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PERFORMANCE EVALUATION OF IRRIGATION SCHEMES IN THE TRANSITION AGRO-ECOLOGICAL ZONE OF GHANA

BY

FRANCIS OWUSU SEKYERE

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(BSc. Water and Sanitation)

(UDS/MID/0011/19)

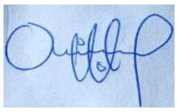
A THESIS SUBMITTED TO THE DEPARTMENT OF AGRICULTURAL ENGINEERING, SCHOOL OF ENGINEERING, UNIVERSITY FOR DEVELOPMENT STUDIES IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF A MASTER OF PHILOSOPHY DEGREE IN IRRIGATION AND DRAINAGE ENGINEERING

AUGUST, 2022

DECLARATION

DECLARATION BY CANDIDATE

I hereby declare that this submission is my own work and that no part of it has been presented for a degree in this university or elsewhere to the best of my knowledge, it contains no material previously published by another person, nor material which has been accepted for the award of any other degree of the University, except where due acknowledgement has been made in the form of references.



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DECLARATION BY SUPERVISORS

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

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ABSTRACT

The study assessed the performance of irrigation schemes in the Transition Agro-ecological Zone of Ghana using a set of comparative performance indicators. The study was conducted on two (2) functioning schemes and two (2) defunct schemes. It was carried out in Akumadan, Tanoso, Kaniago and Subinja irrigation schemes in the Transition Agro-ecological zone of Ghana. The performance of the functioning schemes (Akumadan and Kaniago) spanning the years of 2018 – 2022 were evaluated using selected comparative indicators categorized into five (5) groups, namely; water delivery, physical structures, financial, environmental condition and agricultural production performance. The challenges of the schemes were also identified through the study. Data collection sources included literature reviews, interviews, field measurements and laboratory analysis. The study revealed that the main pipe at Akumadan had 100 % maximum flow length whilst the canal system at Kaniago recorded a flow length of 64 % due to low gravity flow in the downstream of the canal. The developed irrigable areas in Akumadan and Kaniago were under-utilised with irrigation rates ranging from 15 – 36 % and 18 – 57 % respectively. The sustainability indices of the irrigated areas in Akumadan and Kaniago were low with recorded values of 31 % and 28 % respectively. Irrigation service charges recovery was poor in the Kaniago scheme with recovery efficiency ranging from 25 – 59 % whereas the recovery was good in the Akumadan scheme with efficiency ranging from 82 – 88 %. A low degree of financial autonomy (25 %) was recorded in Akumadan whereas a high degree of financial autonomy (100 %) was recorded in Kaniago. Some irrigation structures in the Akumadan and Kaniago schemes were in poor working condition as they recorded poor structure indices of 27 % and 14 %. The road network in the Akumadan scheme was in good working condition as roads passability efficiency of 100 % was achieved whereas Kaniago had no major road construction in the scheme. Both schemes recorded 100 % environmental stability indices indicating stable and resilient irrigable areas with regards to pH, salinity and sodicity problems. Production in the schemes was gradually in decline due to the constant reduction in size of the cultivable area of the schemes. Poor agronomic practices, inadequate sprinklers and laterals and low gravity flow were major causes of the low production performance in the schemes. The Impact-sprinklers located at the up-stream and down-stream areas of the Akumadan scheme recorded Distribution Uniformity (DU) values of 73 % and 83.3 % respectively. At the same time, the Uniformity Coefficient (UC) values of the sprinklers were found to be 85.2 % at the up-stream and 90.8 % at the down-stream. At Kaniago, the water conveyance efficiencies measured in the up-stream, mid-stream and down-stream of the canal system were found to be 100 %, 93 % and 36 % respectively. The Tanoso and Subinja schemes had been abandoned for years because of their defunct state. Hence, these schemes required rehabilitation so as to improve performance and promote irrigated agriculture in the transition agro-ecological zone of Ghana.

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Lastly, my unreserved thanks goes to my family for the encouragement and financial support throughout the study. In fact, God bless them all abundantly.

DEDICATION

I dedicate this work to my beloved mother, Florence Birago.

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LIST OF ACRONYMS AND ABBREVIATIONS

DU	Distribution Uniformity
E- Agriculture Portal	Electronic- Agriculture Portal
EC	Electrical Conductivity
EDAIF	Export Trade, Agricultural and Industrial Development Fund
ESP	Exchangeable Sodium Percentage
FAO	Food and Agricultural Organisation
FAOSTAT	Food and Agriculture Organisation Corporate Statistical Database
GIDA	Ghana Irrigation Development Authority
Ha	Hectares
Hp	Horsepower
ICOUR	Irrigation Company of Upper Region
IDC	Irrigation Development Centre
IFAD	International Fund for Agricultural Development
IPTRID	International Programme for Technology and Research in Irrigation and Drainage
IWMI	International Water Management Institute
JICA	Japan Institute for International Cooperation
Mha	Million Hectares
MoFA	Ministry of Food and Agriculture
NASS	National Agricultural Statistics Service
NEPAD	New Partnership for Africa's Development
NGO	Non-Governmental Organization
PIM	Participatory Irrigation Management
RPIP	Research Programme on Irrigation Performance
SAR	Sodium Adsorption Ratio
SFIP	Small Farmers Irrigation Project
UC	Uniformity Coefficient
UN	United Nations
USDA	United States Department of Agriculture
WB	World Bank
WUA	Water Users' Association

CHAPTER ONE

INTRODUCTION

1.1 Background

Water is essential for all kinds of life, every facet of socioeconomic growth, and the correct functioning of ecosystems. While sufficient freshwater resources exist on a worldwide scale to ensure continuing agricultural and industrial expansion, the long-term sustainability of water resources is a developing problem (FAO, 2015). Agriculture accounts for 70 % of all water withdrawals globally (Rosegrant *et al.*, 2009). Irrigation systems are installed on roughly 330 million hectares worldwide, accounting for 20 % of all cultivated land. This represents 40 % of all food produced globally (Siebert *et al.*, 2010). The demand for food, and consequently agricultural water for irrigation, is growing in tandem with population increase and rising food demand. By 2025, the global population is expected to increase by roughly 30 % to 8 billion people (Postel, 1998). Living standards are predicted to rise due to enhanced communications, globalization, and increased urbanization (Al Radif, 1999). This means that rivalry for water resources will rise to new heights among agricultural, industrial, household, and other users. As a result, irrigated agriculture water management is critical in addressing the growing global population's food needs (Takeshi and Abdelhadi, 2003). Although water resources are renewable, they are finite in quantity. Many countries are anticipated to run out of water supplies over the next two decades, making it impossible to meet present agricultural, domestic, industrial, and environmental needs. It is vital to make the most efficient use of available resources in order to achieve maximum efficiency (Cosgrove and Loucks, 2015). Waterlogging, sodicity, salinity, and an increase in the level of subsurface water will all be reduced as a result of efficient use of limited water resources, particularly for irrigation. In many countries, irrigation is quite important; as it is significant in terms of agricultural productivity and food security, rural incomes, governmental investment in rural development, and, in many cases, recurring public expenditures in the agricultural sector. However, in developing countries, frustration with the performance of irrigation projects is frequent. Irrigation projects, despite their potential as engines for agricultural growth, typically perform much below their potential (Small and Svendsen, 1992). According to Cakmak *et al*. (2004), a substantial percentage of low performance could be attributed to poor facility management and insufficient water management at the system and field levels. Rapid population increase and the resulting demand for food pose threat to food security in developing countries. The upsurge in food demand has led to a major increase in food costs on the global market (Eme *et al.*, 2014). According to Styles *et al.* (2008), improving food supply and reducing the impact of high food prices necessitates significant expenditures in changing existing farming systems or building new ones if appropriate.

Despite significant development potential and focus on irrigation development in numerous ways, less than 2 % of Ghana's total cultivable area is irrigated. Without considerable improvements in the agricultural sector, Ghana would be unable to meet its economic development and poverty reduction ambitions (Kyei-Baffour and Ofori, 2006). Extensification (placing more land under cultivation) and intensification (raising the productivity of existing land) are two methods for achieving agricultural growth. Ghana has ample water resources to support irrigation-based intensification. Ghana's irrigation potential has been estimated to be anywhere between 0.36 and 1.9 million hectares, with barely more than 33,000 hectares under irrigated cultivation (Agodzo and Bobobee, 1994; FAO, 2005).

The development of irrigation in Ghana has been justified as a means of achieving (1) food security, (2) poverty reduction, and (3) rural employment. This argument is relevant to the northern regions, which have a mono-modal, highly variable rainfall distribution. Despite irrigation's huge potential and emphasis put on it in contemporary plans, the size of the potential irrigable land that is actually irrigated is negligible; a situation perceived of most irrigable areas within the transition agro-ecological zone of Ghana. Furthermore, existing irrigation schemes, particularly those that are publicly developed, have generally poor performance and productivity (GIDA and JICA, 2004).

Long-term growth can be achieved by assessing and enhancing the effectiveness of current irrigation systems. This evaluation and improvement could act as a baseline for new irrigation projects. The performance evaluation's findings provide information for model validation, design and most importantly serves to advise irrigators on how to enhance their management practices. According to Molden *et al.* (1998), it is essential to evaluate the performance of irrigation systems in order to:

i) improve system operations
ii) assess progress against strategic goals
iii) as part of performance-based management
iv) to assess the general health of a system
v) to assess the effectiveness of interventions
vi) to identify challenges
vii) to comprehend better the factors that affect performance and
viii) to assess how well a system has performed over time in comparison to other systems or the same system.

Comparative indicators were used to evaluate the outcomes and effects of irrigation management interventions across various systems and system levels, as well as to contrast different irrigation seasons and technologies, while process indicators were used to gauge actual irrigation performance in relation to system-specific management objectives and operational targets (Kloezen *et al.*, 1998).

The objective of the study was to evaluate the performance of irrigation schemes in the transition agro-ecological zone of Ghana in terms of production levels, water delivery, environmental conditions, physical and financial structures, and further determined the infrastructural and managerial challenges that incapacitated certain major schemes in the transition zone and rendered them defunct.

1.2 Problem Statement and Justification

Wide across Africa, development of irrigation is one of the leading strategies for ensuring food security and combating poverty (FAO, 1996a). Irrigated agriculture represents 20 % of the total cultivated land, but contributes 40 % of the total food produced worldwide (FAO, 2004). Shaw (2007) indicated that, World Food Summit in 1996 estimated that 60 % of the extra food required to sustain the world in the future must come from irrigated agriculture. Unfortunately for Africa the goal envisaged at the World Food Summit in 1996 has been impeded by poorly performing irrigation facilities leading to a decline in Africa's irrigation potential. This is often due to faults and breakdowns within the schemes usually resulting from poor management, technical and other impeding environmental factors (eg. salinity, waterlogging). 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 impediments hinder their performances. In other instances, irrigation facilities of high potential are under-utilised; this is perceived of irrigation facilities in the transition ecological zone of Ghana. A visit to the irrigation schemes further revealed the defunct condition of major schemes in the transition agro-ecological zone that supported and promoted irrigated agriculture. This research therefore was aimed at evaluating the performance rate of the functioning irrigation schemes against a set of comparative performance indicators as recommended by the International Programme for Technology and Research in Irrigation and

Drainage (IPTRID) on performance evaluation and to further determine the challenges of the defunct irrigation schemes in the transition agro-ecological zone.

1.3 Objectives of the Study

1.3.1 Main Objective

The main objective of the study was to evaluate the performance and assess the conditions of irrigation facilities in the transition agro-ecological zone of Ghana.

1.3.2 Specific Objectives

The specific objectives of the study were to;

- Evaluate and compare the performance levels of the functioning irrigation schemes in terms of water delivery, environmental conditions, production levels, physical and economic.
- Measure the distribution uniformity, coefficient of uniformity and conveyance efficiency of water delivery in the functioning schemes.
- Identify the challenges of the functioning schemes which affect efficient performance.
- Determine the challenges of the defunct irrigation schemes in the Transition Zone.

1.4 Research Questions for the Study

1) How is irrigated agriculture faring in the transition agro – ecological zone of Ghana?
2) What is the state of facilities and installations within the irrigation schemes?
3) Are irrigation schemes performing well in the transition agro-ecological zone of Ghana?
4) Are irrigation schemes in the transition agro-ecological zone effectively utilised?
5) What factors hinder the efficient performance of irrigation schemes in the transition agro-ecological zone?
6) What is the management structure within the irrigation schemes?

7) What are the challenges of the defunct irrigation schemes in the Transition Zone?

8) At what level of efficiency are the irrigation systems measured?

CHAPTER TWO

LITERATURE REVIEW

2.1 The Meaning of Irrigation

Irrigation is the process of applying water to soil, primarily to meet the water needs of growing plants. Water from rivers, reservoirs, lakes, or aquifers is pumped or flows by gravity through pipes, canals, ditches or even natural streams. Applying water to fields enhances the magnitude, quality and reliability of crop production. According to the FAO (2004), irrigation contributes to about 40 % of the world's food production on 20 % of the world's crop production land (Postel, 1998). Playan and Mateos (2006) stressed that various irrigation methods have been developed over time to meet the irrigation needs of certain crops in specific areas. The three (3) main methods of irrigation are surface, sprinkler and drip/micro. Water flows over the soil by gravity for surface irrigation. Sprinkler irrigation applies water to soil by sprinkling or spraying water droplets from fixed or moving systems. Micro irrigation applies frequent, small applications by dripping or bubbling and usually only wets a portion of the soil surface in the field, subsequently the root zone of the crop. A fourth and minor irrigation method is sub irrigation where the water table is raised to or held near the plant root zone using ditches or subsurface drains to supply the water (Tindula *et al.*, 2013).

2.2 Irrigation in Worldwide Perspective

According to the International Commission on Irrigation and Drainage (1996), surface irrigation is used on about 85 % of the 299 Mha of irrigated cropland in the world. India and China, each irrigate more than 60 Mha of cropland, accounting for almost half of the irrigated land in the world (Bjorneberg, 2013). Approximately 95 % of the irrigated land is surface irrigated in India and China. The United States and Pakistan each have about 20 Mha of irrigated land. All other countries each have less than 10 Mha of irrigated land. In the United States, sprinkler and micro irrigation are used on a greater percentage of irrigated cropland compared to the other three countries, and the percentages have steadily increased during the past 20 years. Sprinkler irrigation is used on 54 % of the 22 Mha of cropland irrigated in the United States, while micro irrigation is used on about 7 % of the irrigated cropland (Lumen and Tweddale, 2008).

2.3 Irrigation in Africa Perspective

Irrigation does not currently play a vital role in African agriculture. Despite highly variable and—in many cases—insufficient rainfall and a high incidence of droughts, food production in Africa is almost entirely rain-fed. Irrigated area as a share of total cultivated area is estimated at only 6 % for Africa, compared with 37 % for Asia and 14 % for Latin America (FAOSTAT, 2009). Moreover, more than two-thirds of existing irrigated area is concentrated in five countries—Egypt, Madagascar, Morocco, South Africa, and Sudan—which each have more than 1 million hectares of irrigated area. For the remaining countries, the irrigated area varies from a few thousand hectares to almost half a million hectares each for Algeria, Libya, and Tunisia (FAOSTAT, 2009). The African continent has ample water resources overall; however, they are spread unevenly over a wide range of agro ecologic zones. Efforts to manage water and to make it available where it is most needed are hampered by the undeveloped state of institutions for irrigation (and water-resource management more generally) and by the prevalence of subsistence farming. Ample groundwater resources in much of the continent remain largely untapped, except in southern Africa and parts of northern Africa, where overexploitation of the resource is common. Compared with the global average, Africans withdraw only a quarter as much water for human uses as does the world as a whole and the irrigated share of their cropland is less than one-fourth of the world average (Svendsen *et al.*, 2009).

