

- Abandonment of irrigation by farmers due to high irrigation service charges and high prices of farm inputs.

Doba Irrigation Scheme: The calculated irrigation rates for the scheme over the past five years (2010 -2014) were also significantly lower ranging from 0 – 36 %. There was no irrigated farming in 2014 due to low reservoir water level. The broken canals and laterals as a result of lack of maintenance and repairs over the years also contributed to the low irrigation rates. Sener *et al.* (2007) recorded irrigation rates which ranged from 15.77 - 54.47 % in the Hayrabolu Irrigation Scheme in Turkey for a period of 13 years (1989 - 2001). The reasons cited for the low irrigation rates recorded on the schemes included low interest of farmers and poor state of irrigation infrastructure.

Libga, Bontanga and Golinga Schemes: From 2010 – 2014, the irrigation rates recorded for the Libga, Bontanga and Golinga schemes respectively were found to be 94 %, 83 – 91 % and 50 – 100 %. The rates obtained for the Bontanga, Libga and Golinga schemes indicated that the schemes were performing better than the other schemes when compared to the notional normal value for irrigation rate (90 – 100 %) as given by Ijir (1994).

4.4.2.2 Sustainability of Irrigated Area Index (SIAI)

Sustainability of irrigated area index is the relationship between the current irrigated area and the initial irrigated area when the scheme was first fully developed. Table 4.13 presents the sustainability of irrigated area indices (SIAI) for the schemes.

Table 4.13: Sustainability of Irrigated Area Index

Scheme	Irrigated Area (ha) in 2014*	Initial Irrigated Area (ha) After Completion*	Sustainability of Irrigated Area Index (%) **
Tono	637	1293	49
Vea	155	594	26
Doba	0	7	0
Libga	15	16	94
Bontanga	449	471	95
Golinga	40	40	100

(Source: * - Project Records, 2015 and ** - Desk Computation, 2015)

The SIAI were found to be low at Tono (49 %) and Vea (26 %). The causes of the low level of SIAI at Tono include reduced flow lengths of main canals due to the low reservoir water levels and poor condition of laterals, and environmental problems such as waterlogging and erosion. At Vea, the very poor SIAI recorded have been attributed to the severely breached and silted canals and laterals, defunct off-take valves and the drastically reduced flow lengths of main canals. The Doba irrigation scheme recorded zero index as a result of non-cropping of the irrigable area due to the low reservoir water level in 2014.

However, the Libga, Bontanga and Golinga schemes respectively recorded high index of 94 %, 95 % and 100 %. This indicates that the schemes have sustainable irrigated area since the indices are within the ideal range of 90 – 100 % (Ijir, 1994). The Libga, Bontanga and Golinga Schemes recorded high sustainability indices because the demand for plot for irrigation among the farmers on the schemes was very high. There was too much pressure on the small developed irrigable areas on the schemes. Sener *et al.* (2007) reported an average sustainable irrigated area of 97 % for irrigation schemes in Turkey. Ijir (1994) recorded 85 % sustainability of irrigated area for Wurno Irrigation Scheme in Nigeria.

4.4.2.3 Poor Structure Index (PSI)

Poor structure index describes the percentage of the total number of conveyance, regulatory and flow measuring structures installed within the scheme that are in a poor state (not functioning, not functioning properly or at the risk of failure, and not attaining design standards). The poor structure indices of the schemes are presented in Table 4.14.

Table 4.14: Poor Structure Index of the Irrigation Schemes

Scheme	No. of Structures*			Total No. of C, R, Fm Structures*	No. in Good Condition*	No. in Poor Condition*	Poor Structure Index (%)**
	C	R	Fm				
Tono	84	107	1	195	105	90	46
Vea	62	75	2	139	18	121	87
Doba	11	14	0	25	1	24	96
Libga	9	18	0	27	19	8	30
Bontanga	16	80	2	98	95	3	3
Golinga	14	24	0	38	37	1	3

Where: C - Conveyance, R – Regulatory and Fm - Flow measurement
(Source: * - Project Records, 2015 and ** - Desk Computation, 2015)

Tono Irrigation Scheme: The scheme recorded PSI of 46 % which strongly revealed that the conditions of the structures of the scheme were in very poor working condition when compared to the recommended value (0 %) as given by Bos (1997). The conveyance structures in a very poor condition were the laterals. The scheme has 82 laterals of which 75 were severely breached; all the concrete slabs and linings were removed (Plate 4.1). The buried lateral pipes were also exposed and broken (Plate 4.2). The regulatory structures in poor working condition were the lateral gates. A total of 93 lateral gates were installed on the right and left bank canals of which 15 were not functioning due to detached stem from plates and worn out angle-iron (Plate 4.3).

Plate 4.1: Conditions of Laterals in Tono Irrigation Scheme

Plate 4.2: Exposed and Broken Lateral Pipes in Tono Irrigation Scheme

Plate 4.3: Broken Lateral Gates in Tono Irrigation Scheme

Vea Irrigation Scheme: The scheme recorded 87 % poor structure index, which clearly indicates the conveyance, regulatory and flow measuring structures of the scheme were in poor condition. The two main canals were weedy, silted and severely breached at several sections, 4 out of the 5 off-take valves were defunct, the parshall and cutthroat flumes were silted-up making flow measurement impossible, all the 60 concrete lined laterals were broken, and 54 out of the 70 lateral gates were broken. Farmers found it very difficult to regulate flow into their fields. They resorted to the use of stones, grasses, sand bags or mud as lateral gates to regulate flow in their fields. In a similar study, Ijir (1994) reported that 89 % of the structures of the Wurno Irrigation Scheme in Nigeria were in poor conditions and therefore operating ineffectively.

Plate 4.4: Conditions of Main Canals in Vea Irrigation Scheme

Doba Irrigation Scheme: The scheme had the highest poor structure index (96 %) as presented in Table 4.14. This indicates that almost all the structures of the scheme were in poor working condition. It is only the offtake valve which was functioning properly. All the 10 concrete lined laterals were broken. 0.35 km of the 0.6 km long concrete lined canal was severely breached with all lateral gates and check structures removed.

Libga Irrigation Scheme: About 30 % of the scheme's conveyance and regulatory structures were in poor working condition. Portions of the canal and the laterals were breached and silted. Water could not flow to the tail-end, due to faulty construction.

Bontanga and Golinga Irrigation Schemes: The Bontanga and Golinga schemes had recorded the lowest PSI values of 3 % and 1 % respectively. This means that 97 % and 99 % of the conveyance and regulatory structures of the Bontanga and Golinga schemes respectively were in good working condition. Therefore, in terms of structure condition index, the performances of these two schemes were better than the Tono, Vea, Doba and Libga irrigation schemes. This might be the effect of the rehabilitation of the two schemes in 2011 - 2012 by the Millennium Development Authority (MiDA). In a similar study, Palmer *et al.* (1991) reported that the poor structure index of most irrigation schemes in the United States of America fall within the range of < 1 to 20 %.

4.4.2.4 Efficiency of Roads Passability

Except the Doba Irrigation Scheme, roads are constructed around and within the other five irrigation schemes for the purposes of accessibility to farms, inspection and maintenance of canals and laterals, and transportation of farm inputs and produce. Ideally they should remain passable all year round to serve the intended purpose. However, in practice some of the roads or parts of them often have limited access at certain times of the year especially during the peak of the rainy season. This performance indicator was therefore applied on the schemes to assess the current state of the roads around and within the schemes. The results are presented in Table 4.15.

Table 4.15: Roads Passability in the Irrigation Schemes

Scheme	Total Length of Roads Constructed Within the Scheme (km) *	Actual Length of Roads which have all Year Round Accessibility (km) *	Efficiency of Roads Passability (%)**
Tono	120	115.2	96
Vea	39	20.7	53
Doba	0	0	0
Libga	1	1	100
Bontanga	30.7	30.7	100
Golinga	5.6	5.6	100

(Source: * - Project Records, 2015 and ** - Desk Computation, 2015)

Vea Irrigation Scheme: The scheme recorded 53 % efficiency of roads passability. The results revealed that the road network was in a poor state. Approximately half of the total length of the road network within the scheme was not motorable especially in the rainy season. These stretches of the road network were eroded leaving visible gullies as illustrated in Plate 4.5.

Plate 4.5: Condition of Canals Inspection Road Network in Vea Irrigation Scheme

The road networks have not been rehabilitated since construction, leaving them in a poor condition. This makes it difficult for canals and laterals inspection and maintenance. Access to some farms and transportation of farm inputs and produce also become very difficult as a result. The scheme had no lateral inspection road networks. The road network on the scheme needed rehabilitation. Ijir (1994) recorded 80 % road passability efficiency for the Wurno Irrigation Scheme in Nigeria.

Tono Irrigation Scheme: The scheme recorded 96 % efficiency in roads passability. Though this efficiency appears to be satisfactory, several potholes were seen on some sections of the canal inspection road networks. The canal inspection road networks were rehabilitated in 2008. The Libga, Bontanga and Golinga irrigation schemes recorded satisfactory roads passability efficiency values of 100 %. The road networks in the

Bontanga and Golinga irrigation schemes were re-graveled during the rehabilitation in 2011 - 2012. All the canals and laterals inspection road networks were still in good condition and accessible. According to Ijir (1994), the ideal efficiency of roads passability of an irrigation scheme is 100 %. The road networks must be accessible all year round.

4.4.3 Economic Performance

The economic performance of the schemes was assessed using the indicators of efficiency of irrigation service recovery, scheme financial autonomy factor and financial self-sufficiency rate.

4.4.3.1 Efficiency of Irrigation Service Recovery

The efficiency of irrigation service charges recovery (EISCR) refers to the proportion of irrigation service charges collected out of the total expected amount. This indicator measures the performance of the management as well as the willingness of the water users to pay. The willingness of the farmers is largely influenced by their satisfaction with the quality of service provided by the irrigation system (Sener *et al.*, 2007). The funds generated from irrigation service charges depend both on the amount levied and on the recovery rate (Ijir, 1994). This indicator is one of the most important indicators for irrigation schemes especially for WUAs like Doba because an irrigation service charge is the only source of revenue to the sustainability of the schemes. The results of the efficiency of irrigation service charges recovery (EISCR) for the schemes are presented in Table 4.16.

Table 4.16: Efficiency of Irrigation Service Charges Recovery (%)

Indicator	**Expected Total Annual Irrigation Service Charges (GH¢) – *a****				
Year	2010	2011	2012	2013	2014
Tono	85,141	80,775	68,084	50,766	74,491
Vea	9,355	5,525	6,610	9,420	14,450
Doba	108	53	73	53	-
Libga	1,125	1,125	1,125	2,250	2,250
Bontanga	10,300	10,500	10,590	43,103	44,861
Golinga	1,500	2,025	2,400	5,850	5,850
Actual Total Annual Irrigation Service Charges (GH¢) – *b**					
Year	2010	2011	2012	2013	2014
Tono	79,266	70,506	55,148	41,628	55,868
Vea	4,400	1,099	2,020	2,600	2,720
Doba	100	51	65	49	-
Libga	394	461	416	540	720
Bontanga	2,480	3,200	5,493	9,879	12,326
Golinga	215	1,649	1,928	4,933	4,640
Efficiency of Irrigation Service Charges Recovery (%), ($\frac{b}{a}$) x 100 % **					
Year	2010	2011	2012	2013	2014
Tono	93	87	81	82	75
Vea	47	20	31	28	19
Doba	93	96	89	92	-
Libga	35	41	37	24	32
Bontanga	24	30	52	23	27
Golinga	14	81	80	84	79

(Source: * – Project Records, 2015 and ** – Desk Computation, 2015)

Irrigation Service Charges (ISC): The irrigation service charges at the Tono, Vea, Libga, Bontanga and Golinga schemes in 2010 – 2012 was GH¢ 75 per ha and GH¢ 100 per ha in 2013 – 2014. The ISC for all the public irrigation schemes in the country which deliver water by gravity is the same per hectare. The ISC at the Doba scheme was GH¢ 2.50 per 0.06 ha in 2010 - 2014. The Doba scheme is operated by the WUA.

Tono and Doba Schemes: The EISCR for the Tono and Doba schemes respectively were found to be between 75 – 93 % and 89 – 96 % during the years of 2010 – 2014. These recovery rates are said to be satisfactory when compared to other schemes either managed by Government or by Water Users Allocation (WUA) worldwide. The high rates recorded at Doba could be attributed to the lower irrigation service charges per year; GH¢ 2.50 per 0.06 ha per season during the period of 2010 - 2013. Based on the irrigated area each year, the expected total irrigation service charged for 2014 was GH¢ 90, but due to low reservoir water level, there was no irrigation. According to Ijir (1994), the notional normal value for irrigation service charges recovery is between 90 – 100 % of the expected total irrigation service charges for the season or year. Yercan *et al.* (2004) recorded recovery rates of 90 – 98 % for eight irrigation schemes in Gediz River Basin in Western Turkey.

Vea Irrigation Scheme: During the years 2010 – 2014, the EISCR recorded by the scheme were found to be in a range of 19 – 47 %. These recovery rates are very poor since less than half of the expected total irrigation service charges are recovered. The poor recovery rates have been attributed to the poor attitude of farmers towards payment of irrigation charges due to the poor state of the canals and laterals leading to non-regulatory delivery of water to fields. Most of the farmers lift water with pumps from the main drain for irrigation. These farmers normally refuse to pay the irrigation charges with the excuse that they are not using water from the canals and laterals. Administrative corruption is another cause of the low recovery rates, as the study revealed that some of the service charges collected from farmers were not recorded by management. The expected and actual irrigation services for the periods of 2010 – 2014 are presented in Table 4.16. The low amount collected out of the expected amount resulted in the poor recovery efficiency. Sayin *et al.* (2013) determined the mean irrigation service charge rate of 29 irrigation schemes in Antalya in Turkey as 62.7 %.

Libga and Bontanga Irrigation Schemes: The EISCR for the Libga and Bontanga Schemes respectively were also found to be in a range of 24 – 41 % and 23 – 52 % for the period of 2010 - 2014, which could be said to be at unsatisfactory levels when compared with the average values for Tono and Doba. Sener *et al.* (2007) recorded recovery rates in the range of 5.6 – 61.1 % for the Hayrabolu irrigation scheme in Turkey.