Eighty-five percent of Africa's poor live in rural areas and depend largely on agriculture for their livelihoods. Agricultural growth is clearly the key to rural poverty reduction and can make an important contribution to achieving the Millennium Development Goal of halving poverty by 2015 (Rosegrant *et al.*, 2006). Given that irrigated crop yields are double or more of comparable rain-fed yields on the continent, irrigation development is considered by many as an important cornerstone for agricultural development in Africa. The Commission for Africa report (2005), for example, called for a doubling of the area of irrigated arable land by 2015. Faures and Santini (2008) noted that 58 % of the rural population in Sub-Saharan Africa could benefit from some type of investment in water. Finally, irrigation development is a key investment priority for NEPAD (New Partnership for Africa's Development). To implement such area expansion, there is the need to improve understanding of the locations and technologies with greatest potential for irrigation. In particular, information is needed about geographic, agronomic, and economic factors that need to be considered when assessing the long-term viability and sustainability of planned projects.

According to Commission for Africa (2005), the continent of Africa receives, on average, 124 millimetres less precipitation per year than the world average. Internal renewable water resources per capita are above world average in Sub-Saharan Africa but below average for all of Africa. However, total water withdrawals per capita are less than half the global average, and withdrawals in Sub-Saharan Africa are less than a third of the global average. This is explained, in large part, by the much lower share of area equipped for irrigation, i.e., 6 % versus a global average of 18 % (Namara *et al.,* 2010).

Table 2.1: Basic Descriptive Features of Africa and the World

Variable	Unit	World	Africa	Sub-Saharan Africa
Cultivated area (2003)	1,000 ha	1,541,488	225,284	197,189
Share of total area	%	11	7	8
Per inhabitant	ha	0.24	0.25	0.27
Per person engaged in agriculture	ha	1.16	1.07	1.02
Total population (2005)	1,000	6,464,452	887,965	732,836
Population density	inhab/km^2	47	78	81
Rural population as % of total	%	51	60	62
Precipitation	mm/year	1,169	1,045	1,136
Internally renewable water resources	km^3/year	43,744	5,570	5,463
Per inhabitant	m^3/year	6,859	6,273	7,455
Total water withdrawals	km^3/year	3,818	214	120
Per inhabitant	m^3/year	599	241	163
Irrigation (total area equipped)	1,000 ha	277,285	13,416	7,117
Percent of cultivated area	%	18	6	4

Source: Svendsen *et al.* (2009).

2.4 Irrigation in Ghana

According to Namara *et al.* (2011), the current productivity of developed farmlands in the country is generally low and variable due to reliance on rain, particularly in the drought and flood prone northern regions. With abundant cultivable land and enormous water resources, Ghana offers enough scope and potential for growth in agricultural production through irrigation development. Yet, as stated above, very little potential irrigable land is developed. The performance and productivity of existing irrigation schemes, especially those that were developed publicly, are generally low, this is due to managerial, technical and certain environmental constraints.

2.4.1 Irrigation Potential of Ghana

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. Of the total 6.9 million ha of cultivable area in 2007, there were only 33,800 ha of irrigated land. This represents less than 0.5 % of the total area. Of the gross estimated 1.9 million ha of potentially irrigable area, less than 2 % has been developed. Currently, public irrigation systems play an insignificant role in the overall agricultural economy of Ghana despite substantial efforts to develop the sector since 1950s. The cost of development (and also of rehabilitation) per unit area in use or per unit volume of water supplied is higher than the figures for comparable developing countries (Inocencio *et al.*, 2005). Capacity under-utilization is a major problem in many existing irrigation facilities. The potential areas that can be developed in each of the public irrigation schemes are much higher than the developed or equipped areas. In addition, in any given year, only a fraction of the developed or equipped area is actually cultivated. Rehabilitation of many of the irrigation schemes is long overdue. Unfortunately, the quality of the implemented rehabilitation projects is also questionable, as some schemes still suffer from structural defects despite repeated rehabilitation works.

2.4.2 Irrigated Agriculture in Ghana

Irrigated agriculture in Ghana is focused on the production of rice and vegetables. Despite the downward trend in rice production, Ragasa *et al.* (2013) reported that, the consumption of rice over the last decade almost doubled. The consumption of rice is growing in comparison with former staple foods such as yams and other tubers, because rice has the advantages of being easy to cook and easy to store. Ghana's Ministry of Food and Agriculture has attempted to reduce the amount of imported rice by increasing domestic rice production. This policy, however, is sabotaged by the decreasing profitability of rice cultivation. Namara *et al.* (2011) indicated that, competition with imported rice, which is less expensive and better, combines with the increasing prices of imported agricultural materials and equipment to reduce farmers' incentives for cultivating rice. Under these circumstances, farmers' interests shift to the cultivation of more profitable vegetables (including okra, fresh maize, cabbages, red peppers, tomatoes, and onions).

2.4.3 Irrigation Development in Ghana

Ghana is enriched with abundant water resources for irrigation-based intensification. Estimates of Ghana's irrigation prospects are wildly divergent, ranging from 0.36-1.9 million hectares to a little more than 33,000 hectares under irrigated cultivation (Agodzo and Bobobee, 1994; FAO, 2005). Irrigation systems observed in Ghana may be classified into two types: conventional systems, which are mainly initiated and developed by the Ghanaian government or various nongovernmental organizations (NGOs), and emerging systems, which are initiated and developed by private entrepreneurs and farmers. Little information is generally known about emerging systems, but they are expanding at a rapid rate, mainly fuelled by access to relatively affordable pumping technologies and to export markets for horticultural crops (Namara *et al.*, 2011).

2.4.4 Irrigation Management in Ghana

GIDA is a government organization that comes under the jurisdiction of the Ministry of Food and Agriculture. GIDA is the only public organization linked directly to irrigation development and management. Prior to the establishment of GIDA was the Land Improvement and Preservation Unit, which was established in the early 1950s within the Department of Agriculture to conserve soil in the northern part of Ghana. This Unit was expanded to the Irrigation Development Department within the Ministry of Agriculture in 1965, and then established as GIDA by government decree in 1977 (MoFA, 2013). GIDA is responsible for surveying potential sites for irrigation development, designing and constructing facilities, managing and maintaining irrigation-project districts under further development, and disseminating farming technology among farmers. GIDA had developed 22 irrigation project districts of varying sizes covering a total area of 8,800 ha across the country as of 2006 (Miyoshi and Nagayo, 2006). As part of structural adjustment, GIDA's budget has been cut drastically. As detailed in Table 2.2, by 2003, personnel expenses accounted for 82 % of total expenditure which cumbered the smooth management, operation and maintenance of the schemes.

Table 2.2: Breakdown of GIDA Expenditure in 2003

Account	**Expenditure (US$)**	
	Government of Ghana	**Aid Agencies**
Personnel expenses	548,183 (82%)	
Administrative expenses	78,045 (12%)	
Service expensive (project expenses)	43,974 (6%)	
Investment (facilities construction)		2,699,093
Total	670,202 (100%)	

Source: Miyoshi and Nagayo (2006)

As previously stated, the total developed land area in the public irrigation schemes is approximately 8,800 ha, but actual irrigation land areas have been decreasing year after year. As of 2003, the area had decreased to approximately 5,200 ha. This decrease results from such problems as a decline in capacity to convey and distribute water due to aging facilities, abandonment of irrigated agriculture due to the complete collapse of facilities (pumps, etc.), and suspension of irrigated agriculture (due to inability of users to bear the costs of operating pump stations). Recent government investments, including rehabilitation of nine existing irrigation schemes at a total cost of GH¢6.5 million, has brought much of this irrigated area back in production (Kunateh, 2010).

GIDA over the years have developed a lot of community-based irrigation infrastructure for the use by small scale farmers. According to E-Agriculture Portal (2018), Fifty-seven (57) irrigation schemes have been so far developed by GIDA throughout the country, with a total of about twelve thousand, one hundred and forty-three (12,143 ha) hectares of land being put under irrigation for the cultivation of various vegetable crops and rice. This is to enable small scale farmers cultivate the land all year round and consequently increase their farm income annually.

Table 2.3: Existing Public Irrigation Schemes Developed by GIDA

Region	No. of Irrigation Schemes	Name of Irrigation Scheme	Potential Area (ha)	Actual Area Developed (ha)	Status of Scheme Existing Scheme
Upper West	4	Jawia	40	40	On-going Project
		Tizza	83	83	On-going Project
		Belebor	120	120	On-going Project
		Sing-Bakpong	116	116	On-going Project
Upper East	5	Tono	2,490	2,490	Existing Scheme
		Vea	852	852	Existing Scheme
		Baare	12	12	Existing Scheme
		Goog	186	186	Existing Scheme
		Tiegu-Yarugu	150	150	Existing Scheme
Northern	10	Dinga	115	115	Existing Scheme
		Sogo	40	40	Existing Scheme
		Dipali	148	50	Existing Scheme
		Bontanga	570	570	Existing Scheme
		Golinga	40	40	Existing Scheme
		Yapei	194	50	Existing Scheme
		Buipe	85	60	On-going Project
		Libga	40	40	Existing Scheme
		Wambong	6	6	Existing Scheme
		Karimenga	6	6	Existing Scheme
Brong Ahafo	8	Subinja	121	121	Existing Scheme
		New Longoro	190	90	Existing Scheme
		Tanoso	115	100	Existing Scheme
		Asantekwa	88	30	Existing Scheme
		Kokroko	66	20	Existing Scheme
		Kaniago	60	60	Existing Scheme
		Akurobi	55	40	Existing Scheme
		Nobeko	60	30	Existing Scheme
Ashanti	5	Akumadan	125	125	Existing Scheme
		Sata	56	56	Existing Scheme
		Anum Valley	140	70	Existing Scheme

		Asuoso	10	10	Existing Scheme
		Adiembra	45	0	Existing Scheme
Central	4	Okyereko	111	111	Existing Scheme
		Mankessim	260	100	Existing Scheme
		Ekotsi	20	20	Existing Scheme
		Baifikrom	4	4	Existing Scheme
Volta	10	KpandoTorkor	356	50	Existing Scheme
		Weta(Afife)	950	880	Existing Scheme
		Dordoekope	68	68	Existing Scheme
		Aveyime	150	150	Existing Scheme
		Afaode	78	78	Existing Scheme
		Volo	60	60	Existing Scheme
		Agorveme	72	72	Existing Scheme
		Koloe-Dayi	30	30	Existing Scheme
		Tordzinu	4	4	Existing Scheme
		Torgorme	2000	450	Existing Scheme
Greater Accra	6	Weija	1,500	200	Existing Scheme
		Kpong	3,028	3,028	Existing Scheme
		Ashaiman	155	155	Existing Scheme
		Dawhenya	450	450	Existing Scheme
		Ada	110	110	Existing Scheme
		Tokpo	60	60	Existing Scheme
Eastern	2	Dedeso	40	40	Existing Scheme
		Amate	81	81	Existing Scheme
Western	2	Moseaso	81	81	Existing Scheme
		Aponapon	83	83	Existing Scheme
Total	57		16,175	12,143	

Source: E-Agriculture Portal (2018)

Other externally supported stakeholder (EDAIF) projects undertaken by GIDA are outlined in Table 2.4.

Table 2.4: EDAIF-Supported Irrigation Schemes as of 2018

Name of Irrigation Scheme	Location (Region)	Proposed Area (ha)	Proposed Activities	Remarks
Tamne irrigation scheme	Upper East	1,500	Design & construction	New development
Nasia irrigation scheme	Northern	40	Design review & construction	Rehabilitation of existing scheme
Mprumem irrigation scheme	Central	200	Design review & construction	New development
Sabare irrigation scheme	North	200	Pre-feasibility study	New development

Ho-Keta Plains irrigation scheme	Volta	3,000	Pre-feasibility study	New development
Kpli irrigation scheme	Volta	3,000	Pre-feasibility study	New development
Kamba irrigation scheme	Upper West	4,000	Pre-feasibility study	New development
Amate irrigation scheme	Eastern	120	Design review & construction	Rehabilitation of existing scheme

Source: E-Agriculture Portal (2018)

2.4.5 Typologies of Irrigation Systems in Ghana

Ghana's irrigation systems may be classified into four major typologies based on such criteria as ownership/management, source of water, type of infrastructure or technology involved, and source of power for abstracting, conveying, and distributing water. These are:

- public systems,
- small reservoirs and dugouts,
- river/lake lift private systems, and
- groundwater systems.

These four typologies can be subdivided:

- Public-owned surface irrigation systems,
- Public-private partnership commercial systems,
- Small reservoir- and dugout- based systems,
- Private- or group-based river-lift systems,
- Groundwater-based irrigation systems, and
- Lowland/inland valley rice water capture systems (Namara *et. al.*, 2010)

The distribution of these six irrigation systems in the regions of Ghana is shown in the map (Figure 2.1).

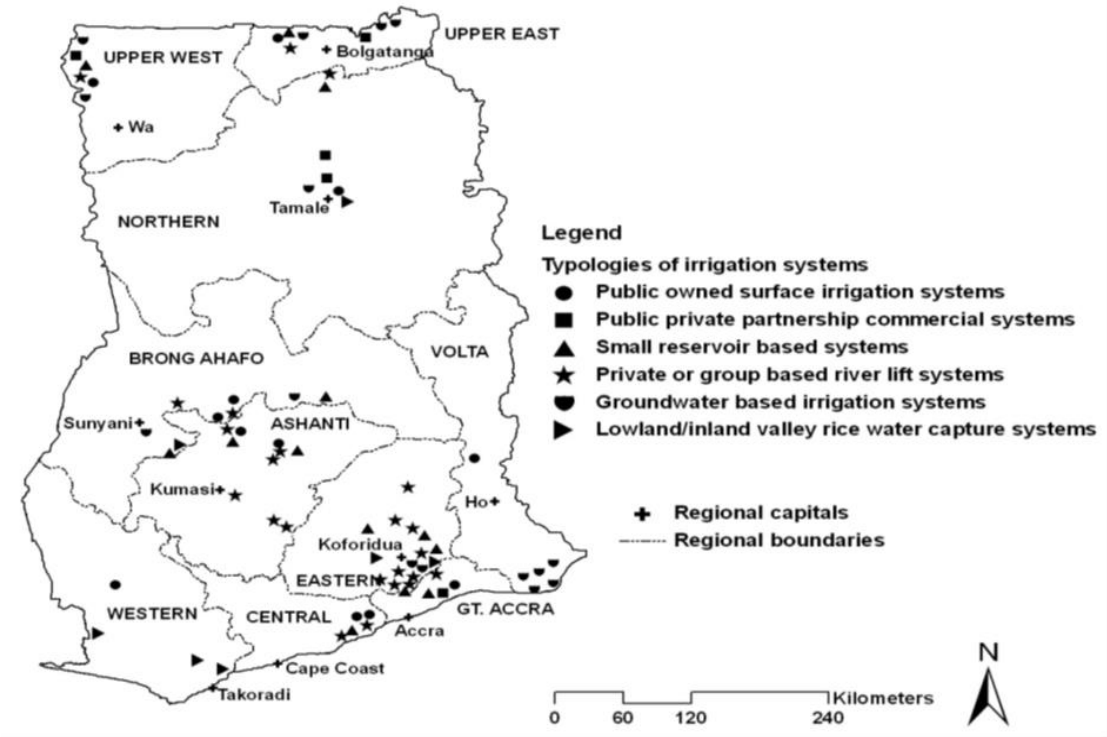


Figure 2.1: Distribution of Irrigation System Typologies across Regions in Ghana

Source: Miyoshi and Nagayo (2006)

2.4.5.1 Conventional/Public Irrigation

According to Namara *et al.* (2011), the government of Ghana developed little less than 9,000 ha of irrigated land, with the private sector developing the remaining area. Government-developed irrigation includes 22 public irrigation schemes in the entire nation, there are 22 public irrigation schemes that were established by the government. These public irrigation schemes have been developed in large part thanks to financial and technological assistance from bilateral partnerships with China, Taiwan, Japan and the Republic of Korea. International agencies including the UN, FAO and World Bank have provided additional support. Table 2.5 lists the 22 public irrigation projects that GIDA and ICOUR are in charge of. These public irrigation projects, which total 8,800 ha and are located all over Ghana. With an average cultivated area of 0.8 ha per household, these programs serve about 11,000 farming families. The 22 irrigation projects are divided into 13 minor irrigation projects of 100 ha or less (which make up around 60 % of all the projects), five medium irrigation projects of 100 – 500 ha and four major irrigation projects of 500 ha or more (Miyoshi and Nagayo, 2006). Many irrigation schemes must build and maintain expensive pumps since Ghana is topographically flat and has little land suitable for gravity-type irrigation development.

Table 2.5 shows that, as of June 2003, six (6) of the 22 public irrigation schemes had ignored irrigated agriculture. Although some of these abandoned projects used gravity irrigation, all of them required pumps. Only 5,192 ha of the entire 8,800 ha were still possibly usable for irrigation as a result of this negligence.

Table 2.5: Public Irrigation Schemes (as of June 30, 2003)

No.	District	Area of developed land (ha)	Area of irrigated land (ha)	Irrigation type	Target crop	Remarks
1	Ashaiman	155	56	Gravity-type	Rice and vegetables	Operational
2	Dawhenya	200	150	Gravity & pump-type	Rice	Operational
3	Kpong	2,786	616	Gravity-type	Rice and vegetables	Operational
4	Weija	220	0	Pump-type	Vegetables	Abandoned 2003-Rehabilitated
5	Afife	880	880	Gravity-type	Rice	Operational
6	Aveyime	60	0	Gravity & pump-type	Rice	Abandoned 1998-Rehabilitated
7	Kpando Torkor	40	6	Pump-type	vegetables	Operational
8	Mankessim	17	17	Pump-type	vegetables	Operational
9	Okyereko	81	42	Gravity & pump-type	Rice	Abandoned
10	Subinja	60	6	Pump-type	vegetables	Abandoned
11	Tanoso	64	15	Pump-type	vegetables	Abandoned
12	Sata	34	24	Gravity-type	vegetables	Abandoned
13	Akumadan	65	0	Pump-type	Vegetables	Abandoned-Rehabilitated
14	Anum Valley	89	0	Gravity & pump-type	Rice	Abandoned-Rehabilitated
15	Amate	101	0	Pump-type	Rice	Abandoned

16	Dedeso	20	8	Pump-type	Vegetables	Abandoned
17	Kikam	27	0	Gravity & pump-type	Rice	Abandoned
18	Bontanga	450	390	Gravity-type	Rice and vegetables	Operational
19	Golinga	40	16	Gravity-type	Rice and vegetables	Operational
20	Libga	16	16	Gravity-type	Rice and vegetables	Operational
21	Tono	2,490	2,450	Gravity-type	Rice and vegetables	Modernised
22	Vea	850	500	Gravity-type	Rice and vegetables	To be rehabilitated
	Total	**8,745**	**5,192**			

Source: Miyoshi and Nagayo (2006).

Namara *et al.* (2011) further provided a broad sub-categorisation of the 22 irrigation schemes listed in Table 2.5 based on their modes of irrigation. This categorisation is presented in Table 2.6.

Table 2.6: Twenty-Two Public Irrigation Schemes and their Modes of Irrigation

Mode of Irrigation	**Name of Irrigation Scheme(s)**
Run-off-river diversion and gravity-fed systems	Sata, Annum Valley
River pumping-based and gravity-fed systems	Aveyime, Kikam
Reservoir-based gravity-fed systems	Libga, Afife, Bontanga, Golinga, Tono, Vea, Ashaiman, Kpong, Okyereko
Reservoir pumping-based gravity-fed systems	Dawhenya
Lake pumping-based sprinkler irrigation systems	Weija, Kpando-Trokor, Amate, Dedeso
River pumping-based sprinkler irrigation systems	Subinja, Tanoso, Akumadan
Reservoir pumping-based sprinkler irrigation systems	Mankessim

Source: Namara *et al.* (2011)

About 10,848 farmers benefitted from these schemes. These projects have a total potential area of around 14,699 hectares, however only 8,745 (59.5 %) of those were developed for irrigated farming (Miyoshi and Nagayo, 2006). The actual land cultivated has been varying from season to season and occasionally decreasing due to inadequate and degraded facilities at the various schemes. Pumps are used in the majority of poorly performing schemes.

2.4.5.2 Emerging Irrigation Systems

In terms of irrigated area, yield obtained, production levels and production value, emerging irrigation methods exceed traditional systems. These methods include out-grower systems, tube-well irrigation, tiny motor-based irrigation, and others. All ten administrative regions of Ghana have widespread surface-water pumping-based irrigation systems, but the Eastern, Ashanti, Brong-Ahafo and Volta regions have the most of them (Namara *et al.*, 2011). The primary crops cultivated by emergent irrigation systems are horticultural, as opposed to public irrigation systems which appear to be largely intended for the production of rice. However, some staple crops like maize, rice and cassava are grown either apart from or in close proximity to vegetables.

2.4.5.3 Groundwater Irrigation

Due to increased availability of pumping technologies, groundwater that was formerly mostly used for domestic purposes is now increasingly being used for agriculture. According to Kortatsi (1994), in the upper regions, hand-dug wells and dugouts were methods of drawing groundwater from alluvial channels along streams for vegetable production during the dry season. Water was manually pumped from these wells to irrigate vegetable plots that were between 0.07 and 0.3 hectares in size. Abdul-Ganiyu and Prosper (2021) indicated that, in the Atankwidi catchment in the Upper East region, 100 to 200 hectares were irrigated using groundwater.

2.4.5.4 Small Reservoirs and Dugouts

Small reservoirs and dugouts differ mostly in the following ways:

- size,
- water use priority,
- structural information, and
- system of management.

The surface area, volume of water impounded, and number of beneficiaries are often smaller for dugouts. A dugout is an area scooped to increase depth and water retention. Dugouts are designed primarily for domestic and livestock use, with restricted use for irrigation, unlike tiny reservoirs which feature intake structures, canals, and laterals. In all ten administrative regions of Ghana, tiny reservoirs and dugouts are typical. In contrast to dugouts, which are made by digging down to remove earth, small reservoirs are made by impounding water behind embankments. Donors typically initiate and fund the construction of small reservoirs and dugouts, with GIDA or private contractors handling design or construction. Starting in the 1970s and 1980s, a variety of NGOs and funders, including the Red Cross, Action Aid, International Fund for Agricultural Development (IFAD), Plan Ghana, and others have been actively promoting these systems. The district assembly is primarily responsible for building dugouts, which represent a significant commitment from the community to growth and development. When the construction is finished, Water User Associations (WUAs) are created to oversee and carry out maintenance and operation tasks. Road and mining construction projects can occasionally unintentionally produce dugouts. Members of the local neighbourhood claim collective ownership in these situations. Small reservoirs and dugouts are utilized for cattle farming, irrigation, fish farming, and domestic water supplies, and their surface areas range from 3 to 30 hectares. Recently, the ten administrative regions of Ghana were inventoried by GIDA and MOFA for tiny reservoirs and dugouts (GIDA and MOFA, 2008). As can be seen in Table 2.7, 786 tiny reservoirs and 2606 dugouts were identified in these regions.

Table 2.7: Number of reservoirs and dugouts in Ghana as of 2008

No.	Region	Number of		Total 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	1,360.0
10	Northern	131	398	529	649.0
	Total	**786**	**2,606**	**3,392**	**6,116.0**

Source: GIDA and MOFA (2008).

Total estimated area irrigated by these systems is about 6116 ha, which is comparable to the area irrigated by the 22 public irrigation schemes described in the preceding section. Despite the general perception that the number of small reservoirs and dugouts is greater in the three northern regions of Ghana as compared to the rest of the regions, Table 2.7 shows that they are distributed evenly around the country.

2.6 Impact of Irrigation on Soil Health

Doran *et al*. (1994) and Adeboye *et al.* (2011) reported that soil health refers to the capacity of soil to carry out a variety of ecosystem functions, including supporting biological productivity, preserving environmental quality, and promoting plant and animal health. This has an effect on the productivity and health of a particular ecosystem as well as the environment that surrounds it. In the irrigable area, changes in soil quantity and quality might result from the setup and operation of the irrigation system, according to Bardak-Meyers (1996). The author continued to make the case that, despite increased food production, diversification, and associated economic benefits, irrigation's sustainability is doubtful because it can occasionally pose negative impact on soils (for example; waterlogging, rocky terrain, soil salinity, sodicity, nutrient deficiency, alkalinity and groundwater contamination).

The construction of irrigation systems may have detrimental consequences on the soil in addition to its positive impacts on a nation's economic health (Pereira *et al.,* 1996). In addition, Binns *et al.* (2003) noted that year-round use of establised irrigable areas under irrigation and rainfed conditions could result in difficulties with salinity, sodicity and fertility that could have an impact on the quality of the soil. Crop output is negatively impacted by poor irrigation water quality (Bello, 2001).

2.6.1 Soil Salinity and Sodicity

Regardless of the source, irrigation water does conatin some dissolved salts (Bauder *et al.,* 2011). The volume and concentration of dissolved salts, among other factors, affect whether water is suitable for irrigation (Ajayi *et al.,* 1990; Adamu, 2013). Tellefson and Hogg (2007) claim that as the long-term impact of irrigation on soil physico-chemical properties is related to soil production, hence quantifying these qualities is necessary. According to Horneck *et al.* (2007), fertlizers, irrigation water and other soil amendments are all potential sources of soil salinity. Saline, saline-sodic and sodic soils are the three soil states that might result from soil piling up, according to Waskom *et al.* (2010). Saline soils contain excess soluble salts that negatively affects plant growth. Senon *et al.* (2012) stated that excessive concentrations of soluble salts in soils are known as salinity. Plants roots are unable to absorb water from the soil around them because of the excessive salts in the root zone. In spite of the fact that less water is really present in the root zone, the presence of salt reduces the amount of water that is available to the plant. The chloride anions (Cl^-), sulphate (SO_4^{2-}), nitrate (NO_3^-), bicarbonate (HCO_3^-) and carbonate (CO_3^{2-}), are found alongside cations like sodium (Na^+), potassium (K^+), calcium (Ca^{2+}) and magnesium (Mg^{2+}) in the soluble salts. Long-term land use practices, such as irrigation with water that contains a lot of salt, can cause soils to become saline. Adongo *et al.* (2015) indicated that, irrigating with water from wells with salt contamination or using salty industrial water may result in the development of salty soils.

However, soil sodicity describes the soil's high concentration of sodium ions in comparison to other cations. It is brought on by sodium concentrations in soils that are higher than 15 % of the cation exchange capacity. Senon *et al.* (2012) reported that, sodic soils typically have a weak structure that affects physical qualities like water infiltration and air exchange, which can inhibit plant growth. According to Sumner *et al.* (1998), a low infiltration rate caused by poor structure can also result in significant soil erosion. pH values for sodic soils range from 8.5 to 10. The hydrolysis of Na_2CO_3 is what causes the high pH. Sodicity was described by Charm and Murphy (2000) as the relative dominance of exchangeable sodium in comparison to other exchangeable cations, primarily calcium, magnesium, potassium, hydrogen and aluminium and is expressed as ESP (Exchangeable Sodium Percentage). Another way to express sodicity is the sodium adsorption ratio (SAR), which is the ratio between sodium adsorbed and the sum of calcium and magnesium. The condition of soils known as soil salinity refers to how much salts that are soluble in water present in the soil. It is often expressed as ECe (electrical conductivity of saturation paste extract) and is measured in dSm^{-1}. The presence of Na^+ in the soil can predict how dangerously acidic it could become (Singh *et al.,* 2007).

Horneck et al. (2007) revealed that, sodic soils are abundant in sodium and other minerals while saline-sodic soils are frequently black in colour and have apparent salt deposits on the surface. Saline-sodic soils are characterized by electrical conductivity (EC) higher than 2.5 dS/m (mmhos/cm), SAR higher than 13, and ESP higher than 15.

2.6.1.1 Visual Diagnosis of Salt-Affected Soils

Waskom *et al.* (2010) presented some physical observations or symptoms which could aid in diagnosis of salt-related soil problems (Table 2.8).

Table 2.8: 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)

2.6.1.2 Treatment of Salt-affected Soils

Identifying the kind and quantity of salt and applying the appropriate leaching requirements, chemical treatment, or a mix of both are necessary for reclaiming a salt-affected soil. It is advised that if a salinity issue is discovered, it receives rapid attention and the best course of action. Prompt action will be less expensive, minimize the danger of plant damage, and increase the likelihood of regaining the salinity impacted soil (Senon *et al.*, 2012).

Leaching: Excess salts will be removed from well-structured, internally-draining soils by applying good quality irrigation water in the right proportions. To reduce the EC of the soil solution below the critical threshold for the crop, more salts should be leached below the root zone. When the EC is greater than 1.25 mmhos/cm at a soil-to-water ratio of 1:2, Senon *et al.* (2012) suggested leaching procedures to remove salts from the root zone. Table 2.9 lists the depth of low-salt water required to dissolve and leach any significant amounts of salts from the soil. A typical rule of thumb states that 15 cm of water will remove roughly 50 % of the salt, 30 cm will remove 80 % of the salt, and 60 cm would remove 90 % of the salt (Sreenivas and Reddy, 2008). Breaking root-restrictive hardpans or clay pans by deep tillage is advised for soils with poor drainage.

Table 2.9: Estimated Leaching Requirements for Removal of Salts Present in Soils

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

Source: (Sreenivas & Reddy, 2008)

Chemical Treatment: A soil is classified as sodic if it has a SAR value of more than 13 (or an ESP value of more than 15), which indicates that it has an excess of sodium. A surplus of sodium can lead to soil dispersion, which prevents the agglomeration of soil particles and leads to surface crusting or sealing. Excess salt dispersing across the soil limits water infiltration and movement through the soil and also results in poor aeration. To eliminate sodium in order to remove the surface sealing. Gypsum (calcium sulphate dihydrate; $CaSO_4.2H_2O$), one of the frequently used calcium sources, is used to treat soil that has been contaminated with salt. Good aeration and water circulation are both necessary for plant roots to grow unfettered. After adding gypsum to the soil, irrigation water devoid of salt is applied. The amount of sodium in the soil determines how much calcium should be applied (Senon *et al.*, 2012).

2.6.2 Relationship between Salinity, Sodicity and Physical Properties of Irrigated Soil

It has taken many years of research, according to Pearson and Bauder (2006), to identify the connection between the salinity (EC) and sodicity (SAR) of irrigation water and how it affects the physical characteristics of soil. It is now possible to forecast with a high degree of accuracy how particular soils will respond to irrigation with water that contains various concentrations of sodium and salts.

The effects on soil infiltration rates and hydraulic conductivities are the key issues raised by the interaction between salinity and sodicity of irrigation water (Bethune and Batey, 2002).