Some of the reasons for the low recovery rates in the study schemes include:

- Poor attitude of farmers towards payment of irrigation charges due to the permanent field allocation to farmers in the schemes,
- No penalties for farmers who default in the payment of irrigation service charges,
- Administrative corruption, because the study revealed that some of the collected irrigation service charges were not declared by management.

Golinga Irrigation Scheme: The scheme recorded 14 – 84 % recovery rates over the five years period. As presented in Table 4.16, the recovery rate was very low (14 %) in 2010 because of low reservoir water level. However, during and after the rehabilitation in 2011 – 2012, the recovery rates increased to 80 – 84 %. These rates indicate satisfactory performance though slightly falling below the notional normal value for irrigation service charges recovery of 90 – 100 % (Ijir, 1994). Ijir (1994) recorded 80 % recovery rate for the Wurno Irrigation Scheme in Nigeria.

4.4.3.2 Scheme Financial Autonomy Factor (SFAF)

This indicator deals with the percentage of the scheme's collected irrigation service charges retained by the scheme management to the percentage passed to the Central Government (GoG). It is widely believed that there is greater potential to improve irrigation performance if the agency responsible for management has significant degree of financial control over internally generated revenue rather than being dependent upon the Central Government for its budget.

The study revealed that all collected irrigation service charges (100 %) of the Tono and Vea Schemes were being retained by ICOUR which is the managing agency for the two schemes. According to ADB (1986) and Ijir (1994), for an irrigation scheme to be described as financially autonomous, at least 50 % of the collected irrigation service charges should be retained by the managing agency. Therefore, the two schemes are financially autonomous. The Doba Scheme which is managed by the Doba Irrigation Farmers Association has a full degree of financial autonomy since all collected irrigation service charges (100 %) were retained by the scheme to cater for its operation and maintenance costs, but due to the small amount charged for irrigation service (GH¢ 2.50 per 0.06 ha) at the scheme it could not be financially autonomous. At Libga, Bontanga and Golinga Schemes, 90 % of collected irrigation service charges were being retained by the schemes while 10 % passed to GIDA office in the Northern Region. This means that these three (3) schemes were also financially autonomous.

Ijir (1994) reported that the managing agency of the Wurno Irrigation Scheme in Nigeria had no degree of financial autonomy because all the irrigation services were passed to the central Government. A study by the ADB (1986), found that financial autonomy is almost always partial, as irrigation agencies generally receive subsidies from the government budget. However, it is generally felt that financial autonomy could lead to better performance of systems through increased accountability of the managers to water users, and through greater participation of the farmers in operation and maintenance.

4.4.3.3 Financial Self-Sufficiency Rates (FSSRs)

This is an index which relates to the ability of a scheme to sustain itself financially with respect to regular management, operation and maintenance expenditures. The financial self- sufficiencies of the schemes between the periods of 2010 - 2014 are presented in Table 4.17. This indicator was calculated based on the annual income from water charges and other revenue sources and total annual management, operation and maintenance expenditures of the scheme (major rehabilitation costs not included but Government subsidies in the form of staff salaries included).

Table 4.17: Financial Self-Sufficiency Rates (%) of the Irrigation Schemes

Total Annual Income from Water Charges and other Revenue Sources (GH¢) *					
Year	2010	2011	2012	2013	2014
Tono	79,266	70,506	55,148	41,628	74,491
Vea	4,400	1,099	2,020	2,600	2,720
Doba	100	51	65	49	-
Libga	114	133	120	4,544	5,592
Bontanga	4,591	5,311	7,604	11,793	14,240
Golinga	215	1,649	1,928	4,933	4,640
Total Annual MOM Costs of the Scheme (GH¢) *					
Year	2010	2011	2012	2013	2014
Tono	133,610	129,320	160,161	150,021	185,708
Vea	41,040	40,120	60,600	61,000	66,080
Doba	180	150	160	145	-
Libga	6,101	6,106	9,081	10,187	10,899
Bontanga	21,390	20,190	30,269	35,000	37,360
Golinga	6,215	6,575	9,632	10,307	10,927
Financial Self-Sufficiency Rate (%) **					
Year	2010	2011	2012	2013	2014
Tono	59	55	34	28	40
Vea	10.7	2.7	3.3	4.3	4.1
Doba	55.6	34	40.6	33.8	-
Libga	1.9	2.2	1.3	45	51
Bontanga	21	26	25	34	38
Golinga	3	25	20	48	42

MOM – Management, Operation and Maintenance

(Source: * – Project Records, 2015 and ** – Desk Computation, 2015)

Tono Irrigation Scheme: The FSSRs for the scheme were found to be in the range of 28 – 59 %. The study revealed that from year 2010 - 2014, an average of 43 % of the scheme's management, operation and maintenance costs were generated internally while the 57 % was covered by the GoG. The scheme is under government subvention and all salaries of staff are paid by the government. The lowest FSSR was recorded in 2013 with 28 % whereas the highest was recorded in 2010 with 59 %. These rates recorded by the Tono scheme indicate that the scheme cannot attain financial self- sufficiency if the cost recovery rates remained low as recorded in previous years. According to Ijir (1994), an irrigation scheme is financially self-sufficient if it records financial self-sufficiency rates of 100 % or more (> or = 100 %). The author determined the financial self-sufficiency rate of the Wurno Irrigation Scheme in Nigeria as 40 %.

Vea Irrigation Scheme: The FSSRs for the scheme were found to be very poor in a range of 2.7 - 10.7 %. The low efficiency of irrigation services charges recovery recorded for the periods of 2010 – 2014 resulted in these low rates. The study revealed that for the five year period, an average of 5 % of the scheme's management, operation and maintenance costs were generated internally while 95 % was covered by the GoG. The scheme is also under government subvention and all salaries of staff are paid by the Government. Beyribey (1997) determined financial self-sufficiency rates of state operated irrigation schemes in Turkey to be in the range of 21 – 91 %.

Doba Irrigation Scheme: This scheme which is managed by WUA recorded low FSSRs of 33.8 – 55.6 %. These rates clearly indicate that the scheme is not financially self-sufficient. The internally generated revenue through irrigation service charges could only cover 30 – 50 % of its annual management, operation and maintenance expenditures. The irrigation service charge of GH¢ 2.50 per plot (0.06 ha) is too small to make the scheme financially self-sufficient. Apart from the irrigation service charges, the scheme had no other sources of generating revenue. Ijir (1994) reported that an irrigation service charge is the only source of revenue for the sustainability of the schemes of most WUA operated schemes. Molden *et al.* (1998) determined the financial sufficiency rates of 18 irrigation schemes located in 11 different countries in Africa as 100 – 139 % for the WUA operated irrigation schemes and 28 – 50 % for the state operated irrigation schemes.

Libga Irrigation Scheme: The scheme also recorded low FSSRs of 1.3 – 51 %. The study revealed that an average of 20 % of the scheme's management, operation and maintenance costs was generated internally during the period of 2010 - 2014 while the 80 % was covered by the GoG. The salary of the Scheme Manager is paid by the GoG while the allowances of the water bailiff are paid from the irrigation service charges collected. The low irrigation service charges recovery rates recorded each year are the cause of the low FSSRs of the scheme. Sener *et al.* (2007) determined the Hayrabolu Irrigation Scheme's financial self-sufficiency to be in a range of 6 - 179 % in the period from 1989 - 2001. Sayin *et al.* (2013) determined the mean FSSR of 29 irrigation schemes in Antalya in Turkey as 82.2 %.

Bontanga Irrigation Scheme: The scheme recorded low FSSRs of 21 – 38 %. The study revealed that an average of 29 % of the scheme's management, operation and maintenance costs was generated internally during the period of 2010 - 2014 while 71 % was covered by the GoG. All permanent staff on the scheme were paid by the government. However, allowances of the two water bailiffs are paid from the irrigation service charges collected. For the scheme to attain high FSSRs, the service recovery rates have to be improved. In a study conducted in the Karacabey irrigation network, Kuscu *et al.* (2009) found an average financial sufficiency rate of 94 % for the period between 2002 and 2007. Yercan *et al.* (2004) determined FSSRs as between 100 – 260 % for eight irrigation schemes in Gediz River Basin in Western Turkey.

Golinga Irrigation Scheme: The scheme recorded low FSSRs of 3 – 48 % over the five years period. It was revealed that an average of 21 % of the scheme's management, operation and maintenance costs was generated internally during the years 2010 - 2014 whereas the 79 % was covered by the GoG. The salary of the Scheme Manager is paid by the GoG whereas the allowances of the two water bailiffs are paid from the collected irrigation service charges. Cakmak *et al.* (2009) recorded FSSRs of 52 – 170 % for the Asartepe Irrigation Scheme in the period from 2001 - 2004.

4.4.4 Environmental Performance

Environmental performance deals with the percentage of the developed irrigable area not affected or lost due to negative environmental conditions such as salinity, erosion and waterlogging as a result of the impact of irrigation. The environmental stability index was used to assess the environmental performance of the schemes.

4.4.4.1 Environmental Stability Index

This index was used to evaluate the stability of the developed irrigable areas of the schemes regarding the levels of salinity and sodicity, and the prevalence of erosion and waterlogging as a result of adverse impact of irrigation. The environmental stability indices of the schemes are presented in Table 4.18.

Table 4.18: Environmental Stability Index

Scheme	Developed Area (ha)*	Total Developed Area Affected (ha)*	Type of Environmental Problem in the Scheme*	Total Developed Area Unaffected (ha)*	Environmental Stability Index (%) **
Tono	2,490	59	waterlogging, erosion	2,431	98
Vea	850	44	waterlogging, erosion	806	95
Doba	7	0	-	7	100
Libga	16	2	waterlogging, salinity	14	86
Bontanga	495	0	-	495	100
Golinga	40	0	-	40	100

(Source: * – Project Records, 2015 and ** – Desk Computation, 2015)

The Doba, Bontanga and Golinga irrigation schemes were environmentally stable as each recorded an environmental stability index of 100 %. The irrigable areas of the schemes were free of erosion, waterlogging and salinity problems.

Waterlogging and erosion were recorded on the Tono and Vea irrigation schemes but the situation was not yet acute as they recorded an environmental stability index of 98 % and 95 % respectively. At Tono, the waterlogging is caused by seepage from the broken laterals. Some portions of the uplands of the irrigable areas are eroded annually during heavy rains.

At Vea, the causes of the waterlogging include:

- Poor drainage network,
- Improper and poor water control,
- Leakages or seepage from canals and laterals and,
- Spillage from canals due to poor water control by water bailiff.

As a result of the poor state of the canals and laterals, most farmers resorted to lifting water from the main drain using pumps for irrigation, so the water bailiff deliberately opened the water to spill-over the canal banks (Plate 4.6) and subsequently flow to the main drain for such farmers to use. This practice consequently caused waterlogging in some fields.

Plate 4.6: Spillage from Canal Causing Waterlogging in the Vea Irrigation Scheme

Libga Irrigation Scheme: Following the continuous cultivation in the scheme for 46 years, the irrigable area of the scheme was becoming unstable as it recorded an environmental stability index of 86 %. The problem of salinity was identified since 2009 and it was said to be increasing especially at the downstream portions of the irrigable area. The total area affected by salinity was estimated to be about 2 ha and in various patches. According to Ijir (1994), the notional normal environmental stability index was in the range of 90 – 100 %, but the author found the environmental stability index of the Wurno Irrigation Scheme in Nigeria to be 87.5 %. This means that the 86 % index for the Libga Irrigation Scheme slightly fell below the normal index. Sener *et al.* (2007) reported 99 % environmental stability index for the Hayrabolu Irrigation Scheme in Turkey.

4.4.4.2 pH in the Soils of the Irrigable Areas of the Schemes

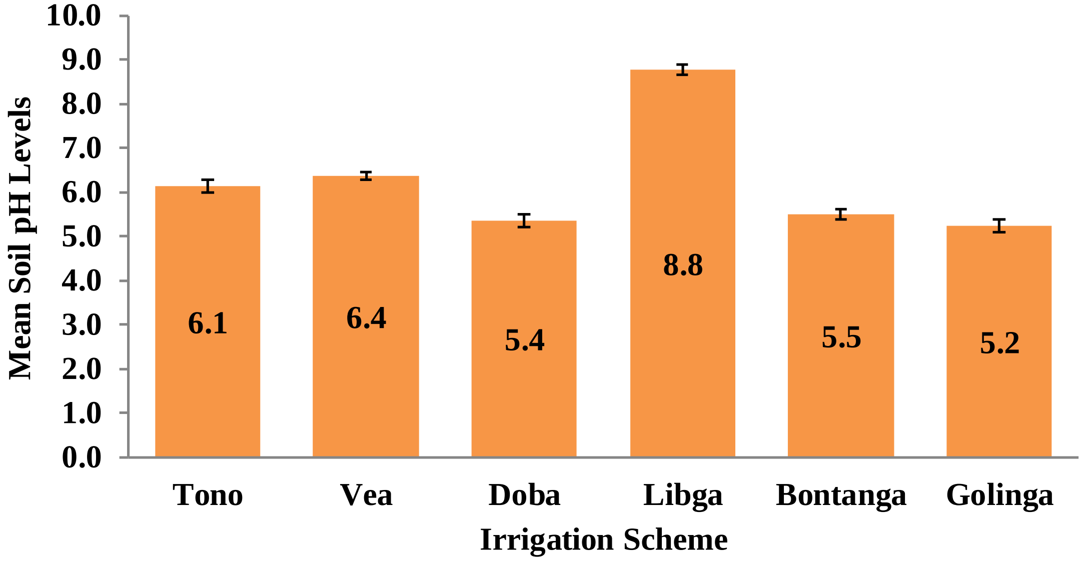

Figure 4.3: pH in the Soils of the Irrigable Areas

The results presented in Figure 4.3 show that the pH of the soils from all the schemes except Libga were fairly uniform, that is, slightly acidic with average values of 5.2 – 6.4 while the soils from the Libga scheme have a pH of 8.8 which was slightly alkaline. The analysis of variance (ANOVA) performed at 5% level of significance on pH of soils for the various schemes gave F pr value of < 0.001, hence pH for soils among the irrigation schemes are statistically significant. With reference to LSD of 0.523, there is a significant difference between pH at Libga and all the other schemes. The alkaline nature of the Libga scheme soils might be attributed to the high levels of sodium (440.7 mg/kg) in the soils. The slightly acidic nature of soils from Tono, Vea, Doba, Bontanga and Golinga might also be attributed to the lower levels of sodium ranging from 47.3 - 81.3 mg/kg in the soils. According to Senayah *et al.* (2009), soil pH within the drier Savannah agro-ecological zones, particularly both the Volta and Lima series are strongly acidic (mostly less than 5.0). The top soil pH ranges from strongly acidic to neutral for Lapliki series.