2.6.2.1 Infiltration Rate of Irrigated Soils

Assessing the effects of irrigation water quality on infiltration rates is one method suggested by Pearson and Bauder (2006) for determining the effects of salinity (EC) and sodicity (SAR) on soil physical attributes. Salinity, sodicity, and infiltration rates are correlated, as seen in Figure 2.2. For instance, if the irrigation water has a low salinity and a high sodicity, there could be serious issues. At an EC = 1 dS/m, an extreme drop in infiltration will take place at SAR = 15. Infiltration is slightly or moderately reduced when the EC is 2.5 or less. There will not be a decrease in infiltration when the EC is higher than 2.5. The relationship between EC, SAR, and infiltration rates is expressed numerically in Table 2.10. Factors such as climate, soil type, crop and plant species and management practices, require consideration when assessing the permissible levels of salinity and sodicity of irrigation water. The relationship between salinity, sodicity, and the physical characteristics of the soil is significantly influenced by rainfall. Even while heavy rains can drain salts out of the root zone, the amount of sodium bound to the soil is frequently not greatly reduced.

Rainfall therefore has the ability to both promote sodium-induced dispersion and decrease the possibility of soil agglomeration from salts.

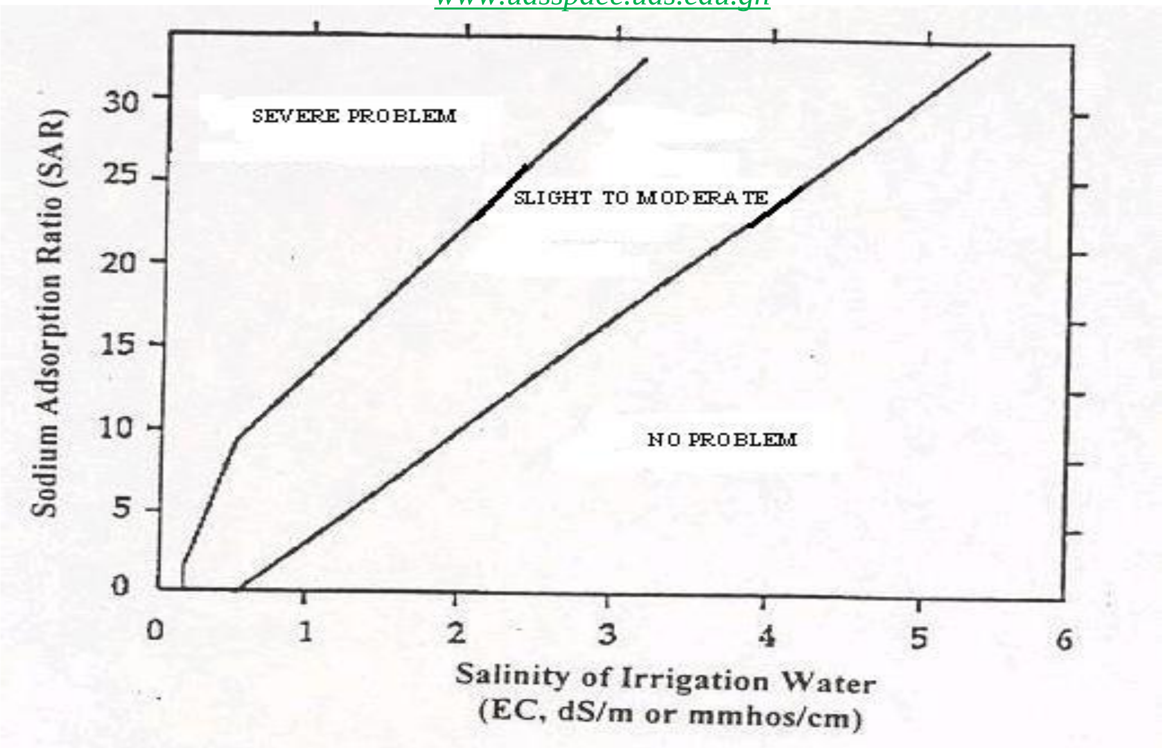


Figure 2.2: Potential for Reduction in Infiltration Rates Resulting from Various Combinations of EC and SAR of Applied Water

Source: (Hanson and May, 2004; Pearson and Bauder, 2006).

Table 2.10: Guidelines for saline-sodic water quality suitable for irrigation, presented in terms of reduced infiltration

	EC dS/m	**EC dS/m**	**EC dS/m**
SAR	No Problem	Slight to Moderate	Severe Problem
0 to 3	> 0.9	0.9 to 0.2	< 0.2
3 to 6	> 1.3	1.3 to 0.25	< 0.25
6 to 12	> 2.0	2.0 to 0.35	< 0.35
12 to 20	> 3.1	3.1 to 0.9	< 0.9
20+	> 5.6	5.6 to 1.8	< 1.8

Source: (Pearson and Bauder, 2006)

2.6.3 The Role of Soil Texture in Irrigated Agriculture

All facets of irrigated agriculture rely heavily on soil texture, and the consequences of salinity and sodicity are no exception (Warrence *et al.*, 2003). The ability of sodium to bind to the soil and how much water can be stored in the soil are both influenced by the texture of the soil. Clay soils can hold more water and are slower to drain than soils with a coarse texture because they are made up of small particles. Smaller particles can pack tightly together, obstruct the spaces between them, and hinder the passage of water. Sand has bigger pore openings for water to travel through since the particles are larger (Pearson and Bauder, 2006). Sandy soils have a natural ability to flush more water through the root zone than clayey soils under typical watering conditions. As a result of more dissolved salts being removed from the root zone via leaching, sandy soils may resist irrigation water with a higher salinity (Jangbarwala, 2007).

Surface area is cited by Kuila and Prasad (2013) as another important aspect of soil texture. A given volume of clay particles has a far bigger surface area than the same volume of a larger sized particle due to their extremely small size. Simply put, this means that clay soils have a higher chance of excess salt binding to them and causing dispersion than soils with a coarse texture. Sand cannot hold as much sodium as clay particles because they have smaller surface areas and greater particle sizes.

2.6.4 Soil pH

The acidity or alkalinity of a soil is determined by its Ph. Soil reaction is another name for it. pH levels vary from 0 to 14. A pH of 7.0 is referred to as neutral, a pH value less than 7.0 is described as acidic, and a pH value over 7.0 is referred to as basic/alkaline.

Soil pH affects the solubility of nutrients. Additionally, it has an impact on soil microbes that are in charge of decomposing organic materials and carrying out the majority of chemical reactions. Thus, soil pH has an impact on the nutrients that are available for plants. Because the majority of plant nutrients are easily accessible in this pH range, a pH range of 6 to 7 is typically the most favourable for plant growth. Some plants, however, have soil pH requirements that are either above or below this range.

Calcium, magnesium, and phosphorus are typically not readily available in soils with pH levels below 5.5. Aluminium, iron, and boron are very soluble at these low pH values, but molybdenum's solubility is minimal. Calcium and magnesium are prevalent at pH 7.8 or above. If molybdenum is found in the soil minerals, it is also available. Iron, manganese, copper, zinc, and notably phosphorus and boron, may not be readily available in high pH soils (USDA, 1998). Table 2.11 displays the various soil pH classes.

Table 2.11: The Most Common Classes of Soil pH

pH Class	Range
Extremely acid	3.5 – 4.4
Very strongly acid	4.5 – 5.0
Strongly acid	5.1 – 5.5
Moderately acid	5.6 – 6.0
Slightly acid	6.1 – 6.5
Neutral	6.6 – 7.3
Slightly alkaline	7.4 – 7.8
Moderately alkaline	7.9 – 8.4
Strongly alkaline	8.5 – 9.0

Source: (USDA, 1998)

2.7 Performance Evaluation of Irrigation Schemes

2.7.1 Significance of Performance Evaluation

Performance is evaluated for a variety of reasons, according to Molden *et al.* (1998): to enhance system operations; to assess progress toward strategic goals; as a crucial component of performance-oriented management; to assess the general health of a system; to assess the effects of interventions; to identify obstacles; to better comprehend performance determinants; and to compare the performance of a system with that of other systems or with the same system over time.

2.7.2 Factors Affecting the Performance of Irrigation Schemes

Odi (1995) identified the causes of irrigation systems' poor performance, among others:

- Inadequate system administration and service delivery.
- Poor comprehension of the priorities of farmers and insufficient markets for produce.
- Lack of explicit and enduring water rights granted to users, either individually or collectively.
- Absence of well-defined and acknowledged authority granted to controlling organizations.
- Lack of open accountability and incentives for scheme management.

2.7.3 Performance Evaluation Methods

The type of performance metric relies on the goal of the performance activity. Irrigation system performance disparities generally fall into one of four categories (Douglas and Juan, 1999).

A performance gap in technology comes first. This happens when an irrigation system's infrastructure is unable to meet a certain hydraulic performance criterion. Changing the kind, design, or state of the physical infrastructure is typically the answer to a technology performance gap.

The second results from management weaknesses. This occurs as a result of the discrepancy between the intended processes and those actually followed, i.e., how people operate gates, maintain canals, and report information. This is referred to as a performance gap in the implementation. This kind of issue typically calls for adjustments to the procedures, oversight, or training.

Differences between management goals and actual accomplishments constitute the third type of performance gap. This is known as an accomplishment gap. Such issues are typically resolved by either altering the goal or boosting management's ability to accomplish it (expanding the pool of resources or restructuring organizations).

The fourth one is management impacts, which refers to the discrepancy believe what people believe should be the end outcomes of irrigation and what really transpires. These performance gaps in terms of impact include productivity per unit of water used, poverty reduction, and environmental issues like salinity and water logging. The issue is not that the controlling organization has performed poorly. These effects are usually out of direct control if management procedures are being followed and targets are met but the final results are not what were expected. The issue is one more of management than one of policy. Most authors propose to use different indicators and different methodologies or tools to measure the same indicators (Bos, 1997). But this causes much confusion in evaluation. Recent research divided indicators used to evaluate irrigation systems into two categories; process/internal performance and comparative/external performance evaluation methods to ensure a much clearer understanding.

2.7.4 Performance Indicators

Performance is measured via indicators. An indicator describes the degree of actual success in realation to irrigation objectives. To illustrate the various forms and uses of performance indicators, it is helpful to think of an irrigation system in terms of embedded systems (Small and Svendsen, 1992). A system of irrigated agriculture, which is a subset of the agricultural economic system, contains an irrigation system. Process, output, and impact measures can be taken into account for each system. Two sets of goals can be thought of for an irrigation system that consists of water delivery and water consumption subsystems. In the first set, the outputs from the irrigated region are discussed, and in the second set, the performance traits of the water delivery system are discussed (Oad and Sampath, 1995).

The performance indicators utilized by the Research Program on Irrigation Performance (RPIP) recently are outlined by Bos (1997). About 40 multi-disciplinary performance indicators are tested and quantified using field data acquired as part of this initiative. Water delivery, water use effectiveness, maintenance, irrigation sustainability, environmental considerations, socioeconomic factors, and management are all covered by these indicators. Bos (1997) added that not every situation calls for the usage of the specified indicators. Depending on how much detail needs to be quantified on performance (e.g., research, management, public information), different indicators should be employed. A genuine performance indicator has both an actual and a planned value, which makes it possible to calculate the degree of variance. It should also include details that enable the manager to decide whether the variance is acceptable.

According to Boss (1997), some desired qualities of performance indicators include:

i) **Scientific foundation:** The indicator should be based on an experimentally measured, statistically tried causal model of the irrigation process it describes.

ii) **The indicators must be measurable:** The data required to quantify the indicator must be accessible or attainable (measurable) with current technology. Reproducible measurements are required.

iii) **Reference to a target value:** Given the definition of a performance indicator, this is, of course, apparent. It suggests that the goal values and tolerances for the indicator can be determined to be relevant and appropriate. Bos *et al.* (1991) stressed that, these target values and their margin of error should be tied to the level of technology and management.

iv) **Provide unbiased information:** Performance indicators should ideally not be created from a limited ethical standpoint. This is actually very challenging because even technical measures include value judgements.

v) **Cost-effectiveness and ease of use:** Performance indicators, particularly for routine management, should be technically possible and simple for agency workers to utilize given their level of motivation and skill. Additionally, the expense of using indicators should be well within the agency's resources in terms of money, equipment, and human resource commitment.

2.7.4.1 Comparative Performance Indicators

The objective of the comparative indicators is to assess the results and effects of interventions and management strategies for irrigation across multiple systems and system levels, as well as to analyze and contrast different irrigation methods and seasons. The use of comparative performance indicators will inform system managers, researchers, and policy makers about performance discrepancies and as a result, allow them to spot weaknesses in irrigation management programs. Molden *et al.* (1998) stressed that comparative performance indicators generally:

- Reveal broad ideas about the general state of the irrigation system, but they are not too data-intensive to prevent widespread and regular implementation.
- Instead of making reference to norms or goals, the indicators are based on a relative comparison of absolute numbers.
- The indicators relate to phenomena that are typical of irrigation and irrigated agriculture systems.
- It enables comparisons across nations and regions, between various infrastructure and management models, between diverse settings and for the assessment over time of the trend in performance of a particular project.
- Makes it possible to identify systems that work well in diverse situations and those that do not.

- Enable managers to evaluate performance in relation to long-term, strategic goals and the impact of actions.
- Provide enough details about the system's output despite its size.
- Ensure that procedures for gathering data are not overly expensive or cumbersome.
- The indicators are bulk measures of irrigation and irrigated agricultural systems that relate to outputs; as a result, they offer little insight into internal processes.

At the very least, a comparative analysis of values enables us to assess how well one system is performing in comparison to others. Furthermore, if we have sufficient samples, this strategy might eventually enable us to establish criteria and goals. In contrast, the primary audience for internal indicators is irrigation system managers who are interested in day-to-day operations where ratios of actual to target values may be quite significant. These individuals are responsible for making long-term and strategic decisions as well as policy makers and managers who are looking for relative differences between irrigation systems.

2.7.4.2 Selected Performance Indicators

Researchers have developed a number of performance indicators for assessing the effectiveness of different irrigation schemes. These indicators are typically produced in relation to goals established for the effectiveness of the irrigation system. It is well acknowledged that the broad goals of irrigation systems must be transformed into precise standards by which their effectiveness can be assessed (Ijir, 1994).

Eighteen (18) comparative performance indicators were developed and used by Ijir (1994) to assess the effectiveness of the Wurno Irrigation Scheme in Nigeria. The set of indicators are as follows:

1. Scheme development ratio = $\frac{\text{Adev}}{\text{Ap}}$ 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/yr) and,

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

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. Culture-related practices affecting crop output.

Additionally, Molden *et al.* (1998) included nine external and internal comparable indicators from the International Water Management Institute (IWMI) in their research. With the intention of enabling performance comparisons between irrigation schemes, several indicators were created. These indicators were used on 18 irrigation systems, and the findings revealed significant variations in each scheme's performance. The following are the indicators:

1. Output per cropped area $(\frac{\$}{ha}) = \frac{Production}{Irrigated\ cropped\ area}$ -------------------Equation (2.18)
2. Output per unit command $(\frac{\$}{\mathrm{ha}}) = \frac{Production}{Command\ area}$ --------------------------Equation (2.19)
3. Output per unit irrigation supply $(\frac{\$}{\mathrm{m3}}) = \frac{Production}{Diverted\ Irrigation\ supply}$ ------Equation (2.20)
4. Output per unit water consumed $(\frac{\$}{\mathrm{m3}}) = \frac{Production}{Volume\ of\ water\ consumed\ by\ crop}$ ---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)

2.8 Distribution Uniformity (DU) and Uniformity Coefficient (UC) of Pressurized Irrigation Systems

Distribution Uniformity (DU) and Uniformity Coefficient (UC) are performance indicators that gauge how evenly water is supplied to a specific region (Burt *et al.*, 1997). Inevitable occurrences that contribute to irregular water distribution include unexpected blowouts in irrigation pipes and broken sprinklers. However, field tests may reveal flaws in a system, even when it seems to be functioning properly. Over-irrigation and inconsistent irrigation practices might result in salt accumulation, nitrogen leaching and harming of crops. Regardless of the effectiveness and efficiency of the overhead (sprinkler) irrigation system, conducting a simple DU and UC test can show how uniformly water is actually distributed. Running periodic DU and UC tests on pressurized systems is worthwhile since uniformity has a substantial impact on yield and water usage.

2.9 The Efficiency of Water Conveyance through Canals

The effectiveness of water transportation in a canal is known as conveyance efficiency. The Irrigation Innovation Consortium (2018) defines water conveyance efficiency as the ratio of the volume of water delivered for irrigation to the volume of water placed in the conveyance system. For open channel conveyance systems, this ratio is typically lower than 1.0. Seepage, evaporation, and transpiration are the main factors that affect the effectiveness of water transportation in open channel conveyance systems, including ditches, canals, and streams. By employing lined tubes and managing vegetative growth, these losses can be decreased. There will be some unavoidable evaporation losses. Because well-designed and well-managed pipelines have low leakage, seepage and other losses are avoided in pipelined conveyance systems. The conveyance efficiency thus dictates how much water must be provided to the field depending on the characteristics of the channel.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Description of Study Areas

The study was conducted at Akumadan Irrigation Scheme in the Ashanti Region, Kaniago and Tanoso Irrigation Schemes in the Bono East Region and Subinja Irrigation scheme in the Bono Region of Ghana. For this study, the Akumadan and Kaniago schemes constituted the functioning irrigation schemes whilst the Tanoso and Subinja schemes represented the defunct irrigation schemes. These schemes thus represent the principal irrigation facilities in the transition agro-ecological zone, hence promoting dry season farming and agricultural production in the zone. The Figure 3.1 depicts the map of the study area.

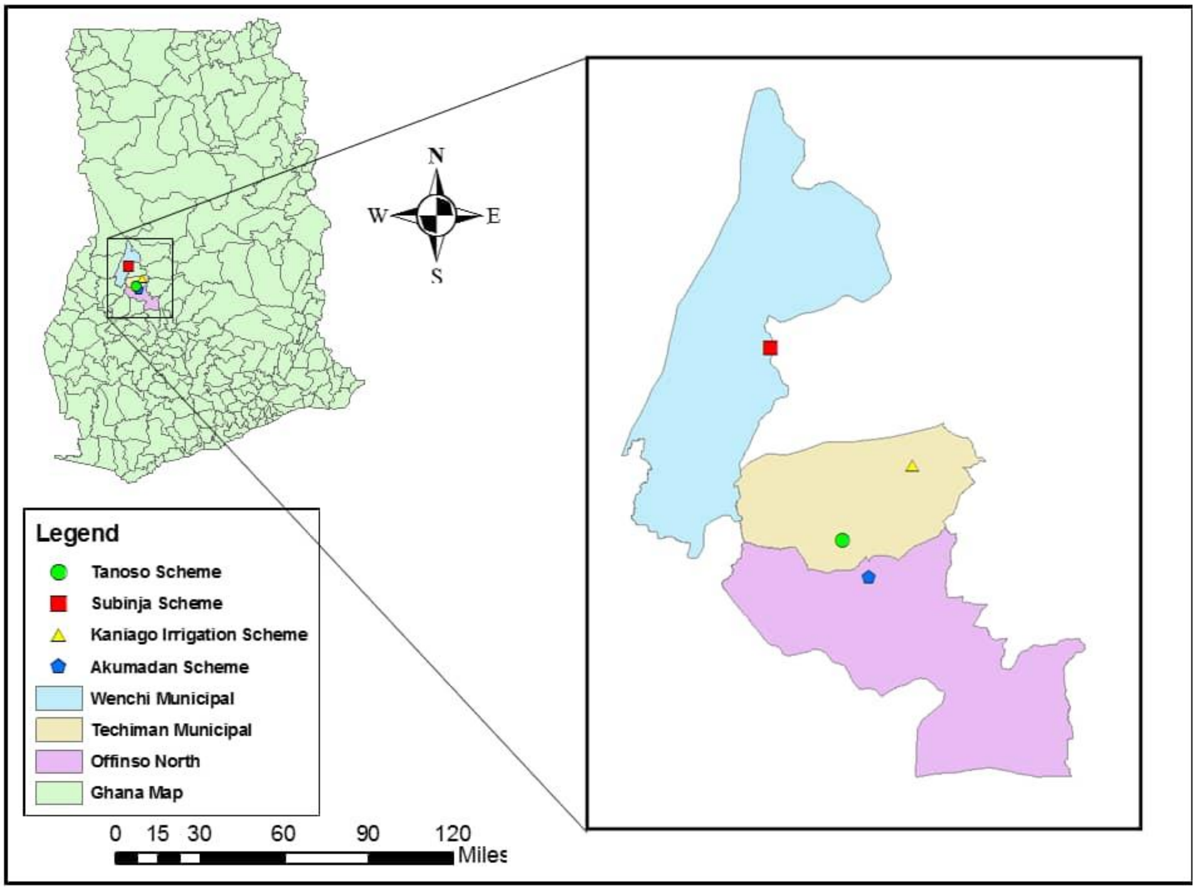


Figure 3.1: A map showing the locations of Akumadan, Tanoso, Kaniago and Subinja Irrigation Schemes

3.1.1 Akumadan Irrigation Scheme

The irrigation scheme is located at Akumadan, the district capital of Offinso North District in the Ashanti Region of Ghana. The scheme lies within latitude 7°24'46 North and longitude 1°56'7 West. The project was constructed by Government of Ghana in the year 1976 through Ghana Irrigation Development Authority (GIDA) and rehabilitated in 2006 through financial supports from World Bank and CIDA. Moreover, provision of pumps were executed by Emix-Bank of India. The facility is a sprinkler irrigation system with four (4) electric pump engines each having 100 horsepower (hp) capacity with voltage of 415 volts.The scheme takes its source of water from Ayadan River with a weir built across it. The scheme's reservoir has capacity of 5.2 MCM . The current irrigable area is 166 ha of land with a potential irrigable area of 1000 ha. Crops cultivated on the scheme are tomato (*Solanum lycopersicum*), bell pepper (*Capsicum annuum*), and okra (*Abelmoschus esculentus*).

3.1.2. Tanoso Irrigation Scheme

The irrigation scheme is located at Tanoso in the Techiman Municipality of the Bono East Region of Ghana. The scheme is located within latitude 7°27'50 North and longitude 1°58'20 West. The project was commissioned by the Government of Ghana in the year 1975 through Ghana Irrigation Development Authority (GIDA) and rehabilitated in 2004. The scheme is a sprinkler irrigation system powered by electrical pump engines. The scheme takes its source of water from the Tano river. A weir of length 18.75 m, crest elevation of 292.7 m and height of 1.8 m has been built across the river to divert water into the scheme's reservoir. Existing in the scheme is a pump house which harbours five pump units; thus three low-head pumps and two high-head pumps. Each of the low-head pumps has capacity of 45 horsepower (hp) with the high-head pump having capacity of 55 hp. The scheme is operated by fixed rotor type sprinkler. The scheme has a total developed irrigable area of 64 ha and a potential irrigable area of 130 ha. Crops cultivated on the scheme were okra (*Abelmoschus esculentus*), chili pepper

(*Capsicum annuum*), cabbage (*Brassica oleracea var. capitata*), tomato (*Solanum lycopersicum*), garden eggs (*Solanum melongena*) and watermelon (*Citrullus lanatus*).

3.1.3 Kaniago Irrigation Scheme

Kaniago Irrigation Scheme is found at Kaniago village in the Techiman Municipality. The Municipality is located in the Bono East Region of Ghana. The scheme lies within latitude 7°34'6 North and longitude 1°52'31 West. The project was constructed by Government of Ghana in 2008 under the Small Farm Irrigation Project (SFIP) through Ghana Irrigation Development Authority (GIDA). It is a surface irrigation system that supplies water to crops by gravity. The source of water for the scheme is the Fia River. Water is diverted from the river by a weir into an intake chamber where it is further directed into canal and canal structures then through hydrants until it finally reaches the farmers field. The scheme has night storage reservoir which stores water and supplies farmers at middle and tail ends of the scheme. The scheme is irrigated at an area of 60 ha. The project benefits an average of 22 farmers and crops cultivated on the scheme include; tomato, garden eggs, cabbage, groundnut and maize.

3.1.4 Subinja Irrigation Scheme

Subinja Irrigation Scheme is found at Asubinja in the Wenchi Municipality. The Municipality is located in the Western part of the Bono Region of Ghana. It is bounded to the South by Sunyani Municipality and to the North by Kintampo South District. It also shares common boundaries with Tain District to the West and Techiman Municipality also to the East. The scheme lies within latitude 7°43'52 North and longitude 2°4'40 West. It is a sprinkler irrigation system and is named after River Subin. The project was commissioned in 1976 by Government of Ghana through Ghana Irrigation Development Authority (GIDA) and rehabilitated in 2006. The source of water supply in the scheme is the Subin River. A weir is built across the river to divert water for irrigation purposes. The full potential area of the irrigation project is 121 ha with a total developed irrigable area of 60 ha. Crops produced on the scheme were maize (*Zea* *mays*), cowpea (*Vigna unguiculata*), tomato (*Solanum lycopersicum*) and chilli pepper (*Capsicum annuum*).

3.1.5 Climatic, Vegetation and Soil Characteristics of the Transition Agro-ecological Zone

The transition zone separates the Forest and the Savannah. It mainly comprises the Bono and Bono East regions of Ghana with narrow portions of the Ashanti and Eastern regions adding up to the total zonal area. It is called a transition zone because it shares its climate with the Savannah. It receives an annual rainfall of 1200mm, which is quite fair as compared to the forest and the Savannah. It is characterised by semi-deciduous forest and guinea savannah vegetation, with a bimodal rainfall pattern peaking in June–July and again in September–October, and a dry period from December–March. The zone has a temperature of 23.9 ^{0}C averaging throughout the year and an average humidity of 75 %. Three substantive soil groups are found within the transition ecological zone . These are:

i) Forest Ochrosols; covering the south-western part.

ii) Savanna Ochrosols; this stretches as wide belt from the west and gradually narrows toward the east.

iii) Ground water Laterite Ochrosols Inter; This intergrades in the northern parts of the zone. Besides these soil groups, there are some small patches of Oxysols and Rubrisols. The transition zone covers 28 % of land which makes up to 180-200 days of rowing. This means that farmers have adequate time to prepare their land, and plant when there is rainfall. The transition zone mainly supports annual food crops and also crops like maize, roots and also plantain. In the transition zone, the pattern of rainfall has shifted because of the mixed weather.

3.2 Methods of Data Collection

3.2.1 Desk Study

Desk study or secondary research was done on the irrigation schemes by reviewing existing literature such as journals, articles, thesis and other relevant documents worldwide on irrigation system performance evaluation and management. Documents were also obtained from scheme management offices and Ghana Irrigation Development Authority (GIDA) middle-belt zonal office.

3.2.2 Interviews

Informal interviews were conducted asking farmers pertinent questions regarding the condition of the irrigation facilities, their performance and management. Semi-structured questionnaires were randomly administered to a number of forty-one (41) farmers on the functioning irrigation schemes. Seven (7) key informants comprising scheme managers, irrigation technician, association chairpersons and a GIDA administrator were contacted for certain relevant information on the irrigation schemes.

3.2.3 Direct Observation and Field Measurements

At the locations of the schemes, precise observations and measurements were made. Photographs were taken while taking into account the current condition of the pumps, sprinklers, hydrants, conveyance structures, flow control structures, and flow measurement structures in the scheme. Additionally, the type and state of the soils, their geographical variability, and the physical and chemical characteristics linked to soil erosion, waterlogging, salinity, and sodicity were considered. Since scheme management did not make data on these parameters available, the canal size and area of the canal flow were measured manually in the scheme. These pertinent information served as baseline of the research.

3.2.3.1 Measurement of Canal Flow Velocity and Area Dimensions for Discharge Determination

Flow Velocity: The canal flow velocity in the Kaniago scheme was measured to determine discharge of water through the canal since there was no flow measurement structure coupled with lack of concrete data from scheme management on water discharge through the main canal in the scheme. The float method was used to measure the flow velocity. The 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 depth (d) and width (w) of the canal structure in Kaniago was determined using measuring tape. Since the canal system was rectangular in shape, the flow area was determined as;

Flow area (m^2) = Width of flow (*m*) × Depth of flow (*m*)………………....Equation (3.2)

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

Discharge, Q (m^3/s) = Velocity (*m/s*) x Area (m^2) ……………………….. Equation (3.3)

Plate 3.1: Measurement of Canal Dimensions and Flow-depth at Kaniago Irrigation scheme

3.2.3.2 Physical and Chemical Properties of Soil in Irrigable Areas of the Functioning Schemes

The irrigable areas in the schemes were partitioned into three zones namely; up-stream, mid-stream and down-stream for soil sampling. Composite soils (0 – 30 cm depth) were sampled in each stream of the scheme. A total of six (6) samples were obtained from the two (2) functioning schemes with three samples each from a scheme. Illustrated in Table 3.1 are various soil sampling points within irrigable areas of the functioning schemes. 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 soil extract using the EC meter. The exchangeable sodium percentage (ESP) method was used to determine the sodicity level in the soils (Senon *et al.*, 2012).

Table 3.1: Soil Sampling Coordinates in the Functioning Irrigation Schemes

Scheme	Sampling Location	Latitude (N)	Longitude (W)
Akumadan	US	7.412728	-1.935346
	MS	7.413639	-1.935815
	DS	7.413362	-1.937482
Kaniago	US	7.571162	-1.877907
	MS	7.569272	-1.877418
	DS	7.567714	-1.874527

US - Up-stream, MS - Mid-stream, DS - Down-stream; N – North, W- West.

3.3 Comparative Performance Indicators

In the study, the following set of comparative performance indicators certified by the International Programme for Technology and Research in Irrigation and Drainage (IPTRID) were used in the performance evaluation of the irrigation schemes. These indicators are classified into five groups namely; water delivery, physical structures, economic, environmental state and crop production performance (Malano and Burton, 2001; Cakmak *et al.*, 2009).

3.3.1 Water Delivery Performance

Two (2) sub-type indicators were used in the evaluation of water delivery performance of the irrigation facilities.

3.3.1.1 Total Irrigation Water Supply per Hectare per Season

This indicator defines more the total quantity of water that can be supplied from the scheme's reservoir in an irrigation season. As given by Cakmak *et al.* (2009), total irrigation water supply per hectare per season was determined using the equation:

$$\text{TIWSHS} = \frac{\text{Tawd}}{\text{Ia}} \quad \text{..} \text{Equation (3.4)}$$

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/Pipe Flow Length

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

Extent of main canal flow lengths = $\frac{\text{La}}{\text{Lt}}$ x 100 % …………………………Equation (3.5)

Where: La - Actual total length of main canal/pipe sections still flowing (km) and,

Lt - Total length of main canal/pipe sections constructed (km)

3.3.2 Physical Performance

Physical indicators relate to the alteration or loss of irrigated land in the command area as a result of factors including dilapidated conveyance, regulatory, distribution and energy utilization structures in the scheme. The physical performance of the schemes was evaluated using four (4) sub-indicators.

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 the ratio of the irrigated area to the total developed irrigable area of the scheme. Irrigation rate can be described as irrigable land utilization efficiency (Bekisoglu, 1994).