Buri *et al.* (2006) stated that exchangeable acidity is also relatively higher within the savannah agro-ecology which can adversely affect basic cation balances particularly Ca and Mg leading to adverse effect on crop growth especially rice. A pH range from 5.5 - 7.0 is suitable for most vegetable crops (Liu and Hanlon, 2012). This pH range can assure high bioavailability of most nutrients essential for vegetable growth and development (Ronen, 2007). At soil pH of 8.0 or higher, iron and/or manganese bioavailability cannot satisfy most vegetable crops' requirements. However, when soil pH reaches 5.0 or lower, aluminum, iron, manganese, and/or zinc solubility in soil solution becomes toxic to most vegetable crops (Osakia *et al.,* 1997). The bioavailability of most nutrients is controlled by soil pH, thus, as soil pH increases, the bioavailability decreases for P, Fe, Mn, B, Zn, and Cu. As soil pH decreases, the bioavailability decreases for Ca, Mg and Mo (Liu and Hanlon, 2012). According to Whiting *et al.* (2014), pH of 6.0 – 7.5 is acceptable for most plants growth and development, pH of 4.6 is too acidic for most plants, pH 5.5 reduces soil microbial activity and pH > 8.3 is too alkaline for most plants. This means that the soils at Tono (pH 6.1) and Vea (pH 6.4) are within the acceptable limits for optimum plants growth and development whereas the soils at Doba (pH 5.4), Bontanga (pH 5.5) and Golinga (5.2) can potentially reduce microbial activity. The Libga soils (pH 8.8) are too alkaline for plants growth and development resulting in poor yield.

4.4.4.3 Salinity in the Soils of the Irrigable Areas of the Schemes

Electrical conductivity (EC) which describes the levels of salinity in soils was measured in all the soil samples collected from the schemes and presented in Figure 4.4.

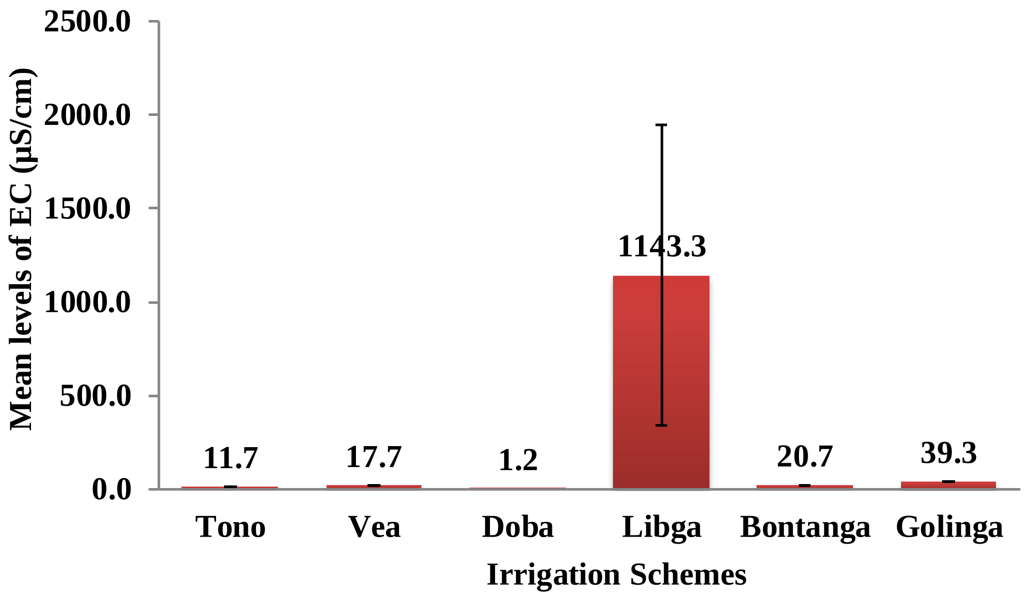

Figure 4.4 : Level of Salinity in the Soils of the Irrigable areas of the Schemes

With reference to Figure 4.4, the average concentrations of EC of the various schemes namely; Tono, Vea, Doba, Bontanga, Golinga, and Libga were 11.7 µS/cm, 17.7 µS/cm, 1.2 µS/cm, 20.7 µS/cm, 39.3 µS/cm and 1,143.4 µS/cm respectively. The mean values recorded except Libga are within the recommended range for crop production. The Libga scheme recorded significantly high salinity levels of 317 – 4,106 µS/cm with a high mean level of 1,143.3 µS/cm (Lamond and Whitney, 1992). This could be attributed to higher concentrations of cations such as sodium and potassium (Khai *et al*., 2008). Analysis of variance performed at 5 % level of significance yielded F pr value of < 0.001; thus, electrical conductivity among the soil samples of the schemes are statistically significant. Low salinity level suggests that injury to plants is very little while high salinity level indicates that most high salt tolerant plants such as grain sorghum and maize will show injury and low/moderate salt-sensitive plants such as rice, onion, tomato, pepper, cabbage and okra will show severe injury including stunting, chlorosis and severe dwarfism (Igartua *et al*., 1994; Krishnamurthy *et al*., 2007). As a result of salinity in substantial quantities, moderately salt tolerance crops like tomato, cabbage, lettuce, carrot and onion were not cultivated on the scheme except roselle, jute mallow, okra, pepper and rice (Singh *et al.,* 2007). The 4,106 µS/cm recorded at the Libga downstream is described as high which indicates that, the growth and yield of most low and moderately salt-sensitive crops like tomato, okra and vegetables can be severely affected. Plate 4.7 illustrates patches of land affected by salinity in Libga irrigation scheme.

Plate 4.7: Salinity Affected Crop Fields at Libga Irrigation Scheme

One of the causes of salinity in the Libga scheme over the time is the accumulation of salts as a result of the continuous application of inorganic fertilizers for about 46 years without proper drainage network which causes waterlogging and high water tables. Similar management practices were observed at the other schemes but with a minimal residual effect, probably, due to proper management. The total area affected by salinity was estimated to be about 2 ha in various patches. Horneck *et al.* (2007) stated that salinity in soil can originate from soil parent material; from irrigation water and from fertilizers or other soil amendments. Ijir (1994) indicated that the high soil salinity levels in the Wurno scheme were caused by waterlogging due to poor water control and drainage system. Horneck *et al.* (2007) and Senon *et al.* (2012) reported that salinity in irrigated soils can reduce crop yields, reduce the effectiveness of irrigation, reduces water availability for plant use, ruin soil structure and affect other soil properties.

4.4.4.4 Sodicity in the Soils of the Irrigable Areas of the Schemes

The sodicity levels in the soils were determined using the Exchangeable Sodium Percentage (ESP) indicator and the results are presented in Figure 4.5.

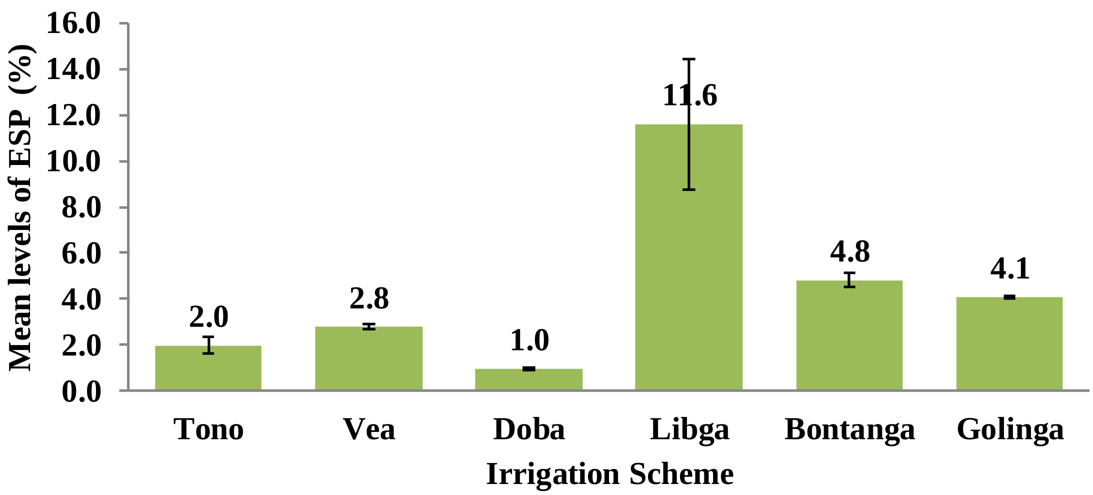

Figure 4.5 : Level of Sodicity in the Soils of the Irrigation Schemes

The results showed that sodicity levels were low at Tono (2.0 %), Vea (2.8 %), Doba (1.0 %), Bontanga (4.8 %) and Golinga (4.1 %). Low levels of ESP necessitate low EC (Hanson *et al.*, 1990). It can be ascertained that ESP and EC concentrations in all the schemes except Libga were low; hence the soils were free of salt-related problems (salinity and sodicity). However, the Libga scheme recorded moderately high to excessively high sodicity levels of 8.5 – 30 % with a mean level of 11.6 %. The upstream recorded the lowest sodicity level of 8.5 % whereas the downstream recorded the highest sodicity level of 30 %. Analysis of variance performed at 5 % level of significance gave F pr = 0.018, indicating that there was significant difference in the sodicity levels of the various irrigation schemes.

USDA Natural Resources Conservation Service (2003) reported that, soils with ESP less than 15 % are normal soils whereas soils with ESP greater than 15 % are sodic soils and soils with electrical conductivity (EC) above 4,000 µS/cm and exchangeable sodium percentage (ESP) above 15 % are described as saline-sodic soils (Horneck *et al.*, 2007). By way of comparing the schemes, it can be observed that, Tono, Vea, Doba, Bontanga, Golinga and Libga (upstream/midstream) irrigable soils were normal but sodic at Libga (downstream). Therefore, the Libga downstream soil can be best described as saline-sodic since the soils have EC of 4,106 µS/cm and ESP of 30 %. Senon *et al.* (2012) reported that sodic soils tend to have poor structure with physical properties such as poor water infiltration and air exchange, which can reduce plant growth. Warrence *et al.* (2003) outlined the principal effects of soil sodicity as reduced infiltration, reduced hydraulic conductivity, surface crusting and reduced crop yield.

4.4.5 Production Performance

Table 4.19: Mean Crop Production Area and Yield in the Schemes (2010 – 2014)

Crop	Scheme	Mean Area (ha)	Mean Area (%)	Mean Yield (t/ha)
Rice	Tono	1,045	91.4	4.2
	Vea	59	56.4	4.0
	Doba	0	0	0
	Libga	2.8	18.6	1.9
	Bontanga	306.6	71.6	4.2
	Golinga	9.6	30.1	2.1
Tomato	Tono	43.9	3.3	6.2
	Vea	43	36.8	4.0
	Doba	0	0	0
	Libga	0	0	0
	Bontanga	0	0	0
	Golinga	0	0	0
Okra	Tono	20.9	1.7	7.5
	Vea	0	0	0
	Doba	0	0	0
	Libga	0.5	3.3	2.5
	Bontanga	52	12.4	8.3
	Golinga	7.6	23.9	4.7
Onion	Tono	4	0.3	8
	Vea	0	0	0
	Doba	0	0	0
	Libga	0	0	0
	Bontanga	19	4.6	9.4
	Golinga	0	0	0
Pepper	Tono	45	4	0.3
	Vea	0	0	0
	Libga	0.5	3.3	0.2
	Bontanga	37.4	8.6	0.4
	Golinga	0.2	0.5	0.2

(Source: Tono, Vea, Doba, Libga, Bontanga and Golinga Records, 2015)

Rice Production: The results in Table 4.19 indicate that Tono, Bontanga and Vea irrigation schemes produce rice in a larger scale as more than 50 % of the total irrigated area of each of these schemes was used for rice production from 2010 - 2014. The average irrigated area of 1,045 ha, 306.6 ha and 59 ha respectively was used for rice production in the Tono, Bontanga and Vea irrigation schemes. The mean yield of 4.5

t/ha was recorded at Tono, 4.2 t/ha at Bontanga and 4.0 t/ha at Vea. The average yields in the three (3) schemes were significantly higher than the average yield of rice in Ghana which was estimated to be 2.5 t/ha (MoFA, 2011). However, the Libga and Golinga schemes which cultivated the crop in a smaller scale over the five (5) years period attained lower average yields of 2.1 t/ha and 1.9 t/ha respectively. The major challenge faced by farmers in the Libga and Golinga schemes in the production of rice was the high costs of fertilizers and agro-chemicals and so they were not able to apply the recommended rates to attained optimum yields per unit area.

Tomato, Okra, Onion and Pepper Production: The results in Table 4.19 clearly show that tomato production in the schemes has drastically declined as four (4) out of the six (6) schemes namely Doba, Libga, Bontanga and Golinga had not cultivated the crop since 2010 – 2014. Though, Tono and Vea schemes produced tomatoes, the average irrigated area for the crop over the five years period under review was 43.9 ha and 43 ha respectively. The average yield of 6.2 t/ha and 4.2 t/ha respectively for the Tono and Vea schemes is far below the annual average yield in Ghana of 15 t/ha (MoFA, 2011). The yield gap of 59 -72 % is quite huge.

For okra, the Vea and Doba schemes had not cultivated the crop since 2010 – 2014, but all the other schemes had cultivated it at smaller scale in a range of 0.5 – 52 ha. The average yield range was 2.5 – 8.3 t/ha. For onion, the production has declined drastically as only Tono and Bontanga schemes cultivated the crop in 2010 – 2014. Average area cropped in the Tono scheme was 4 ha while that of Bontanga scheme was 19 ha.