Irrigation Rate = $\frac{\text{Actual irrigated area (ha)}}{\text{Total developed irrigable area (ha)}}$ x 100 …………………Equation (3.6)

3.3.2.2 Sustainability of Irrigated Area Index (SIAI)

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

SIAI = $\frac{\text{Current irrigated area (ha)}}{\text{Initial irrigated area when the scheme was fully completed (ha)}} \times 100\%$ ….Eqn (3.7)

3.3.2.3 Poor Structure Index of Irrigation Schemes (PSIIS)

Poor structure index of the irrigation scheme was calculated using a modified Bos *et al.* (1997) equation. For the modified equation, structures present in a scheme are assessed as a unit. Thus for a particular set of structures; if the ratio of the number in good condition to the total number of existing structures is 0.9 or above, it is represented with a score of 1. Similarly, if the ratio is less than 0.9, the assigned score is 0.

Poor structure index of irrigation scheme = $\frac{\text{Tnup}}{\text{Tnu}}$ x 100 % ………………………Equation (3.8)

Where: Tnup – Total number of unit structures in poor condition (defunct, not functioning adequately, at the verge of failure) and, Tnu - Total number of unit structures present on the scheme.

These structures include conveyance, regulatory, flow measurement and energy utilization structures. The conveyance structures for this indicator include canals, main pipes, sprinklers and laterals. The regulatory structures also include offtake valves, hydrants, weirs in canals, check structures in canals and laterals, and gates of check structures and laterals. The flow measuring structures comprises Parshall and Cutthroat flumes whiles the energy utilization structures consist of pumps, the power distribution panel and power starting panels, and the power breaker in the pump house.

3.3.2.4 Efficiency of Road Network Passability

The efficiency of irrigation schemes road network passability was determined using Ijir (1994) formula, and is expressed as:

Efficiency of roads network passability = $\frac{\text{Ra}}{\text{Rt}}$ x 100 % …………………………Equation (3.9)

Where: Ra - Actual length of roads which has all year round accessibility (km) and, Rt - 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 calculating the index (Ijir, 1994).

Environmental stability index = $\frac{\text{Tna}}{\text{Tdia}}$ x 100 % ……………………………….Equation (3.10)

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 economic performance of the schemes was evaluated using the following sub-indicators:

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= $\frac{\text{Ataisc}}{\text{Etaisc}}$ x 100 % ……………………………………………………Equation (3.11)

Where: EISR - Efficiency of irrigation service charges recovery (%)

Ataisc – Actual 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 = $\frac{\text{Fs}}{\text{Fg}}$x 100 % ……………………………………………………….Equation (3.12)

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 factor of the schemes was computed using the equation given by Ijir (1994) and Kuscu *et al.* (2009).

$$FSF = \frac{Tai}{Taome} \times 100\ \% \quad \text{......Equation (3.13)}$$

Where: FSF - Financial self-sufficiency factor (%)

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

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

3.3.5 Production Performance

The average yield (t/ha) per crop and average irrigated area (ha) per crop were used in evaluation of production performance of the schemes.

3.4 Determination of Distribution Uniformity and Uniformity Coefficient of the Pressurized Irrigation System

The catch can experiment was conducted in the Akumadan scheme to measure the uniformity coefficient and distribution uniformity. Thirty-two (32) catch cans were used for the data collection. Each can measure an average total volume of 380 ml and height of 110 mm. In a single-leg distribution pattern, the cans were arranged at regular and even spacing of 3 m away from one another. The catch cans covered an area of 30 m x 30 m for a single 15 m throw rotating-impact sprinkler. At a particular pump operating pressure, the test was conducted to capture water falling linearly but in a circular pattern around the overhead system. The cans were checked and emptied of water before the test was conducted; the sprinkler was made to rotate to collect water into the catch cans over a period of one (1) hour. The experiment was conducted at the up-stream and down-stream sections of the irrigable area. After an hour of the experiment, all thirty-two (32) cans at both the up-stream and down-stream sections received water. However, care was taken to prevent the falling of standing catch cans.

Equations for Computations in the Study:

i. According to Burt *et al.* (1997), the Distribution Uniformity (DU) defines the uniformity of water application throughout the field and was computed by:

$$DU = \frac{\text{Average low quarter depth of water received}}{\text{Average depth of water received}} \times 100$$

ii. The Christiansen's Coefficient of Uniformity (CU) was computed by:

$$CU = 100 \times \left(1.0 - \frac{\Sigma x}{nm}\right)$$

Where: CU = coefficient of uniformity test (mm), x = |z − m| = absolute deviation of the individual observations from the mean (mm), n = number of observations, m = (∑ z) ⁄n = mean depth of observations (mm), z = individual depth of catch observations from uniformity test, mm (Christiansen, 1942; Burt *et al.*, 1997).

Figure 3.2: Water Distribution in the Field by the Rotating-impact Sprinkler

Shown in Plate 3.2 was the arrangement of catch cans in the experimental area.

Plate 3.2: Blue Arrows Depicting Catch Cans Arrangement in the Field

3.5 Determination of Conveyance Efficiency of the Surface Irrigation System

The efficiency of water conveyance in the Kaniago scheme was determined using the measured canal flow velocities and depths of flow.

Flow velocity measurements were taken at the source of water supply into the main canal and at the up-stream, mid-stream and down-stream sections of the canal. Measurements were made at two different sections for each stream of flow along the canal system. The average flow depth at each stream was also considered in the computation of the canal discharges.

i.e. Conveyance Efficiency = $\frac{\text{Discharge at Sections along the Main Canal}}{\text{Discharge at the Source of Water Supply}} \times 100\%$

3.6 Method of Data Analysis

The collected field data were analysed using equations of performance evaluation and Excel spreadsheet for T test analysis and drawing of tables and charts. The questionnaires were analysed descriptively using Statistical Package for Social Science (SPSS).

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Principal Characteristics of the Functioning Irrigation Schemes

4.1.1 Principal Characteristics of Akumadan Irrigation Scheme

The principal characteristics of the scheme are presented below in Table 4.1.

Table 4.1: Principal Characteristics of Akumadan Irrigation Scheme

Characteristics of Scheme		
Year of construction and Rehabilitation	Year of construction completion	1977
	Year of rehabilitation	2006
Reservoir	Capacity of reservoir	-
Pump unit	Capacity of pump	100 hp
	Discharge of pump	3 m^3/min
	Height of suction sump	5 m
Main pipe	Diameter nominal	220 mm
	Length	1.6 km
Hydrant	Diameter	63 mm
Lateral	Diameter	63 mm
	Length	6 m
Irrigable area	Potential irrigable area	1000 ha
	Developed irrigable area	166 ha
	Undeveloped irrigable area	834 ha
Water delivery	Mode of water delivery from reservoir	Pumped (sprinkler)
Road network	Total length of road network	(3.5 + 2.1), 5.6 km

Source: (GIDA-Transition Zone and Project Records, 2021)

4.1.2 Principal Characteristics of Kaniago Irrigation Scheme

The principal characteristics of the scheme are presented in Table 4.2.

Table 4.2: Principal Characteristics of Kaniago Irrigation Scheme

Characteristics of Scheme		
Year of construction	Year of project construction completion	2008
Reservoir	Capacity of night storage reservoir	-
Main canal	Canal width	1 m
	Average depth of canal	0.55 m
	Total length of canal	2.2 km
Hydrant	Diameter	62 mm
Flumes	Number of measuring devices (parshal flumes) on the main canal	3
Spillway	Number of spillways	1
Irrigable area	Potential irrigable area	60 ha
	Developed irrigable area	60 ha
	Undeveloped irrigable area	-
Water delivery	Mode of water delivery from reservoir	Gravity flow
Road network	Total length of road network	-

Source: (GIDA-Transition Zone and Scheme Survey, 2021)

4.2 Management and Administrative Structure of the Functioning Irrigation Schemes

Irrigation facility management and administration in Ghana has over the years been the responsibility of government through Ghana Irrigation Development Authority (GIDA) under the Ministry of Food and Agriculture. However, the introduction of "Participatory Irrigation Management" in early 1990's has diversified irrigation facility management, ensuring the involvement of beneficiary farmers and stakeholders in the management and administration of irrigation schemes. Shown in appendix B is the supposed institutional arrangement for GIDA managed schemes which unfortunately has failed implementation due to lack of funding from the government and insufficient Irrigation Service Charges Recovery. As stated earlier, the functioning schemes refer to the Akumadan and Kaniago schemes.

4.2.1 Management of the Akumadan Irrigation Scheme

Administratively, the Akumadan scheme is jointly managed by GIDA and MoFA staff and Water User Association executives of the scheme. The Figure 4.1 shows the management and administrative structure implemented in the Akumadan scheme.

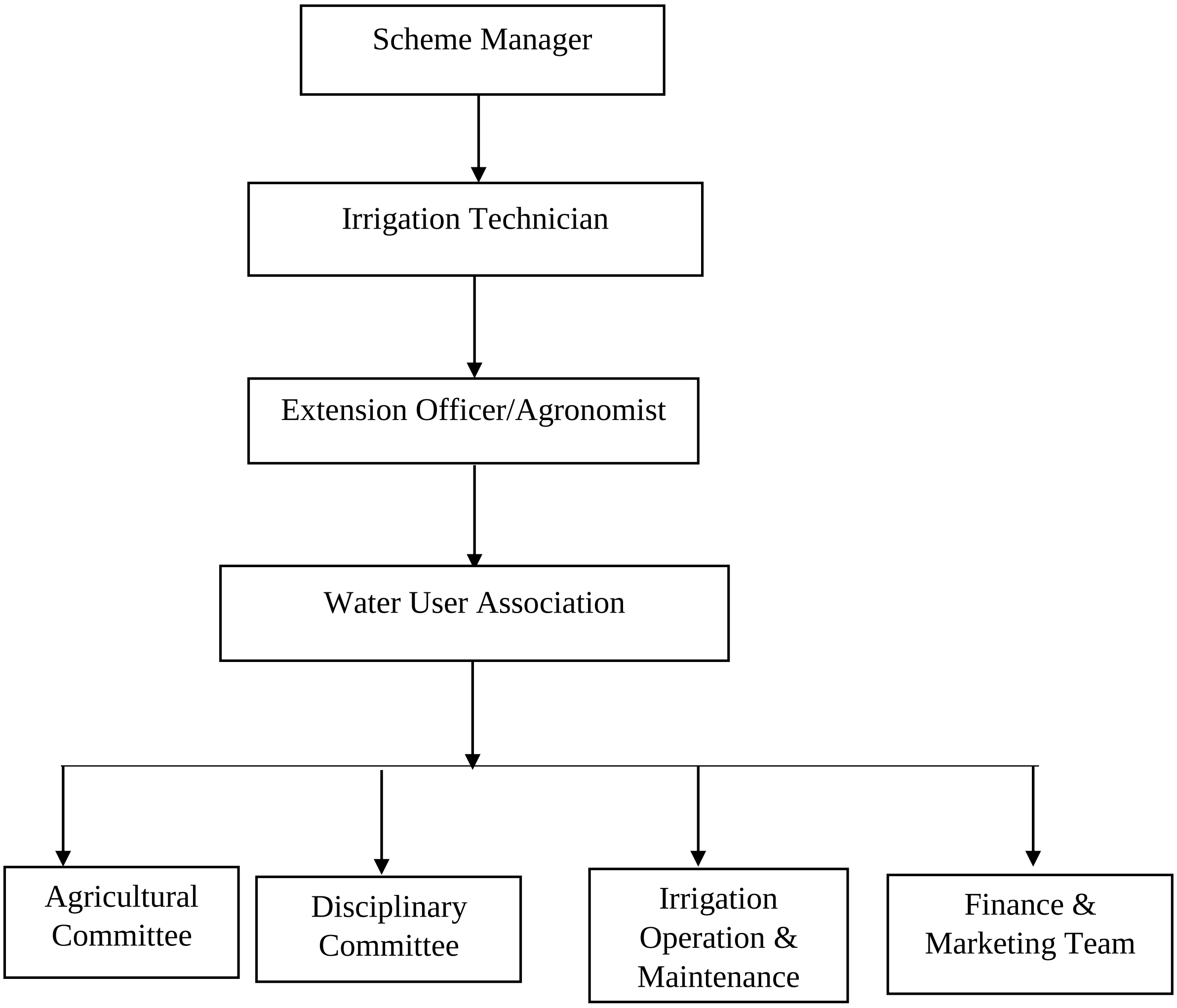


Figure 4.1: Schematic Diagram of Management and Administrative structure at the Akumadan Scheme

4.2.1.1 Scheme Manager

The manager of the irrigation scheme exercises general supervisory role in the scheme. The manager is mandated to implement policies and decisions taken by MoFA through GIDA. The managers of the scheme is often assisted by some selected members of the farmers' co-operative associations. Organising and facilitating trainings and workshops are roles of manager of the scheme. Upon enquiry, it was revealed that these supposed trainings and workshops are not regularly carried out due to inadequate funds to organize such programmes.

4.2.1.2 Project Irrigation Technician

Irrigation technicians are tasked with general operational activities, mainly involving water delivery processes from reservoir to the field where water gets to the cultivated crops. Thus, the Irrigation technician ensures water is made available to farmers on the field where crops are raised. He/she also monitors general performance of the irrigation scheme.

At the time of study, the Akumadan scheme was found to benefit from services of an Irrigation technician.

4.2.1.3 Extension Officer/Agronomist

Agriculture extension officer has an important role in the agriculture sector of any country. However, in case of developing countries, the role of agriculture extension office increases many folds. The extention officer is the pivotal component of the agriculture sector after a farmer. This is because of the nature of duties that keep the farming community up to date with latest and innovative knowledge and farming techniques to increase the efficiency of agricultural produce (Rahman, 2017). Studies on the schemes revealed that the Akumadan scheme benefitted from the services of an agriculture extension officer/agronomist.

Generally, agriculture extension officers are responsible for:

- The development of farmer's capacity to adopt and implement better agronomic practices through exposure to new knowledge, information, skills and inputs.
- Encouraging the farmer to adopt better agronomic practices through exposure to new knowledge , information , skills and inputs.
- Providing technical services for farmers in key parts of value chains where it is more effective and efficient (e.g. For integrated pest and disease management, climate change adaptation techniques, improved data management, veterinary services)
- Working with the Agriculture officer to facilitate and train farmers base on protocol.

- Preparing weekly and monthly reports on activities progress.
- Demonstration to farmers on proper use and application of inputs.

4.2.1.4 Water Users' Association

Established on the Akumadan scheme is a farmer co-operative association, in other words Water Users' Association (WUA). The WUA led by the executives are grouped into various committees to ensure effective and efficient execution of tasks.

These grouping comprises:

- Agricultural Committee
- Disciplinary Committee
- Irrigation Operation and Maintenance Team
- Finance and Marketting Team

However, it was revealed that the chairperson of the association functioned across the groups.

4.2.2 Management of the Kaniago Irrigation Scheme

Kaniago scheme unlike other schemes in the transition agro-ecological zone is solely managed by a Water User Association. Thus, the direct management and day to day operations of the scheme rests on the Water User Association of the scheme. The Water User Association is known as the Kaniago Irrigation and Farmers Association. The structure of the WUA include; Chairperson, Secretary, Treasurer, Organiser and rest of the farmers. There exist in the scheme no water bailiff. Some farmers voluntarily have assumed the responsibility of water bailiff on the scheme. At the time of research, the Kaniago Irrigation and Farmers' Association had 12 farmers registered as part of the association. The scheme is a surface irrigation system unlike Akumadan, Tanoso and Subinja schemes which are sprinkler irrigation systems.