For pepper, the average area cropped in the Tono scheme in 2010 – 2014 was 45 ha while that of Bontanga scheme was 37.4 ha. However, it was not grown on the Vea and Doba schemes. The Libga and Golinga schemes cultivated the crop on an area of 0.5 ha and 0.2 ha respectively. This clearly indicates that pepper production on the schemes has drastically declined.

Some of the reasons cited by farmers and management of the schemes for the reduction in cropped areas and yields of tomato, okra, onion and pepper in the schemes include:

- Farmers inability to apply recommended rates of agro-chemicals and fertilizers due to high cost,
- Pests and diseases infestation especially nematodes,
- Poor market resulting in low price due to Market queens preferences,
- Poor state of irrigation facilities such as canals, laterals and offtake valves,
- Low reservoir water levels due to poor rainfall regime,
- Low levels of soil fertility at the irrigable areas due to continuous cropping and,
- Salinity and sodicity problems at Libga Scheme

Roselle and Vegetable Jute Production: The study revealed that farmers in the Libga and Golinga irrigation schemes undertook production of roselle (*Hibiscus sabdariffa*) and vegetable jute (*Corchorus olitorius*) for both domestic and commercial purposes. Farmers in the remaining schemes were not cultivating the two (2) crops.

In the Libga irrigation scheme, the average irrigated area under roselle cultivation was 7.2 ha while that of vegetable jute was 3 ha. The yields range of roselle was from 45.3 – 60.04 t/ha while vegetable jute was from 3.8 – 4.2 t/ha/season.

In the Golinga irrigation scheme, the average irrigated area under roselle cultivation was 7.8 ha while that of vegetable jute was 3.4 ha. The yields range of roselle was from 43.5 – 58.0 t/ha whereas vegetable jute was from 3.2 – 3.7 t/ha/season.

4.5 Activities in the Watershed of the Dams

Human activities which have the tendency of silting-up reservoirs of the dams were found in the watershed of almost all the irrigation schemes. Management of the schemes were aware of these practices at the upstream and several efforts had been made to stop them, but all proved futile. These activities include:

- **Irrigated Farming at the Upstream of the Reservoirs:** Some farmers did not obey the operation rules restricting farming activities in the watershed and were engaged in irrigated farming at the upstream of the reservoirs using water pumps, buckets or basins to lift water from the reservoirs (Plate 4.8). This activity was seriously practiced in all the schemes except Doba. With the aid of the Global Positioning System (GPS) area calculator, the irrigated areas at upstream of the reservoirs were estimated and presented in Table 4.20.

Table 4.20: Irrigated Farming at the Upstream of the Reservoirs

Scheme	Number of Farmers Involved	Estimated Area (ha)	Landholding Range (ha)	Number of Water Pumps Used	Estimated Year Activity Started
Tono	139	42	0.2 – 0.4	61	2007
Vea	53	9	0.125 – 0.25	12	2005
Doba	0	0	0	0	-
Libga	95	23	0.04 – 0.4	20	2000
Bontanga	11	1.2	0.04 – 0.2	1	2012
Golinga	24	2.5	0.04 – 0.25	2	2010

(Source: Field Survey, 2015)

Plate 4.8: Irrigated Farming at the Upstream of the Libga Reservoir

- **Felling of Trees Protecting the Reservoirs:** The *Eucalyptus spp* and *Cassia siamea* planted to check sediments from being carried into the reservoirs were felled by some people for logs, firewood and to make way for farming (Plate 4.9).

Plate 4.9: Felling of Trees Protecting the Reservoir at Vea Irrigation Scheme

- **Burning of Reservoir Protection Grasses:** The *Panicum maximum* grasses planted at the edges of the reservoir to check erosion were burnt annually by rat hunters and herdsmen to make way for the regeneration of fresh foliage for their animals to graze. This practice is very bad since it renders the ground bare and highly susceptible to erosion during onset of rains and runoff and subsequent increased siltation of the reservoir (Plate 4.10).

Plate 4.10: Burnt Reservoir Protection Grasses at Bontanga Irrigation Scheme

- **Encroachment by Human Settlements:** Human settlements were built too close to Doba's reservoir (Plate 4.11).

Plate 4.11: Human Settlements Built too Close to the Doba Reservoir

4.6 The Condition of the Infrastructure in the Irrigation Schemes

4.6.1 The Condition of Dam Walls, Spillways, Reservoirs, Canals and Laterals

Table 4.21a: The Condition of the Dam Walls

Scheme	Dam Wall	Condition
Tono		• The 3.5 km long dam wall was in good working condition. • The upstream face was fully rip-raped with igneous rocks. • The wave wall had no defects. • The crest and downstream face were periodically regravelled.
Vea		• The 1.6 km long wall was in a very poor working condition. • The upstream slope had caved-in up to 21 metres towards the downstream slope due to poor stone rip-rapping. • Gullies were on the downstream slope. • The crest contained a lot of large potholes.
Doba		• The 0.51 km long dam wall was in a poor working condition. • The downstream slope was severely eroded leaving gullies. • Water erosion had reduced the width of the crest. • Water erosion had reduced the height.

Table 4.221b: The Condition of the Dam Walls

Scheme	Dam Wall	Condition
Libga		• The 0.65 km long dam wall was in a very poor working condition. • The entire upstream slope had caved-in. • The downstream slope was severely eroded. • The crest contained a lot of large potholes. • Seepage through the wall was experienced in the rainy season. • The dam wall was at the verge of breaching.
Bontanga		• The 1.9 km long dam wall was in good working condition. • The upstream slope was fully rip-raped with igneous rocks. • The crest of the wall was in good condition. • The dam wall was rehabilitated by MiDA in 2011 – 2012.
Golinga		• The 0.7 km long dam wall was in poor condition. • The upstream and downstream slopes were eroded. No stone rip-rapping. • There were potholes at some sections of the crest. • Erosion had reduced the height. • It was rehabilitated in 2011 – 2012, but degrading fast due to the poor rehabilitation.

Table 4.22a: The Condition of Spillway Structures

Scheme	Spillway Structure	Condition
Tono		• The spillway was in good working condition with no defects.
Vea		• The spillway was in good working condition.
Doba		• The spillway was been breached in 2007. • It was temporarily repaired with stones and a short concrete wall by the WUA on the scheme.

Table 4.22b: The Condition of Spillway Structures

Scheme	Spillway Structure	Condition
Libga		• The 50 m wide spillway was in poor working condition. • It was breached in 2010. • Not yet rehabilitated.
Bontanga		• The drop inlet spillway was in good working condition.
Golinga		• The 80 m wide spillway structure was in good working condition. • It was rehabilitated in 2011 – 2012 by MiDA.

Table 4.23a: The Condition of Reservoirs of the Dams

Scheme	Reservoir of Dam	Condition
Tono		• Contained considerable amounts of sediments. • The contributory factors include irrigated farming at the upstream of the reservoir and floods. • Water level at dead storage.
Vea		• Contained high level of sediments. • The contributory factors include the irrigated farming at the upstream of the reservoir and floods. • The estimated average sedimentation of the reservoir was 1.4 x 10^5 m^3/year (Adongo *et al.*, 2014).
Doba		• Silted and dried-up. • The contributory factors include low level of agricultural best management practices on the watershed, human settlement and poor vegetative cover. • No desiltation after 59 years of construction.

Table 4.23b: The Condition of Reservoirs of the Dams

Scheme	Reservoir of Dam	Condition
Libga		• The reservoir contained high amounts of sediments and weeds. • No desiltation after 46 years of construction.
Bontanga		• The reservoir was in good condition. • Contained some considerable amounts of sediments.
Golinga		• The reservoir contained high amounts of sediments and weeds. • The average siltation rate of the reservoir was 7.7 cm/y (SNC, 2010). • No desiltation after construction was completed in 1974.

Table 4.24a: The Condition of Main Canals in the Irrigation Schemes

Scheme	Main Canals	Condition
Tono		• The 42 km long main canals had no breaches. • It was rehabilitated in 2008, where the two (2) canals were relined with concrete. • The canals had not been desilted since 2012. The sediments depth was 0.32 m. • Average volume of silt was 17,220 m^3.
Vea		• The two main canals, with a total length of 26.5 km long were breached at several sections, silted and full of weeds and shrubs. • The average depth of sediments in the canals was 0.47 m. • Average volume of sediments (silt) in the canals was 20.670 m^3.
Doba		• The 0.6 km long canal was breached at several sections due to animal crossing and improper practices of farmers. • The average depth of sediments in the canal was estimated to be 0.15 m. • Average volume of sediments was 24 m^3.

Table 4.24b: The Condition of Main Canals in the Irrigation Schemes

Scheme	Main Canals	Condition
Libga		• The 1.3 km long main canal was in a poor working condition. • It had several cracks and displaced slabs at some sections. • It was silted, weedy and contains considerable amounts of shrubs. • The flow length of the canal now stood at 1.15 km due to faulty construction.
Bontanga		• The 11.5 km long main canals were in good working condition. • No breaches, sediments and weeds were found in the canals. • The canals were rehabilitated in 2011 – 2012 by MiDA. • Cracks repaired as and when they occur.
Golinga		• The 2.3 km long canals were in good working condition. • The canals were rehabilitated in 2011 – 2012 by MiDA. • No sediments were found.

Table 4. 25a: The Condition of Laterals in the Irrigation Schemes

Scheme	Laterals	Condition
Tono		• The 82 laterals with a total length of 56 km were in poor working condition. • They had never been rehabilitated since construction was completed in 1985. • The concrete slabs were displaced at several sections and control gates broken. • The condition of the laterals resulted in waste of irrigation water through seepage.
Vea		• The 60 laterals were in poor working condition. • They had never been rehabilitated since construction was completed in 1980. • All the laterals had their concrete slabs, check structures and control gates removed. • The condition resulted in waste of irrigation water through seepage.
Doba		• All the 10 laterals on the scheme were silted-up beyond recognition. • All the lateral gates were removed. • The arrow shows the position of the lateral.

Table 4.25b: The Condition of Laterals in the Irrigation Schemes

Scheme	Laterals	Condition
Libga		• The 8 laterals were in poor working condition. • Each lateral was breached at several sections despite the rehabilitation in 2008. • Two (2) of the laterals at the tail-end were presently not functioning due to faulty construction of the main canal. • The condition resulted in seepage and waterlogging in the scheme.
Bontanga		• The 28 laterals were in good working condition. • There were no breaches and are free of sediments and weeds. • They were rehabilitated in 2011 – 2012 by MiDA. • Cracks repaired as and when they occur. • Check structures were working properly.
Golinga		• All the 12 laterals were in good working condition. No cracks, sediments and weeds. • They were rehabilitated in 2011 – 2012 by MiDA. • Some lateral and check structure gates had been stolen.

4.6.2 Reservoir Water Levels of the Irrigation Schemes

The study revealed that the reservoir levels of the Tono and Vea schemes have been low for the past five years (2010 - 2014), compared to reservoir levels from 10 - 20 years ago. The management of the Doba, Libga, Bontanga and Golinga indicated that due to the high amounts of sediments in the reservoirs, the reservoirs got filled very early, when it rained heavily and continuously in the rainy season but the level reduced quickly at the onset of the dry season. In 2014, however, the rainfall was very poor, resulting in a poor reservoir recharge in all the schemes. The reservoirs of Tono and Vea had not spilled for the past five years (2010 -2014), due to poor recharge. There was no irrigation in Tono for the 2015 dry season, as the reservoir water level was at dead storage.

The reservoirs of Doba, Libga, Bontanga and Golinga had no water level measuring device, hence no available data on reservoir water levels. From 1985 – 2014, the Tono reservoir had spilled 21 times. Also, the Vea reservoir had spilled 14 times from 1980 - 2014. The Tono and Vea reservoir water levels for 2010 – 2014 are presented in Figures 4.6 and 4.7 respectively.

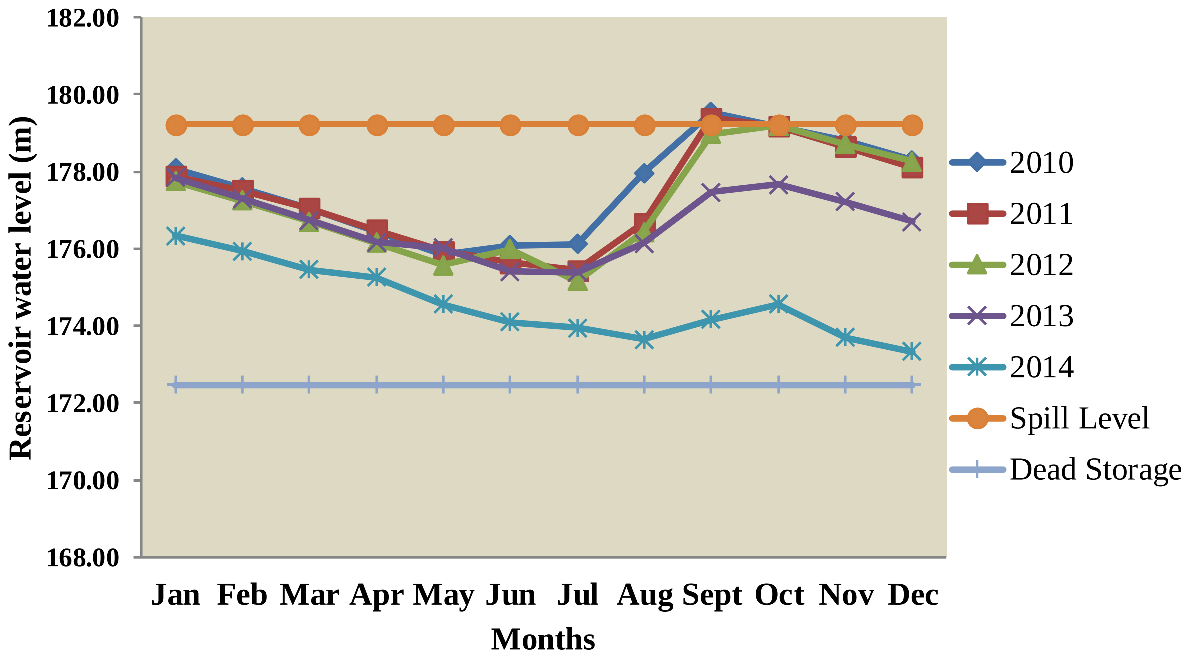

Figure 4.6: Tono Reservoir Water Levels from 2010 – 2014

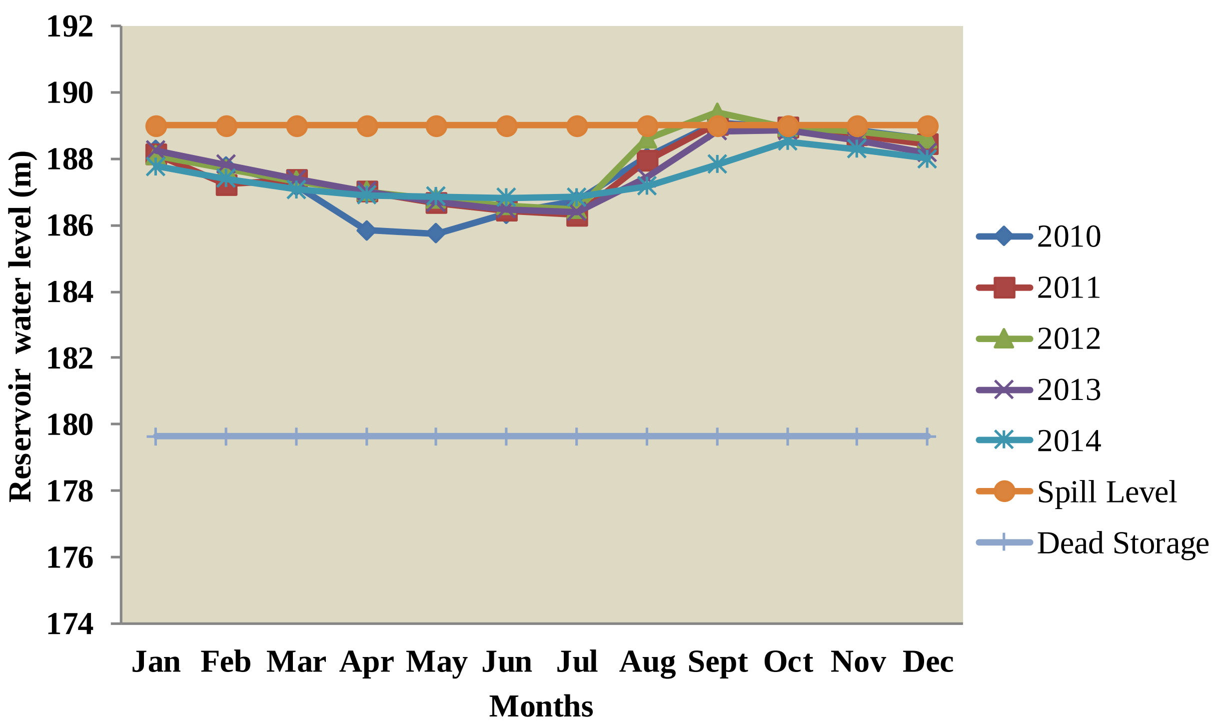

Figure 4.7: Vea Reservoir Water Levels from 2010 – 2014

4.6.3 Night Storage Reservoirs in the Irrigation Schemes

The Tono and Vea irrigation schemes have night storage reservoirs. These structures were constructed at strategic locations at the downstream portion of the schemes. The Doba, Libga, Bontanga and Golinga Schemes have no night storage reservoirs.

The Tono irrigation scheme has seven (7) night storage reservoirs. All were rehabilitated in 2008. However, the night reservoirs were in very poor conditions. They were silted and weedy as illustrated in Plate 4.12.

Plate 4.12: Silted and Weedy Night Storage Reservoir in Tono Irrigation Scheme

The Vea irrigation scheme has only one (1) night storage reservoir (Plate 4.13). It has not been in used since 1997 due to:

- Broken inlet and outlet canals,
- Broken inlet and outlet valves and
- Siltation.

Plate 4.13: Silted Night Storage Reservoir in Vea Irrigation Scheme

4.6.4 Drainage Networks on the Irrigation Schemes

The study revealed that the main, primary and secondary drains across all the schemes except the Doba scheme had some considerable amounts of sediments, weeds and shrubs in them thereby impeding the smooth flow of excess irrigation water and rain water run-off. Some of the primary, secondary and tertiary drains were converted into plots for crop cultivation especially rice. The management of the schemes were only concerned with the periodic desilting, slashing of weeds and cutting of shrubs on canals and laterals to the neglect of the drainage networks which play vital role in the schemes. The drainage networks in the schemes were in poor conditions. Ijir (1994) indicated that poor drainage network and poor condition of drainage networks in the Wurno irrigation scheme in Nigeria were the main cause of waterlogging and salinity problems on the scheme.

Cut-off drains are normally constructed to control run-off and to protect the main canals from sediments. However, the Doba and Libga irrigation schemes had no cut-off drains.

Also, the cut-off drains at the Tono, Vea, Bontanga and Golinga Scheme were filled up with sediments, hence run-off adjacent the canals flowed directly into the canals and consequently filling them up with sediments.

Plate 4.14: Silted and Weedy Primary Drain of the Tono Irrigation Scheme

Plate 4.15: Silted and Weedy Main Drain of the Golinga Irrigation Scheme

4.6.5 Off-take Valves in the Irrigation Schemes

Tono Irrigation Scheme: The five (5) valves - 3 scour tower and 2 off-take valves installed at the headworks of the scheme were in good working condition. The three scour tower valves are emergency valves which discharged water at 11.2 m^3/s. The two off-take valves discharged water at 3.7 m^3/s. Maintenance works on the valves were carried out on monthly basis.

Vea Irrigation Scheme: Four (4) out of the five (5) valves installed at the headworks were not functioning due to broken and worn-out parts. Presently, only one valve on the right bank canal was functioning, which discharged water at 1.26 m^3/s. As illustrated in Plate 4.16, the two (2) valves which were installed to discharge water at 1.07 m^3/s on the left bank canal were defunct; hence no irrigation was carried out on the left bank canal irrigable area in 2015. The two (2) walkways to the off-take valves in the reservoir were in dilapidated condition (Plate 4.17).

Plate 4.16: Defunct Off-take Valves in Vea Irrigation Scheme

Plate 4.17: Condition of Walk-Way to Off-take Valves in Vea Irrigation Scheme

The Doba, Libga, Bontanga and Golinga Irrigation Schemes: The off-take valves in these schemes were all in good working condition. The Doba scheme has one valve on the main canal, which discharged water at 0.15 m^3/s whist the Libga scheme has one valve on the main canal discharging water at 0.4 m^3/s. The Bontanga scheme has two valves; one on the right bank canal and the other on the left bank canal; each valve discharged water at 1.5 m^3/s. The Golinga scheme has two valves; one on the right bank canal and other one on the left bank canal. The right bank canal valve has a discharge of 0.2 m^3/s whereas the left bank canal valve discharged water at 0.3 m^3/s.

4.6.6 Meteorological Stations in the Irrigation Schemes

The meteorological station in the Tono irrigation scheme was installed in 1979. The installed instruments included rain gauges, evaporation pan, sunshine recorder, sunshine drum, anemometer, wind vane, soil thermometers and Stevenson screen which housed dry and wet bulb thermometers. As a result of lack of maintenance and repairs of instruments, the station became defunct in 2008. Presently, in the station were corroded evaporation pan, sunshine drum, rain gauges, sunshine recorder, rotten and empty Stevenson screen and defunct anemometer and wind vane (Plate 4.18).

The meteorological station situated at the Vea irrigation scheme belongs to the Ghana Meteorological Agency - Bolgatanga. The station was in good working condition as illustrated in Plate 4.19. It provides all climatic data to the Vea scheme at no cost.

Plate 4.18: Meteorological Station in the Tono Irrigation Scheme

Plate 4.19: Meteorological Station in the Vea Irrigation Scheme

4.6.7 Workshops, Transport and Farm Equipment System in the Irrigation Schemes

Tono Irrigation Scheme: The scheme has 12 motorcycles, which have been distributed to the extension and irrigation staff. The only pick – up for the scheme was used by the Scheme Manager. It was in good working condition. As presented in Table 4.26 and illustrated in Plate 4.20, the scheme had several farm equipment and implements, but almost all were in defunct condition as a result of worn-out parts, broken parts or outlived lifespan. The workshop was also not functioning as there were no farm equipment and implements for repairs and maintenance even though there were skilled personnel for maintenance.

Table 4.26: Condition of Farm Equipment and Implements in the Tono Irrigation Scheme

Farm Equipment	Number on the Scheme	Number Functioning	Number Not Functioning
Tractors	11	0	11
Disc plough	6	1	3
Disc harrows	1	0	1
Disc ridgers	3	0	3
Rotary cultivators	6	1	5
Combine harvesters	11	0	11
Levelling harrows	5	1	4
Tractor trailers	10	2	8
Seed drills	2	0	2
Power tillers	1	0	1
McConnell ditcher	1	0	1
Rice reapers	2	0	2
Pay loader	1	0	1

Source: (ICOUR – Tono, 2015)

Plate 4.20: Farm Equipment and Implements in the Tono Irrigation Scheme

The Doba, Libga, Bontanga and Golinga Irrigation Schemes: None of these schemes had a pick-up, tractor or any other farm equipment.

Vea Irrigation Scheme: The farm equipment and implements at the scheme were in poor working condition as presented in Table 4.27 and illustrated in Plate 4.21. Worn-out and broken parts were the main cause of the great number of equipment in defunct condition. The workshop stopped operating over 10 years ago.

Table 4.27: Condition of Farm Equipment and Implements on the Vea Irrigation Scheme

Farm Equipment	Number on the Scheme	Number Functioning	Number not Functioning
Tractors	1	0	1
Disc plough	2	1	1
Disc harrows	3	1	2
Mould board plough	1	1	0
Leveling harrows	1	1	0
Threshers	2	0	2
McConnell ditcher	1	0	1
4-wheel trailer	1	0	1
2-wheel trailer	1	0	1

Source: (ICOUR – Vea, 2015)

Plate 4.21: Condition of Farm Equipment and Implements in the Vea Irrigation Scheme

4.7 Farmers Views on Existing Conditions in the Irrigation Schemes

The farmers in the schemes, especially the Vea and Tono Irrrigation Schemes had responded to the constraining issues in three ways, that is, adaptation, improvisation and maintenance and abandonment.

4.7.1 Adaptation

At Vea, as a result of the low command and breached, silted and weedy canals and laterals, farmers had resorted to lifting water from the canals and drains to their fields. Lifting was accomplished by using watering cans, buckets or water pumps. To tackle the severe tail-end problems in some of the areas where the canals no longer flow, farmers lift water from the main drain using water pumps as illustrated in Plate 4.22. At the field level, individual farmers adapted to constructing several small basins and extra field ditches to serve their plots. At Tono, as a result of the breached laterals in many areas, some farmers resorted to lifting water from the canals, main and primary drains to their fields using water pumps. Ijir (1994) reported that the farmers in the Wurno irrigation scheme in Nigeria resorted to water lifting from main drains due to poor conditions of canals and laterals. At Libga, farmers at the salinity affected area resorted to the use of organic fertilizers, such as compost. They had abandoned the use of chemical fertilizers which they think is a contributory factor to the high levels of salts in the soil.

Plate 4.22: Lifting Water from Canal Using Water Pump in theVea Irrigation Scheme

4.7.2 Improvisation and Maintenance

Although maintenance of the main canals was regarded as the responsibility of ICOUR and GIDA, farmers often took initiatives to weed and de-silt the main and secondary canals. From interviews with farmers in the Vea irrigation scheme, this practice was common in the past when the system was in a better condition. Farmers had organised informal groups according to lateral basis, primarily for the purpose of maintaining the system at the communal level at no cost. With continued neglect by ICOUR, the problems and work-load grew beyond the farmers capabilities, so now some of the farmers had stopped cleaning the canals except the laterals. In addition, farmers improvised by using sandbags, mud, sticks and stones to temporarily repair breached canals and laterals to prevent water from spreading as shown in Plate 4.23

Plate 4.23: Breached Canal Temporarily Repaired With Sandbags by Farmers in the Vea Irrigation Scheme

As a result of a collapsed check structure in the main canal, farmers on the lateral at the Tono scheme had to improvise a check structure using sandbags, grasses and stones to control water to their fields as shown in Plate 4.24.

At the Golinga irrigation scheme which experienced stolen lateral check structure gates, the affected farmers had to improvise gates using stones, mud, sandbags, grasses and logs to control water into their fields (Plate 4.25). However, the use of sandbags, mud, stones, logs and sticks is one of the causes of sedimentation of the canals and laterals.

Plate 4.24: Farmers Improvising Check Structure on a Canal Using Sandbags and Stones in the Tono Irrigation Scheme

Plate 4.25: Improvised Lateral Check Structure from Stones and Grass at Golinga

4.7.3 Abandonment

Vea and Tono Irrigation Schemes: The overwhelming technical problems mainly due to the poor condition of canals, laterals and off-take valves at Vea and the poor condtion of laterals at Tono caused farmers wanning interest in irrigation, culminating in the decision to abandon many parts of the scheme. Farmers who could not get water to their field as a result of the problems abandoned them during the dry season to do other alternative dry season activities and only came back to the fields in the wet season to cultivate them under rainfed conditions. However, the efforts of the farmers indicate that for most of them this decision was a last resort. The farmers who had the means have bought at 5.5 or 6.5 HP water pumps in order to continue with irrigated farming at the reservoir upstream though this practice was not allowed. Ijir (1994) reported that some farmers in the Wurno irrigation scheme in Nigeria abandoned their fields due to salinity problems to do other alternative dry season activities.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The study showed that:

- The developed irrigable area in the Tono, Vea and Doba irrigation schemes is under-utilised with irrigation rates ranging from 8 – 54 % while that of Libga, Bontanga and Golinga irrigation schemes were put to near full capacity use with irrigation rates ranging from 91 – 100 %.
- Irrigation service charges recovery was poor in the Vea, Libga and Bontanga irrigation schemes with rates ranging from 19 – 52 % whereas the recovery is good in the Tono, Doba and Golinga irrigation schemes with rates ranging from 75 – 96 %.
- All the irrigation schemes were not financially self-sufficient due to the low irrigation service charges as well as the poor ISC recovery rates recorded annually.
- Considering sustainability of irrigated area index, the Doba, Vea and Tono irrigation schemes performed poorly with indices of 0 – 49 % whereas the Libga, Bontanga and Golinga have high sustainable irrigated area index of 95 - 100 %.
- The flow lengths of the main canals at the Tono, Vea, Doba and Libga irrigation schemes had reduced due to low reservoir water levels and infrastructural deficiencies.
- The main canals in the Tono, Bontanga and Golinga irrigation schemes were in good working condition due to their rehabilitation in 2008 (Tono) and 2011 –

2012 (Bontanga and Golinga) whereas that of Vea, Doba and Libga were in poor working condition due to lack of maintenance and repairs. This has greatly affected efficient conveyance of water downstream.