The chairman of the WUA works in various capacities to ensure general operation and maintenance of the scheme. The chairman is responsible for:

- Exercising general supervisory role over the scheme.
- Chairing meetings organised by the farmer association.
- Opening reservoir gate for water flow through the canal unto the farmer's field
- Resolving conflict between the farmers.
- Farm gate price negotiations
- Pricing of irrigation services charge in consultation with other association executives and land owners

The secretary of the association exercises responsibility of :

- Taking notes during meetings
- Keeping relevant farm records

The treasurer of the WUA is also entrusted with:

- Collection and management of scheme service fees
- Keeping financial records of the association

The organiser is tasked with organizing meetings to discuss relevant issues of concern on the scheme.

The rest of farmers on the scheme co-operate with the executives of the WUA to ensure smooth operation and maintenance of the entire scheme.

4.2.3 Level of Manpower Utilisation on the Functioning Schemes

Manpower refers to the number of people working or available for work or service. A determining factor that impacts the performance of irrigation schemes is the level of manpower utilization. Manpower is responsible for management, operation and maintenance (MOM) of irrigation schemes. According to Carter *et al.* (1986), no specific staffing levels has generally been approved for operation and maintenance of irrigation schemes in literature but the irrigable area could ideally be controlled by an irrigation staff in the range of 3.8 -75.7 ha.

The MOM staffing levels and unit irrigated area per manpower on the functioning irrigation schemes is presented in Table 4.3.

Table 4.3: Level of Manpower Utilization on the Functioning Irrigation Schemes

Scheme	Manpower (No. of Staff) *	Average Irrigated Area (ha) (2018 – 2022) *	Average Unit Irrigated Area Per MOM Manpower (ha/staff) **
Akumadan	3	45	15
Kaniago	4 (WUAE, NFT)	24	6

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

Source: * - Management Records, ** - Desk Calculation, (2022)

As presented in Table 4.5, the average unit irrigated area (ha) managed by an irrigation staff at Akumadan (15 ha/staff) and Kaniago (6 ha/staff) indicate that the level of manpower utilization on the schemes are at acceptable levels since they are within the ideal manpower range of 3.8 -75.7 ha/staff as reported by Carter *et al.* (1986). This shows that Akumadan and Kaniago schemes were not understaffed or overstaffed. Understaffing could affect efficient and effective monitoring of fields which could result in low performance (Adongo *et al.*, 2015). Overstaffing could lead to excess manpower at increased management and operation cost with no positive impact on productivity. In other study, Adongo *et al*. (2015) recorded understaffed manpower values of 96.6 ha/staff in Tono scheme and 142.4 ha/staff in Bontanga scheme, all in the Savanna agro-ecological zone of Ghana. 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. Kaniago scheme is known to have high irrigated area per manpower ratio because the scheme is managed by WUA executives (not full-time staff). Thus, farmers at Kaniago have full managerial control over the scheme.

4.2.4 Farmers Participation in the Management of the Irrigation Schemes

Existing in the functioning irrigation schemes were water user associations that are integral in the management, operation and maintenance of the schemes. These WUA's serve as communication conduit between farmers and the irrigation management staff. The WUA at Akumadan was known as "Akumadan Irrigation Farmers' Association" whereas at Kaniago it was called "Kaniago Irrigation Farmers' Association". However, during the time of research the WUA at Akumadan had been disbanded and awaiting re-organization whiles the Kaniago Irrigation Farmers' Association had 12 registered members.

The roles of the WUAs on the schemes include:

- Removal of weeds around canals and hydrants
- Removal of sediments and debris from canals, laterals and drains
- Assisting in plots allocation and collection of irrigation service charges
- Water distribution to farmer plots
- Minor repairs/maintenance of structures in the irrigation scheme
- Farm gate price negotiations,
- Formulation and enforcement of bye-laws
- Settlement of disputes amongst farmers
- Keeping farm records
- Seeking external funding sources for farmers

4.3 Social and Economic Profile of the Study Area

Farmers' use of technology , how they adapt to it, and their preferred management style are all influenced by their social and economic backgrounds. It comprises quantitative indicators such as; gender distribution of farmers, level of education, age distribution and income levels of farmers.

A survey on the schemes revealed that land-use was extended to non-indigens of surrounding communities and townships of the schemes. Majority of farmers at Kaniago and Akumadan had alternative livelihood source. The farmers were engaged in various other occupations such as petty trade, teaching, carpentry, masonry and driving of commercial vehicles. This enabled farmers to avert risks associated with production such as disease outbreak, low crop yield and low funding which eventually could lead to low farmer income.

4.3.1 Gender Distribution of Farmers

The gender distribution of farmers on the functioning irrigation schemes is presented in Figure 4.2.

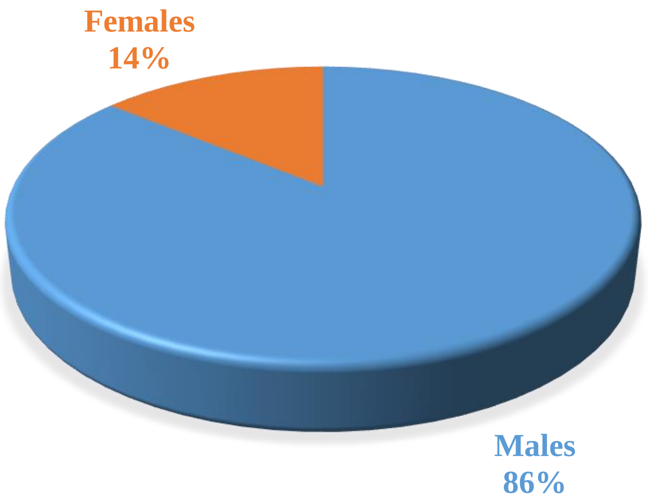


Figure 4.2: Percent Gender Distribution of Plot Holders on the Irrigation Schemes

The chart above shows high percentage of male representation on the irrigation schemes. Males constituted eighty-six percent (86 %) of the farmer population whiles females constituted fourteen percent (14 %). Information gathered on the schemes especially the pumped schemes indicated that the huge gender gap was due to the hectic nature of work on the schemes, such as the movement of sprinklers and laterals from one irrigable area to the other. Thus the women could not conform to the stressy nature of work on the schemes. The majority of females present on the schemes worked as supportive labour either for their husbands or as hired. This situation could negatively impact food production and food security because studies have shown that female farmers having equal access to resources as male farmers tend to be more productive than the male farmers. According to Saito (1994), the average gross value of output per ha from female-managed irrigated plots in Kenya was usually 22 % higher than male-managed plots with the same resources. FAO (2007) reported that in most developing countries, rural women are the centrepiece of small-scale agriculture, farm labour, and day-to-day family subsistence, so as to ameliorate rural poverty and ensure food security. Thus women's active involvement in irrigated agriculture should be encouraged.

4.3.2 Age Distribution of Farmers on the Functioning Irrigation Schemes

Presented in Table 4.4 is the percent age distribution of the farmers in the irrigation schemes. From the table, it was realised that about eighty percent (80 %) of farmers at Akumadan and Kaniago were within the economically active working age group (21 – 60 years). It was identified that majority of the farmers at Akumadan belonged to the youthful age group (21 – 50 years). Active youth involvement in irrigated agriculture has the potential to increase food production and enhance food security especially in the transition agro-ecological zone and Ghana at large. The youth in Kaniago community and at large Techiman municipality should be encouraged and empowered to ensure increased youthful engagement in irrigated agriculture within the transition agro-ecological zone. The increased working age group across the schemes indicates clearly that with provision of enough irrigation facilities in the transition agro-ecological zone, agriculture production would be enhanced.

Table 4.4: Age Distribution of Farmers on the Irrigation Schemes (%)

Age Group (years)	Akumadan	Kaniago
21 - 30	28	-
31 - 40	44	19
41 - 50	16	31
51 - 60	4	38
> 60	8	12

Source: Akumadan and Kaniago Management Records, (2021/22)

4.3.3 Educational Level of Farmers

The educational level of farmers from the functioning schemes showed high level of illiteracy, especially at Kaniago where 56 % of the farmers had no form of formal education. Similarly, results from Akumadan showed that about half of the respondents had had access to basic education.

Generally, the level of farmer literacy on the Akumadan scheme was appreciable compared to the Kaniago scheme. The Figure 4.3 shows the percent distribution of the educational level of farmers on the functioning schemes in the transition agro-ecological zone.

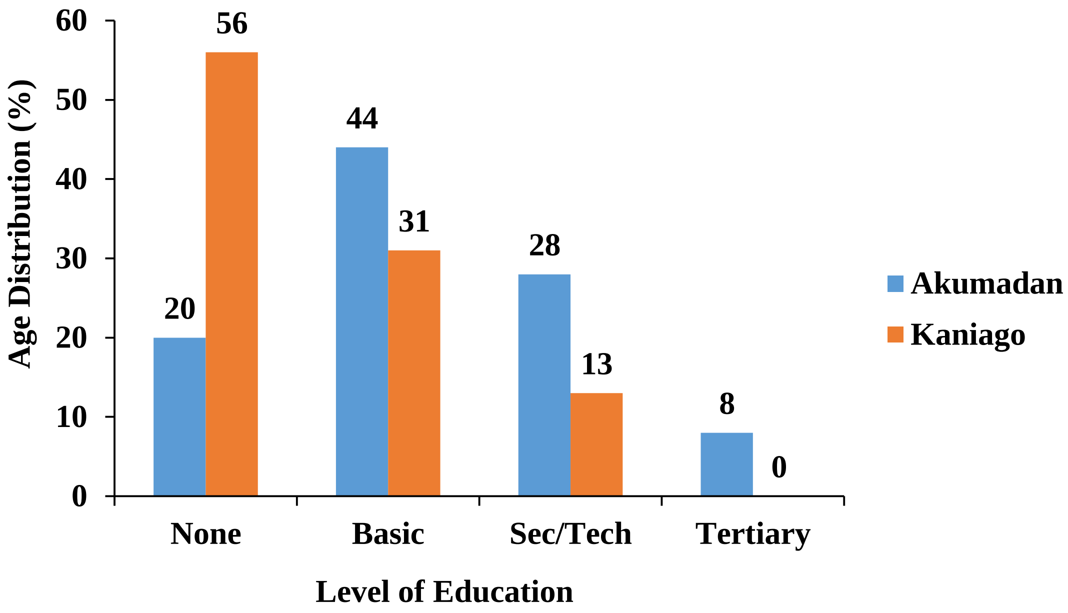


Figure 4.3: Educational Level of Farmers in the Functioning Irrigation Schemes

The high level of farmer illiteracy on the schemes impacts negatively agricultural production as some farmers become reluctant in usage of modern agricultural techniques. Majority of illiterate farmers cannot access credit to finance their farming activities. Also, the low level of education on the schemes was the cause of poor record keeping on cropping activities and lack of knowledge on the need to test the soil before and after the cropping season so as to ascertain the fertility levels of the soil.

Appleton and Balihuta (1996) stressed that, formal education could 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 estimate correct dosage of inputs (fertilizers, weedicides, pesticides) to attain desirable yields.

4.3.4 Land Allocation and Landholdings in the Irrigation Schemes

Land Allocation: At Akumadan, land allocation was done by the WUA executives and superintended by the Scheme Manager and Irrigation Engineer of the scheme. Also irrigation service charges were collected by block leaders who subsequently hand payments over to the manager of the scheme. Unlike other irrigation schemes in the transition zone, lands were reserved by management at Akumadan for research purposes and greenhouse agriculture.

At Kaniago scheme, the WUA executives were solely responsible for land allocations and collection of the irrigation service charges. The reason being that the scheme was fully farmer managed.

Landholdings: Table 4.5 presents various farmer landholdings in the functioning irrigation schemes.

Table 4.5: Percentage Distribution of Landholding on the Functioning Schemes

Scheme	< 0.1 ha	0.1 ha	0.2 ha	0.4 ha	0.6 ha	0.8 ha	1 ha	> 1 ha
Akumadan	-	12	28	32	-	20	8	-
Kaniago	-	-	19	37	-	31	-	13

Source: Akumadan and Subinja Records (2021/22)

As presented in Table 4.5, the major landhold size at both Akumadan and Kaniago was 0.4 ha (1 acre). Since pumped (sprinkler) irrigation systems are characterised by huge irrigation service charges many farmers on the Akumadan scheme were limited to landhold sizes less than 0.8 ha, thus only a few farmers could afford plot size of 0.8 ha (2 acres) or more.

At Kaniago, a surface irrigation scheme, some farmers cropped landhold sizes above 1 hectare. This was because the cost of operation on the scheme was low resulting in low or moderate irrigation service charges, hence boosting farmers capacity to cultivate large landhold sizes.

4.3.5 Labour Sources on the Functioning Irrigation Schemes

Labour is an important contributing and sustaining factor to the growth and development of irrigated agriculture. From several farmer interviews, it was deduced that the chief source of labour on the irrigation schemes was family labour. The majority of the farmers utilised family labour in their daily farming activities and only used hired labour as a supplement to family labour for intensive tasks such as weeding and harvesting. Many farmers asserted that the major constraint with hired labour was the high labour fee charges.

4.4 Comparative Performance Indicators of Irrigation Schemes

4.4.1 Water Delivery Performance

The water delivery performance of the irrigation schemes was evaluated using the following sub-indicators.

4.4.1.1 Extent of Main Canal/Pipe Flow

Adongo *et al.* (2015) indicated that, the measurement of this parameter reveals the practical constraints of irrigation systems in terms of providing water when necessary. It gets more difficult for canal water to flow to some locations, especially the downstream ends, as existing irrigation systems deteriorate. This index reflects the degree to which some areas of the developed irrigable land have placed restrictions on canal or pipe flow. The extent of main canal/pipe flow lengths of the schemes are presented in Table 4.6.

Table 4.6: Extent of Main Canal/Pipe Flow Length of the Schemes

Scheme	Total length of main canal/pipe constructed within the scheme (km) *	Actual total length of main canal/pipe sections still flowing (km) *	Extent of main canal/pipe flow length (%) **
Akumadan	1.6	1.6	100
kaniago	2.2	1.4	64

Source: * - Scheme Survey and Project Records, (2022); ** - Desk Calculation, (2022)

Akumadan irrigation scheme is a sprinkler system powered by electric pump engines. Existing in the scheme is a main pipe which conveys water from the reservoir by pumping unto the cropped field. The main pipe was a high quality and performance HDPE pipe (PE 100) that secured water flow in the scheme. Thus, the scheme recorded 100 % maximum flow length.

This means that water flowed through the entire length of the main pipeline in the scheme without any obstructions.

The main canal at Kaniago was in good condition with no damaged walls and leakages. However due to very low velocity flow at the downstream of the canal, the flow length was reduced by 36 %, equating to 0.8 km of the total canal length (2.2 km). The low gravity flow especially in the downstream of the cultivable area together with certain agronomic challenges in the scheme led to a decline of farmers interest in irrigated agriculture over the years hence a reduction in the cultivable area of the scheme. Ijir (1994) indicated that, the notional normal value for extent of main canals flow length was 100 %. However, the author reported that 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

Akumadan Irrigation Scheme: Lacking in the scheme was a flow meter to monitor quantities of water supply per season in the irrigable area. For this reason, the design discharges of the pumps were used to estimate the quantity of water supply per season on the irrigation scheme.

Pump discharge = 3 m^3/min, and two pumps operate simultaneously during irrigation.

Pump operating time per day = 9 *hours*

Thus, total pump discharge in a day = 3 $m^3 \times 60\ min \times 9\ hrs = 1620\ m^3/day$.