- The laterals in the Bontanga and Golinga irrigation schemes were in good working condition while the laterals in the Tono, Vea, Doba and Libga irrigation schemes were in poor condition. This has greatly affected efficient water distribution to farmlands.
- The road networks in the Libga, Bontanga and Golinga irrigation schemes were accessible all year round but that of Tono and Vea were in poor condition rendering some areas of the schemes inaccessible especially during rainy seasons.
- The irrigable area in the Libga scheme was affected with salinity and sodicity problems. The levels of salinity and sodicity in the soil are high and these adversely affected crop production in the scheme. The Tono, Vea, Doba, Bontanga and Golinga schemes had no salinity or sodicity problems.
- The production levels of cereals and vegetables on the schemes had declined both in area cropped and yield due to poor state of irrigation facilities, high prices of agro-chemicals, poor market, nematodes infestation and, low interest by farmers.
- All the farm equipment and implements for the Tono and Vea irrigation schemes were in derelict condition due to worn-out parts, broken parts or outlived lifespan. The workshops in the irrigation schemes were in defunct conditions. The meteorological station in the Tono irrigation scheme was defunct as a result

of lack of repairs and maintenance.

- The activities in the watershed of the irrigation schemes, such as irrigated farming at the upstream of the reservoirs, felling and burning of reservoir protection trees and grasses have years contributed to the high levels of sediments deposition in the dams' reservoirs.
- The youth (21 – 40 years) were actively involved in irrigated farming.
- Averagely, females had low representation (24.2 %) across all the irrigation schemes.
- Averagely, majority (82 %) of the farmers across all the schemes have not had any formal education.
- Landholding per farmer in the Tono, Vea and Bontanga schemes schemes ranged from 0.2 – 1 ha while that of Libga and Golinga schemes ranges from 0.1 – 0.4 ha due to the small developed irrigable area. The average landholding per farmer in the Doba scheme was 0.06 ha due to the very small irrigable area (7 ha).
- Farmers in the irrigation schemes had responded to some of the constraints and problems by adaptation, improvisation, maintenance and abandonment.

5.2 Recommendations

5.2.1 Recommendations for the Management of the Irrigation Schemes

Based on the findings of the study, the following recommendations were made for policy:

- ICOUR should collaborate with MoFA and GoG to rehabilitate the entire Vea irrigation scheme and the laterals and road networks of the Tono Irrigation scheme.

- GIDA should collaborate with MoFA and GoG to rehabilitate the Libga irrigation scheme. The rehabilitation should include desilting of the reservoir.
- The Doba WUA Executives should ensure that the on-going rehabilitation works in the scheme by MoFA are fully and properly executed.
- ICOUR, GIDA-Tamale and the Doba Water Users Association should collaborate with the respective District or Municipal Assemblies within which the irrigation schemes are situated to enact and enforce the necessary bye-laws restricting farming, human settlements and sand/gravel winning activities close to the reservoirs.
- The Scheme Managers should fully and practically involve farmers in the management of the schemes, which will consequently lead to increased efficiency and improved performance.
- Management should ensure that there is periodic and regular repairs and maintenance of the infrastructure in the schemes.
- Management should ensure that water is properly managed in the schemes.
- Payment of irrigation service charges (ISC) before cropping should be adopted by the management of the irrigation schemes to improve recovery rates. Penalties for non-payment of ISC should be applied to defaulters.
- Unanimous annual adjustment of irrigation service charges to meet cost recovery is needed.
- The management of the Libga irrigation scheme should periodically monitor the salinity and sodicity levels in the irrigable area and take steps to reclaim the affected areas.

- Public Private Partnership (PPP) of the studied irrigation schemes is recommended to ensure proper management and good performance.

5.2.2 Recommendations for Future Research

Based on the findings of the study, the following were recommended for future research:

- Performance assessment of the irrigation schemes using comparative indicators which were not covered by this study should be done.
- Levels of salinity and sodicity in the irrigable area of Libga irrigation scheme should be mapped for remediation.

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APPENDICES

Appendix A_{1a}: Comparison of Performance Indicators between Actual and Notional Normal Values for the Irrigation Schemes (2010 – 2014)

Performance Indicator	Notional Normal Value (%)	Scheme	Actual Values for the Schemes (%)				
			2010	2011	2012	2013	2014
Irrigation rate (%)	90 – 100	Tono	53	48	54	52	26
		Vea	15	8	10	12	18
		Doba	36	21	29	21	-
		Libga	94	94	94	94	94
		Bontanga	83	85	86	87	91
		Golinga	50	58	63	100	100
Efficiency of irrigation service charges recovery (%)	90 - 100	Tono	93	87	81	82	75
		Vea	47	20	31	28	19
		Doba	93	96	89	92	-
		Libga	35	41	37	24	32
		Bontanga	24	30	52	23	27
		Golinga	14	84	85	40	64
Financial self-sufficiency factor (%)	> or = 100	Tono	59	55	34	28	40
		Vea	10.7	2.7	3.3	4.3	4.1
		Doba	125	102	108	109	-
		Libga	1.9	2.2	1.3	45	51
		Bontanga	21	26	25	34	38
		Golinga	3	26	21	23	34
Scheme financial autonomy factor (%)	> or = 50	Tono	100				
		Vea	100				
		Doba	100				
		Libga	90				
		Bontanga	90				
		Golinga	90				
Extent of main canals flow lengths (%)	100	Tono	74				
		Vea	18				
		Doba	0				
		Libga	89				
		Bontanga	100				
		Golinga	100				
Poor structure index (%)	0	Tono	46				
		Vea	87				
		Doba	96				
		Libga	30				
		Bontanga	3				
		Golinga	1				

Appendix A_{1b}: Comparison of Performance Indicators Between Actual and Notional Normal Values for the Irrigation Schemes (2010 – 2014)

Performance Indicator	Notional Normal Value (%)	Scheme	Actual Values for the Schemes (%)				
			2010	2011	2012	2013	2014
Sustainability of irrigated area index (%)	90 – 100	Tono			49		
		Vea			26		
		Doba			0		
		Libga			94		
		Bontanga			95		
		Golinga			100		
Efficiency of roads passibility (%)	100	Tono			96		
		Vea			53		
		Doba			-		
		Libga			100		
		Bontanga			100		
		Golinga			100		
Environmental stability index (%)	90 – 100	Tono			98		
		Vea			92		
		Doba			100		
		Libga			86		
		Bontanga			99		
		Golinga			98		

Appendix A2a: Qualitative Checklist of Identified Performance Measures on the Irrigation Schemes (2010 – 2014)

Performance Indicator	Type of performance measure	Scheme	Performance Ranking 2010	2011	2012	2013	2014
Irrigation rate	Output	Tono	P	VP	P	P	VP
		Vea	VP	VP	VP	VP	VP
		Doba	VP	VP	VP	VP	-
		Libga	G	G	G	G	G
		Bontanga	A	A	A	A	G
		Golinga	P	P	P	G	G
Efficiency of irrigation service charges recovery	Output	Tono	G	A	A	A	P
		Vea	VP	VP	VP	VP	VP
		Doba	G	G	A	G	-
		Libga	VP	VP	VP	VP	VP
		Bontanga	VP	VP	P	VP	VP
		Golinga	VP	A	A	VP	P
Financial self-sufficiency factor	Process	Tono	P	P	VP	VP	VP
		Vea	VP	VP	VP	VP	VP
		Doba	G	G	G	G	-
		Libga	VP	VP	VP	VP	P
		Bontanga	VP	VP	VP	VP	VP
		Golinga	VP	VP	VP	VP	VP
Scheme financial autonomy factor	Process	Tono			Good		
		Vea			Good		
		Doba			Good		
		Libga			Good		
		Bontanga			Good		
		Golinga			Good		
Extent of main canal (s) flow lengths	Input	Tono			Poor		
		Vea			Very poor		
		Doba			Very poor		
		Libga			Adequate		
		Bontanga			Good		
		Golinga			Good		
Poor structure index	Input	Tono			Poor		
		Vea			Very poor		
		Doba			Very poor		
		Libga			Poor		
		Bontanga			Good		
		Golinga			Good		

VP - Very poor, P - Poor, A - Adequate and G - Good

Appendix A_{2b}: Qualitative Checklist of Identified Performance Measures on the Irrigation Schemes (2010 – 2014)

Performance Indicator	Type of performance measure	Scheme	Performance Ranking 2010 2011 2012 2013 2014
Sustainability of irrigated area	Ouput	Tono	Very poor
		Vea	Very poor
		Doba	Very poor
		Libga	Good
		Bontanga	Good
		Golinga	Good
Efficiency of roads passibility	Input, Output	Tono	Good
		Vea	Poor
		Doba	-
		Libga	Good
		Bontanga	Good
		Golinga	Good
Environmental stability index	Output	Tono	Good
		Vea	Good
		Doba	Good
		Libga	Adequate
		Bontanga	Good
		Golinga	Good
Reservoir water availability for irrigation	Input	Tono	Very poor
		Vea	Good
		Doba	Very poor
		Libga	Good
		Bontanga	Good
		Golinga	Good

Appendix A_3: Dimensions of Main Canals on the Irrigation Schemes

Scheme	Bottom With (m)	Top Width (m)	Depth (m)	Total Length (m)
Tono	1.0	4.6	1.2	42,000
Vea	1.3	4.0	1.0	26,500
Doba	0.3	0.7	0.5	600
Libga	0.5	2.5	0.7	1300
Bontanga	1.5	3	0.9	11,500
Golinga	0.5	1.6	0.6	2,300

Appendix A_4: Estimated Volume of Sediments in Main Canals on the Irrigation Schemes

Scheme	Addc *(m)*	Ads *(m)*	Atws *(m)*	Abwc *(m)*	Acasc = $(\frac{Atws+Abwc}{2})$ x Ads (m^2)	TLc *(m)*	EVSC = Acasc x TLc (m^3)
Tono	1.2	0.32	1.69	0.87	0.41	42,000	17,220
Vea	1.0	0.47	2.14	1.16	0.78	26,500	20,670
Doba	0.5	0.15	0.38	0.20	0.04	600	24
Libga	0.7	0.27	1.10	0.50	0.22	1300	286
Bontanga	0.9	0.0	0.0	1.50	0.0	11,500	0.0
Golinga	0.6	0.13	0.60	0.50	0.07	2,300	161

Where: Addc - Average design depth of canals (m), Ads - Average depth of sediments in canals (m), Atws - Average top width of canals in contact with sediments (m), Abwc - Average bottom width of canals (m), Acasc - Average cross-sectional area of sediments in canals (m^2), TLc - Total length of canals (m), EVSC - Estimated volume of sediments in canals (m^3)

Appendix A_5: ANOVA Means of Laboratory Results of Irrigable Area Soils of the Irrigation Schemes

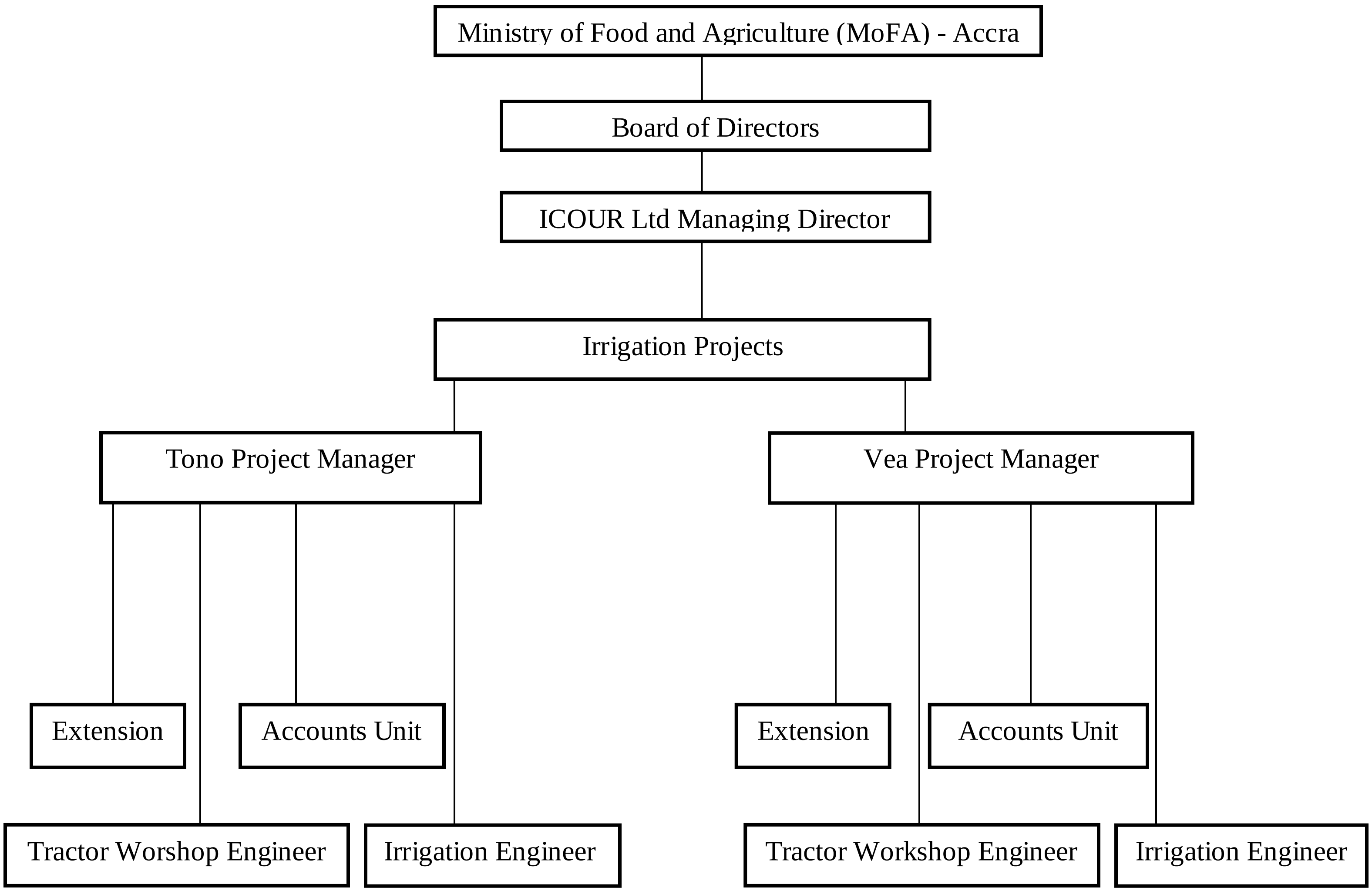
Name of Scheme	Tono	Vea	Doba	Lib	Bont	Gol	Fpr	LSD	CV (%)
pH (1: 2.5 H_2O)	6.1	6.4	5.4	8.8	5.5	5.2	< 0.001	0.5988	5.7
EC (µS/cm)	11.7	17.7	1.2	1143.3	20.7	39.3	0.355	1498	296
ESP (%)	2.0	2.8	1.0	11.6	4.8	4.1	0.018	8.244	86.1

Where; Lib = Libga, Bont = Bontanga, Gol = Golinga, Fpr = F probability, LSD = Least Significant Difference, CV = Coefficient of Variation

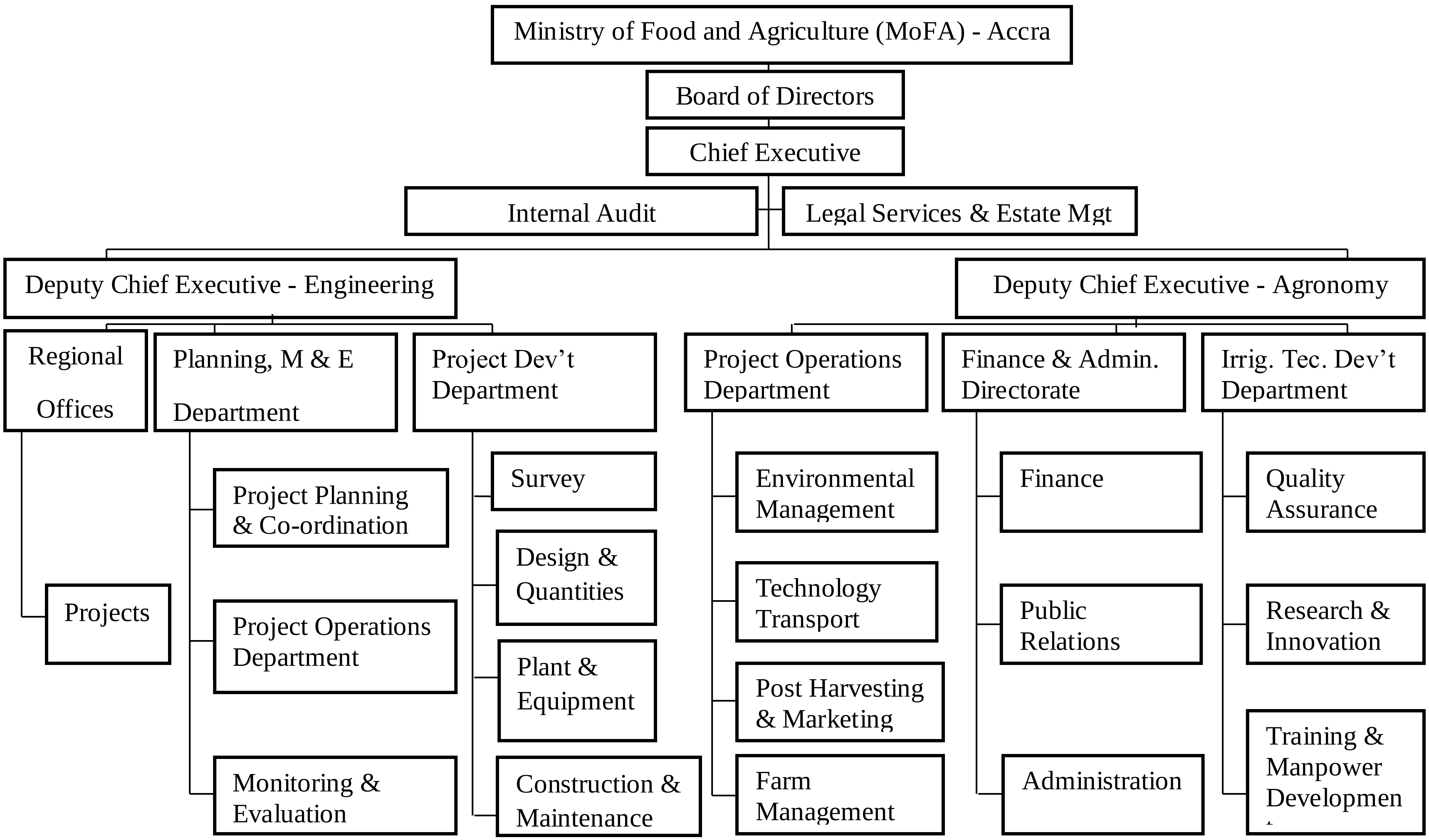
Appendix A6: Human Settlements Built Very Close to the Doba Reservoir

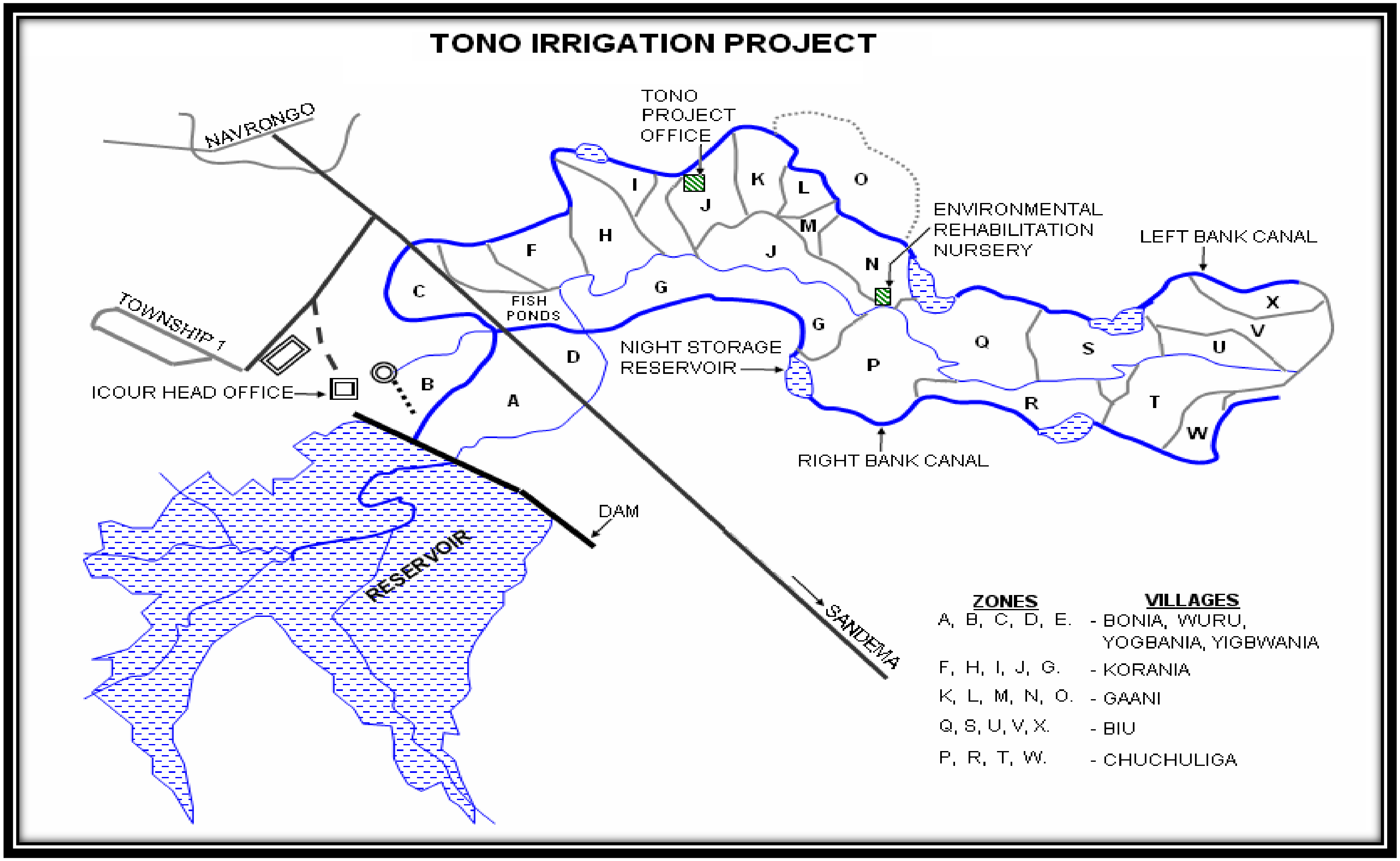
Appendix A7: Left Bank Canal Off-take Valve at Bontanga Irrigation Scheme

Appendix B1: Organisational Structure of ICOUR Managed Irrigation Schemes (Source: ICOUR-Tono, 2015)

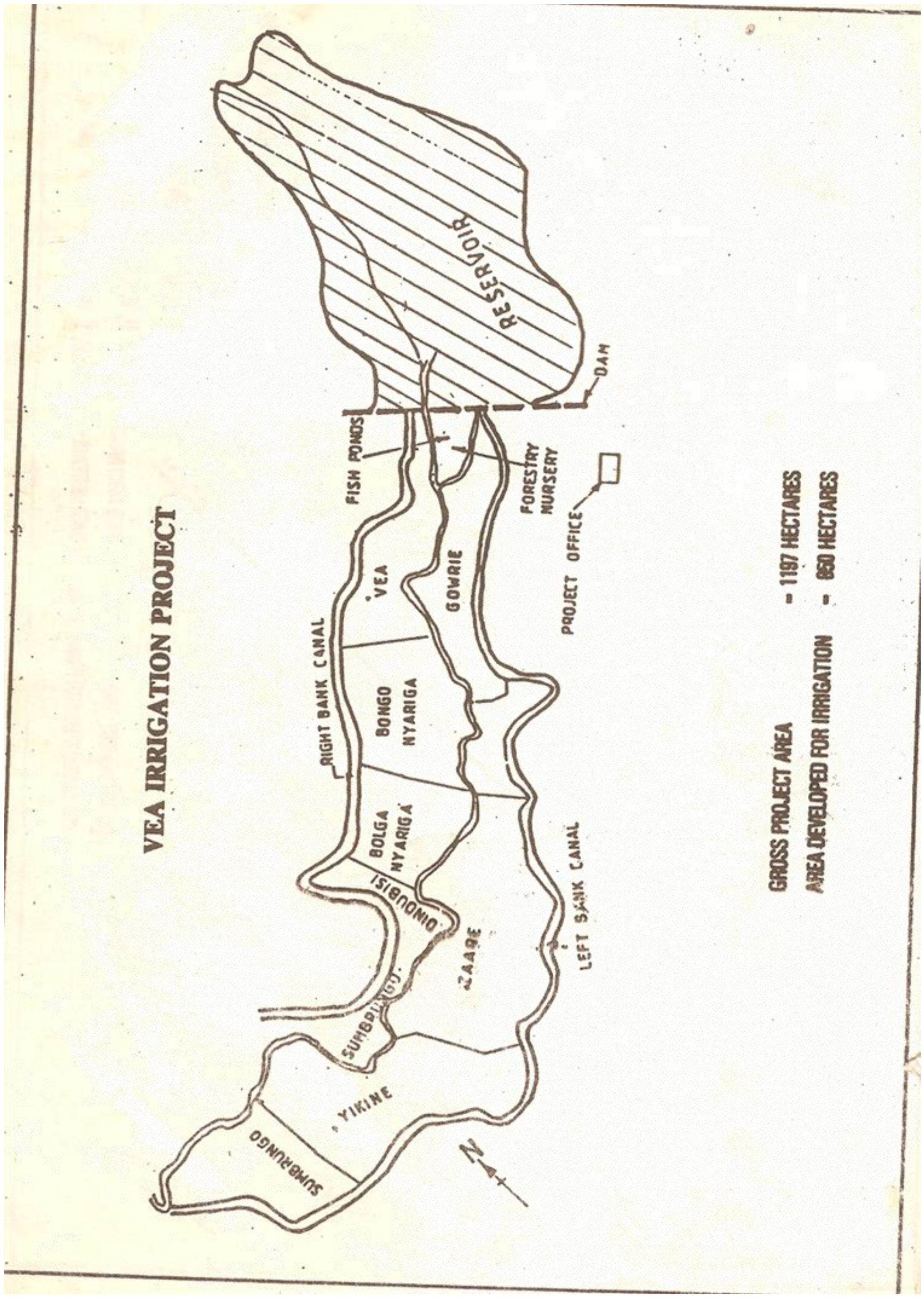


Appendix B2: Organisational Structure of GIDA Managed Irrigation Schemes (Source: GIDA-Tamale, 2015)





Appendix C1: Lay-out Map of the Tono Irrigation Scheme showing the Main System



Appendix C2: Lay-out Map of the Vea Irrigation Scheme showing the Main System

Appendix D1: MPhil Research Questionnaire for Irrigation Farmers

Performance Assessment of Irrigation Schemes in Northern Ghana Using Comparative Indicators

1. Name of interviewee --- Date of interview ---

3. Community of farmer ---

4. Sex. M [ ] F [ ]

5. Age. < 20 Years [ ] 21-30 [ ] 31-40 [ ] 41-50 [ ] 51-60 [ ] > 60 [ ]

6. Educational level. No formal education [ ] Primary school [ ] Secondary school [ ] Diploma/Technical certificate [ ] Graduate [ ]

7. How many acres of land do you hold within the irrigation scheme? < ¼ acre [ ]
¼ acre [ ] 1 acre [ ] 2 acres [ ] 3 acres [ ] 4 acres [ ] 5 - 1 0 acres [ ] >10 acres [ ]

8. What is the nature of your land holding in the scheme? Land owner [ ] Tenant [ ] Labourer [ ]   Share cropper [ ]

9. How many years have you been practicing irrigated farming in the scheme? -------------Years

10a. Some people do not bother to farm in the dry season, what are your objectives for engaging in irrigated farming during the dry season?---

10b. If you do not farm during the dry season, what are the factors that prevent you from doing so?--

11. How do you normally obtain water to irrigate your dry season crops? Gravity flow from canals [ ] Lifting by bucket/calabash from canal [ ] Pumping from the canals [ ] Pumping from hand dug well [ ] Drains [ ]

12a. Do maintenance and repair works undertaken on the scheme periodically? Yes/No

12b.What is the frequency of maintenance and repair works? Daily, weekly, monthly, yearly,---

12b. If yes, by who? ---

12c. Indicate clearly the sections or areas of the scheme that of maintenance and repair works are undertaken. --

13a. Do you take part in the maintenance and repair works in the scheme? Yes [ ] No[ ]

13b. If yes, what is/are your role (s) in the maintenance and repair of the scheme? --------

14a. Do irrigation water fees and plot fees exist in the scheme? Yes [ ] No [ ]

14b. Do you regularly pay for irrigation water fees and land tax? Yes [ ] No [ ]

14c. Who collects the fees? --

14d. How much did you pay for irrigation water fees and plot fees in the following years (Gh¢):

Year	2014	2013	2012	2011	2010
Water fees (Gh¢) per acre					
Plot fees (Gh¢)- acre					

14e. What is the method of charging for irrigation water? (flat rate, volumetric rate, per cropped area, ---).

14f. Are all farmers in the scheme required to pay the established fees and charges?

15. Do staff of the scheme own plots of land and practice irrigation within the project? Yes/No

16. If some individuals or groups of farmers are exempted from the payment of water/ or plot fees, who are they, and why? Estimate the total number of those exempted.------------

17a. Do the farmers in the scheme have an association (s)? Yes [ ] No [ ]

17b. If yes, name it/them ---

17c.What are their role and responsibilities? --

18. If you have other sources of water apart from water in the reservoir and canal system, what factors prompted you to seek these alternatives? No canal or drain network in my area [ ] Distance from headworks and canals [ ] Lack of maintenance of canals [ ] Lack of cooperation with management [ ] Other reasons (please specify)-----------------------------

19. If you did not cultivate your entire allocated land area during the dry season what is/are the factors that prevented you from doing so? No water supply to my area [ ] Inadequate water supply [ ] Unreliable water supply [ ] Water not supplied at the time needed [ ] Too much water in my area [ ] Other reasons (Please specify)--------------------

20. Please indicate the areas and crops you cultivated in 2010-2014 dry seasons

Crop	Year	Area cultivated(acres)	Total yield(kg or bags)

21a. What is the drainage and soil condition in your plot? Never waterlogged [] Waterlogged and saline [] occasionally waterlogged but not saline []

21b. If waterlogged, when does it normally occur? --

22. What are the problems or challenges you are facing as a farmer in the scheme?---------

23.In your own opinion, what are the major problems and constraints affecting the performance of the irrigation system.--

24. Could you please suggest the critical areas in the operation and management of the irrigation system that you think need improvements in order to improve the performance of the scheme?--

Appendix D$_2$: MPhil Research Questionnaire for Irrigation Scheme Management

Performance Assessment of Irrigation Schemes in Northern Ghana Using Comparative Indicators

1. Name of Irrigation Scheme--- Date of interview--

2. Who built the scheme? GoG, NGO, community, ---

3. Who manages the scheme? GIDA, NGO, community, Assembly, --------------------------

4. Please indicate the following regarding the scheme:

Latitude (˚)	Longitude (˚)	Altitude (m)	Mean annual rainfall (mm)	Peak daily evapotranspiration (mm)

5a. What are the objectives for the establishment of the Irrigation Scheme?-----------------

5b. Indicate to what extent you think the objectives of the Irrigation Scheme are being achieved. --

6a.What is the predominant soil type in the irrigable area? ------------------------------------

6b.What is the predominant soil type of the watershed (upstream)? --------------------------

6c.What is the state of the catchment? (Houses, farmlands, constructional works, ---------)

6d. Describe the topography of the watershed? --

7a. Please indicate the following regarding the scheme:

Year construction started	Year construction completed	Year rehabilitated (if any)	Potential irrigable area (ha)	Developed irrigable area (ha)

7b. If rehabilitated, by who: (GoG or NGO), name of NGO ----------------------------------

8a. Please indicate the irrigated area (ha) for the following years (seasons):

Year	2014	2013	2012	2011	2010
Irrigated area (ha)					

8b. What are the causes of the variations in irrigated areas each year (season)?

9a.What is the total number of staff (full-time) who have direct responsibilities on the Irrigation Scheme? ---------------------------------. Fill in the particulars of staff in the table below:

Position/Job title   Highest educational qualification   No. of years with the scheme

9b.What is your perception of the salary level and other entitlements regarding staff responsibilities on the Irrigation Scheme? ---

9c.What working incentives and motivation mechanisms would you suggest be provided to enhance the performance of staff?---

10a. Indicate the numbers of farmers who were served in: 2014 [M= F= 2013 [M F], 2012 [M F], 2011[M F], 2010 [M F]

10b.What is the literacy level of the farmers. No. of Literate [ ] No. illiterate [ ]

10c.What is the maximum number of farmers that the scheme can serve? [ ]

10d.What is the total population of each of the beneficiary communities?-------------------

10e. How many households were served by the irrigation scheme in?

2014 [ ], 2013 [ ], 2012 [ ], 2011[ ], 2010 [ ]

11a. What are the established fees (e.g. water charges, plot fees) which farmers are required to pay in the Irrigation scheme? 2010-2014

Type of fees	year	Amount per farmer (GH¢)	Total amt. collected (GH¢)	Total assessed fees (GH¢)

11b.What is the estimated collection rate (%) of the assessed fees per year for the past 5 years? 2014], 2013 [ ], 2012 [ ], 2011 [ ], 2010 [ ]

11c.What is the method of charging for irrigation water? (flat rate, volumetric rate, per cropped area, ---).

11d.What are the other sources of revenue for the scheme besides water charges and land taxes? (Sale of fishing rights in the scheme reservoir, ------------------------------------)

11e.What is the total amount normally collected from these other sources in 2014 [ ], 2013 [ ], 2012 [ ], 2011 [ ], 2010 [ ]

12. What are the communication channels between management and farmers?

13a. Is there an overall monitoring and evaluation of the irrigation system? Yes/No

13b. What kinds of information are collected regularly? Fill in the table below:

Daily	Weekly	Monthly	Yearly

14a. How do farmers acquire land for farming in the scheme?---------------------------------

14b.What is the average size of land that a farmer can acquire in the scheme? --------------

15a.What are the major crops in the scheme? ---

15b. What are the constraints (challenges) to increased crop production in the scheme?---

16a. Are there conflicts relating to water and land usage in the irrigation scheme? Yes [ ] No [ ]

16b.If yes, what are the causes? --

16c. How do you resolve those conflicts in the scheme?---------------------------------------

17. Indicate the yield per ha (kg or tonnes) for the major crops cultivated in the scheme for past 5 years: For each crop, also indicate the total area cultivated (ha) in the corresponding year.

Year	**Rice**	**Onion**	**Pepper**	**Okra**	**Garden eggs**
2014					
2013					
2012					
2011					
2010					

18. What is the total annual irrigation water delivered to farmers (m^3):

Year	Project water supply (m^3)
2014	
2013	
2012	
2011	
2010	

19a. Are irrigation schedules prepared in advance? Yes/No,

19b If yes, who prepares the schedule? Are they strictly followed? --------------------------

20a. Do you undertake maintenance and repair works on the scheme periodically? Yes/No

20b. If yes, by who and which areas of the scheme do maintenance and repair works being carried out periodically --

20c. Which areas commonly have problems leading to frequent maintenance? ------------

20d. Do you have operation and maintenance budget for the scheme for each year? Y/No

20e.What is the total annual amount actually spent on maintenance and repair of physical facilities in the following years?

Year	Total O & M budget (GH¢)	Amount spent on maintenance (GH¢)
2014		
2013		
2012		
2011		
2010		

20f. How are the scheme expenditures financed? (Direct from revenues within the scheme, state budget, ---)

20g. How is maintenance carried out? (Direct labour within agency, labour mobilized by the farmers, contract to farmers/outsiders, --)

20h. Who has overall responsibility for the management of the scheme? (Farmers, GIDA, joint)

21a. Are there farmers' organisations in the scheme? Yes [ ] No [ ]

21b. If yes, name them ---

21c.If **yes**, what are their responsibilities?--

21d. If **no**, why ---

21e. Are all farmers members of the organisation?---

21f. If no, why --

21g.What is the level of coordination and cooperation between the farmers' organisations and scheme management? (Very good, good, fair, poor, ---------------------------)

22a. Do farmers show initiative, motivation and capacity to sustain irrigated agriculture? Yes/No

22b.What is the general attitude of the farmers in the scheme towards irrigation?-----------

22c. Do staff of the scheme own plots of land and practice irrigation within the project? Yes/No

23a. What is the general condition of the dam wall ?--

23b.What is the general condition of the spillway ?--

23c. Do you experience seepage through the dam wall? Yes [ ] No [ ]

23d.How will you describe the quantity of silt load entering the reservoir? Low, Medium, High,

23e. What causes siltation of the reservoir? ---

23f.What is the water quality of the reservoir for irrigation? (Good, Average, Poor)

24a. Are there any night storage reservoirs within the scheme? Yes [ ] No [ ]

24b. State the capacity for each reservoir.---

24c. Describe their general conditions ---

25a. Are there other industrial projects using the water from the reservoir? Yes/No

25b. If yes, name them ---

25c. Are there any existing water quotas or rights for individual projects, state the amounts for each system? Yes [ ] No [ ]

26a.What are the water levels in the reservoir over the past 5 years (2010 - 2014).

Year	2014	2013	2012	2011	2010
Water levels					

26b.What causes the variation in water levels in the reservoir? -------------------------------

26c. What is the security of water supply for the scheme? Good [ ], Average [ ], Poor []

27a. Are other water sources being used for irrigation in the scheme apart from water from the reservoir Yes [ ] No [ ]

27b. If yes, name them --

27c. How is water abstracted from those sources for irrigation by farmers? Hand , Pumps

27d. What are the reasons for other water sources being used for irrigation in the scheme?

28a. Indicate the number (**A**), design discharges (**B**) and total lengths in lined (**C**) and unlined conditions (**D**) for the following structures in the scheme

Structure	**A**	**B**	**C**	**D**
Canals				
Laterals				
Sub-laterals				
Drains				

28b. Please describe the condition of the canals and laterals in terms of weeds. Categorize the stretches according to severity of problem: severe, fair, good, excellent. ----------------

28c. Please describe the condition canals and laterals in terms of siltation. Categorize the stretches according to severity of problem: severe, fair, good, excellent. ---------------------

28d. Please describe the condition canals and laterals in terms of breaches. Categorize the stretches according to severity of problem: severe, fair, good, excellent ---------------------

29a. Describe the conditions of the drainage networks in terms of weeds. Categorize the stretches according to severity of problem: severe, fair, good, excellent. ---------------------

29b. Describe the conditions of the drainage networks in terms of siltation. Categorize the stretches according to severity of problem: severe, fair, good, excellent. ---------------------

29c.Where does the main drain discharge? (River, lake, Swamp, ----------------------------)

30. Describe the present condition of the road network around and within the scheme (good, fair, very bad, nonexistent --)

31a. Estimate the irrigable area within the scheme which is affected by the following problems (if any)

Environmental problem	Waterlogging	Salinity	Erosion
Estimated affected area (ha)			

31b.What are the causes of the salinity in the scheme's irrigable area? ----------------------

31c.What are the causes of the waterlogging in the scheme's irrigable area? ---------------

31d.What are the causes of the soil erosion in the scheme's irrigable area? -------------

32a.What is the method of irrigation in the scheme? (Basin, furrow, border strip, drip, ---)

32b. How is water distributed between farmers? ("Take as you like", water measurement, scheduling by area/days, ---)

32c. Are fields irrigated continuously or by rotation? Yes/No

32d. If by rotation, give typical irrigation intervals for each crop in days.------------------

32e. For how many days during the week are fields being irrigated? -------------------------

32f. How do the farmers control the discharge of water to their fields? (Outlet structures, pipes, breached canal banks, pumps, ---).

33a. Transport system for the scheme. Fill in the table below:

Vehicle category	Car	Tractor	Power tiller	Motor bike	Tri-cycle
Quantity					

33b. Describe the present condition of the transport system in the scheme -----------------

33c.What are the challenges/problems regarding transport for the scheme?-----------------

34a. Describe the present condition of the meteorological station for the scheme (if any) -

34b.What are the challenges/problems regarding the scheme's meteorological station? ---

35. Indicate all structures which were constructed or installed within the scheme and now not functioning --

36. What are the major problems and constraints affecting the performance of the irrigation scheme?

Technical---
Management--
Environmental---
Financial---
Socio-economic--

37. Could you please suggest the critical areas in the management, operation and maintenance of the irrigation scheme that you think need improvements in order to improve the performance of the scheme ---