Irrigation frequency = 4 *days/wk*

Hence, total pump discharge per week = 1620 × 4 = 6480 m^3/wk

Thus; 6,480 m^3 × 4 = **25920 m^3** of water supply per month

Since active irrigation season begins from January to March (3 months)

Pump discharge per season = 25920 m^3 × 3 = **77760 m^3**

Since two pumps were operated simultaneously during irrigation, the total pump discharge per season = 77760 m^3 + 77760 m^3 = **155520 m^3**

Hence; volume of water supply per hectare per season = 155520 m^3 ÷ 45 *ha*

= 3456 m^3/ ha /season

According to Altinbilek (1997), total irrigation in an intensive vegetable enterprise requires about 8000 m^3 of water per annum for each hectare worked. However, this quantity will be lower in cool, moist areas, especially under sprinkler and drip irrigation, and appreciably higher in hot, dry areas where less efficient flood irrigation is practiced. Thus, water supply quantity of 3456 m^3/ha under overhead irrigation was acceptable especially for a three (3) month irrigation period. This could have impacted positively vegetable crop yields on the scheme.

Kaniago Irrigation Scheme: The flow rate and cross-sectional area of the main canal were employed to estimate total water delivery per hectare per season in the scheme.

Thus:

Canal mean flow velocity = $0.8 \times \left(\frac{10\ m}{29\ s}\right) = 0.276\ m/s$

The scheme consisted of a rectangular canal system with dimensions as follows:

width = 1.0 m, depth = 0.55 m, flow depth = 0.16 m

Hence; canal flow area = *flow width* × *depth of flow*

= 1.0 *m* × 0.16 *m* = 0.16 m^2

canal discharge = 0.276 *m/s* × 0.16 m^2 = 0.044 m^3/s = 2.64 m^3/min

Total irrigation time per day = 10 *hours*

Thus, discharge through main canal per day = 2.64 m^3/min × 60 min × 10 hrs = **1584 m^3/day**.

Irrigation frequency = 4 *days/wk*

Hence, total discharge per week = 1584 m^3 × 4 = **6336 m^3/wk**

Discharge per month = 6336 m^3 × 4 = 25344 $m^3/month$

Therefore;

Irrigation discharge from reservoir through main canal per season;

= 25344 m^3 × 3 = 76032 m^3

Hence; volume of water supply per hectare per season = 76032 m^3 ÷ 24ha

= **3168 $m^3/ha/season$**

The discharge of 3168 m^3 per season was considerable for vegetable crops raised on a hectare of land. However, it was realised that gravity flow in the main canal was very low at the tail end of the canal. This phenomenon could be attributed to the uneven canal slope in the scheme that restricted water supply to the downstream portions of the scheme. The inadequate water supply at the downstream could result in unhealthy growth and development of vegetable crops accompanied with low yieid. Masarirambi *et al.* (2011) indicated that, for leafy vegetables like cabbage, under-watering could cause burst heads.

4.4.2 Physical Structures Performance

The performance of the physical structures is related to changes and the potential loss of irrigated land in the command area due to worn-out conveyance, regulatory, distribution, and energy utilization structures within the irrigation schemes. The physical performance of the irrigation schemes was evaluated using indicators such as irrigation rate, sustainability of irrigated area, poor structure index, and efficiency of road network passability. The assessment was referenced to the past five years (2018 - 2022).

4.4.2.1 Irrigation Rate

Irrigation rate is the percentage of the total developed irrigable area that is actually irrigated in an irrigation season. This indicator is also known as irrigable land utilization efficiency. Presented in Table 4.7 are figures of irrigation rate for the various schemes.

Table 4.7: Irrigation Rates

Indicator	Actual Irrigated Area (ha) *					DIA	Irrigation Rate (%)**				
Year	2018	2019	2020	2021	2022	(ha)	2018	2019	2020	2021	2022
Akumadan	60	55	41	-	25	166	36	33	25	-	15
Kaniago	32	34	26	19	11	60	53	57	43	32	18

DIA - Developed Irrigable Area*

Source: * - Project Management Records, (2022) and ** - Desk Calculation, (2022)

Akumadan Irrigation Scheme: The irrigation rates for the scheme averaged as low as 22 % from the year period of 2018 – 2022. This suggests that only 22 % of the total developed irrigable area was put to cultivation in the scheme. These low rates recorded were attributed to inadequate laterals and sprinklers which made it difficult to efficiently utilize the developed irrigable area of the scheme. According to the scheme manager, no crops were raised on the scheme in the year 2021 due to the drying of the dam. Thus, irrigation rate of 22 % was low compared to the notional normal value for irrigation rate (90 – 100 %) as given by Ijir (1994).

Kaniago Irrigation Scheme: The irrigation rates for the scheme from 2018 – 2022 ranged from 18 – 57 % with the lowest rate recorded in the year 2022. The low rate recordings in recent years on the scheme was ascribed to the gradual subsidence of farmers interest in irrigated agriculture due to:

- Low market prices for the farm produce especially for the years 2018 and 2019.
- Yield losses due to agronomic challenges on the scheme.

- Low gravity flow in the main canal which impeded water conveyance to the downstream of the irrigable area.

4.4.2.2 Sustainability of Irrigated Area Index (SIAI)

Sustainability of irrigated area index describes the ratio of current irrigated area to the initial irrigated area when the scheme was first fully developed. Table 4.8 presents the sustainability of irrigated area indices (SIAI) for the schemes.

Table 4.8: Sustainability of Irrigated Area Index

Scheme	Irrigated Area (ha) in 2022 *	Initial Irrigated Area (ha) After Scheme Completion *	SIAI (%)**
Akumadan	25	80	31
Kaniago	11	40	28

Source: * - Project Management Records, (2022) and ** - Desk Calculation, (2022)

Akumadan recorded SIAI of 31 % which outlies the sustainability range of 90 – 100 % as indicated by Ijir (1994). The reduction in the irrigable area of the scheme over the years was as a result of the following factors:

- Inadequate surface materials (laterals and sprinklers) caused by faults, and materials having outlived their usefulness on the scheme
- Inadequate labour on the scheme to ensure efficient and effective operation.
- Market losses, leading to a decline in farmers interest in irrigated agriculture.
- Lack of credit facilities to boost production on the scheme.

Similarly a low SIAI of 28 % was recorded for the Kaniago scheme. This was as a result of the subsidence of farmers interest in irrigated agriculture due to yield and market losses observed over the years in the scheme. Moreover, the low gravity flow observed especially at the tail end of the canal impeded cultivation in the downstream of the irrigable area of the scheme. The irrigated area continued to decrease hence a low recorded SIAI on the scheme.

Sener *et al.* (2007) reported a suitable average sustainable irrigated area index 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 unit number of conveyance, regulatory, flow measurement and energy utilization structures installed in the irrigation scheme that are in a poor state (defunct, not properly functioning or at the verge of failure, and not meeting design standards). The poor structure indices of the schemes are presented in Table 4.9.

Table 4.9: Poor Structure Index of the Irrigation Schemes

Scheme	No. of Unit Structures				Total No. of Unit Structures*	Unit No. in Good Condition *	Unit No. in Poor Condition *	Poor Structure Index (%)**
	C	R	Fm	Eu				
Akumadan	3	4	0	4	11	8	3	27
Kaniago	1	5	1	0	7	6	1	14

Where: C - Conveyance, R – Regulatory, Fm - Flow measurement, Eu – Energy utilization

Source: *- Management Records and Scheme Survey, (2022); ** - Desk Calculation, (2022)

Akumadan Irrigation Scheme: The Table 4.9 shows PSI of 27 % recorded on the scheme. This means that 73% of the conveyance, regulatory, flow measurement and energy utilization structures were in good working condition. A survey on the scheme revealed the poor physical condition of many sprinklers and hydrants. Moreover, laterals with unfit couplings made connections difficult on the scheme.

Kaniago Irrigation Scheme: The scheme recorded a low PSI of 14 %. As such, 86 % of structures on the scheme were in good working condition. The canal, canal valves, gate structures, weir and flume remained good in operating condition except for the faulty and nearing fault hydrants on the scheme. In all, the condition of structures on the scheme was commendable. 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.

4.4.2.4 Efficiency of Roads Passability

The efficiency of roads passability refers to the percentage of the total length of roads constructed in the scheme which has all year round accessibility. Efficient road network is important to enhance: accessibility to plots, inspection and maintenance works within the scheme and transportation of farm inputs and produce. Roads around and within irrigation schemes should remain passable and accessible all year round so as to serve management and farmers needs. Some roads however are not motorable due to the damaged nature and is caused either by natural or man-made incidents. A major natural incident that affects the efficiency of road passability is erosion. Table 4.10 presents figures of assessment of the current condition of roads on the irrigation schemes.

Table 4.10: Roads Passability in the Irrigation Schemes

Scheme	Actual length of roads which has all year round accessibilty (km) *	Total length of roads within the scheme (km) *	Efficiency of road passability (%)**
Akumadan	5.6	5.6	100
Kaniago	0	0	0

Source: * - Project Records and Scheme Survey, (2022); ** - Desk Calculation, (2022)

Kaniago Irrigation Scheme: There were no constructed roads in the scheme hence no recorded figure on efficiency of road passability. This means farmers accessibility on the scheme was cumbersome making transport of farm produce and inputs difficult in the scheme. Inspection and maintenance works were impeded to some extent.

Akumadan Irrigation Scheme: Recorded at Akumadan was a road network passability efficiency of 100 %. This implies that accessibility by farmers and management was enhanced ensuring easy transport of farm input and produce and improvement of inspection and maintenace works on the scheme. The roads within the Akumadan scheme were rehabilitated in the year 2016 when the President of the Republic of Ghana visited the scheme to commission the Akumadan Greenhouse village project. This gave a facelift to the entire road network in the scheme. According to Ijir (1994), the ideal efficiency of roads passability of an irrigation scheme is 100 %. Shown in Plate 4.1 is the current state of the road network within and around the Akumadan irrigation scheme.

Plate 4.1: The Nature of Road Network at Akumadan Scheme

4.4.3 Economic Performance

The economic performance of the irigation schemes was evaluated using indicators of efficiency of irrigation service charges recovery, scheme financial autonomy factor and financial self-sufficiency rate. The economics of irrigation scheme management comprises income generated by the scheme, funds expended on operation and maintenance activities in the scheme and funds retained by scheme management after expenditures.

4.4.3.1 Efficiency of Irrigation Service Charges Recovery

The efficiency of irrigation service charges recovery (EISCR) refers to the percentage of irrigation service charges retrieved of the total expected charge amount. This indicator assesses the willingness of water users in paying for water usage in the schemes. High efficiency of irrigation service charges recovery reflects management's ability to properly manage the irrigation facilities. Sener *et al.* (2007) reported that farmers consent to payment of irrigation service fees is chiefly influenced by their satisfaction with the quality of service provided in the irrigation scheme. The funds generated from irrigation service charges depend both on the charged amount and on the recovery rate (Ijir, 1994).

Table 4.11 presents the results of the efficiency of irrigation service charges recovery (EISCR) for the schemes.

Table 4.11: Efficiency of Irrigation Service Charges Recovery (%)

Indicator	Expected Total Annual Irrigation Service Charges (GH¢) – a *				
Year	2018	2019	2020	2021	2022
Akumadan	228,000	209,000	170,150	-	103,750
Kaniago	12,800	13,600	10,400	9,500	5,500
	Actual Total Annual Irrigation Service Charges (GH¢) – b *				
Year	2018	2019	2020	2021	2022
Akumadan	193,100	184,324	136,595	-	85,450
Kaniago	7,550	6,820	3,500	3,050	1,350
	Efficiency of Irrigation Service Charges Recovery (%) – $(b/a) \times 100$ % **				
Year	2018	2019	2020	2021	2022
Akumadan	85	88	80	-	82
Kaniago	59	50	34	32	25

Source: * – Management Records, (2022) and ** – Desk Calculation, (2022)

Irrigation Service Charges (ISC): The irrigation service charges for the past five (5) years had ranged from GH¢ 3,800 - GH¢ 4,150 at Akumadan and GH¢ 400 - GH¢ 500 at Kaniago for a hectare of land cultivated per season. The ISC for the Akumadan scheme was high since the scheme utilised energy during operations.

Akumadan Irrigation Scheme: The EISCR for the Akumadan scheme spanning the years 2018 – 2022 was 84 % on average. The seemingly high recovery rate obtained on the scheme was attributed to management's effectiveness in collection of irrigation service fees since operation and management of pumped schemes comes with enormous energy usage cost. Hence, electricity is pre-requisite for the operation of pumped irrigation schemes. According to Ijir (1994), the notional value for irrigation service charges recovery is between 90 – 100 % of the expected total irrigation service charges for the season or year. Therefore recorded at the Akumadan scheme was an unsatisfactory EISCR value. Yercan *et al.* (2004) recorded satisfactory recovery rates of 90 – 98 % for eight irrigation schemes in Gediz River Basin in Western Turkey.

Kaniago Irrigation Scheme: Recorded on the scheme was an average EISCR value of 40 % during the period of 2018 - 2022. The reason for this low figure was because majority of the farm plots in the scheme were family lands and were mostly cultivated by members of those families. Therefore, plot holders did not realise the obligatory sense in paying their irrigation service fees. The willingness of farmers to payment of irrigation service fees was as a result of the quality of services rendered in a particular scheme.

4.4.3.2 Scheme Financial Autonomy Factor (SFAF)

This indicator addresses the portion of the collected irrigation service charges retained by scheme management to the portion passed to Central Government (GoG). According to Adongo *et al.* (2015), the amount of revenue retained by irrigation scheme management shows the degree of the scheme's financial control of internally generated funds rather than over-reliance on Central Government for financial assistance.

According to the manager of the Akumadan scheme, 6 % of the total generated revenue in the scheme was retained for management and overheads whiles 24 % of the revenue was passed to the Central Governement (GoG). This clearly indicates the meagre portion of the total generated revenue retained by management at Akumadan. Therefore, the low SFAF which is characteristic of GIDA managed schemes shows less financial control of internally generated funds, hence rendering GIDA managed schemes financially less autonomous. 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 fees should be retained by the managing agency.

Kaniago being farmer managed irrigation scheme recorded a high degree of SFAF since all collected irrigation service fees were retained by the scheme.

4.4.3.3 Financial Self-Sufficiency Rate (FSSR)

This indicator measures the ability of the irrigation scheme to independently sustain its finances with regards to regular management, operation and maintenance disbursements. The FSSR of the schemes was computed based on the annual income from water charges and other revenue sources (land rent and consultancy) and the total annual management, operation and maintenance expenditures of the scheme. MOM costs do not include major maintenance and rehabilitation works in the schemes.

Management, Operation and Maintenance Costs: The MOM costs incurred by the Akumadan scheme constituted 76 % of the total revenue generated in the scheme. Thus, 70 % of the total revenue was expended on electricity annually whilst the remainder 6 % was disbursed on management activities and overheads.

Akumadan Scheme: The total annual scheme income from water charges and diverse revenue sources recorded on the scheme between the years of 2018 – 2022 ranged from GH¢ 85,450 - GH¢ 193,100 against an annual MOM cost range of GH¢ 64,942 - GH¢ 146,756 within the same period. It was realised that majority of the MOM costs were energy cost that emanated from daily operation of the scheme. An average FSSR of 132 % was recorded in the scheme.

The FSSR was high and acceptable compared to the ideal FSSR value of 100 % or more (> or = 100 %) as reported by Ijir (1994).

Kaniago Scheme: At Kaniago, none of the generated revenue was expended on MOM activities in the scheme. The scheme had no other revenue sources apart from the water-user fees. Albeit no other revenue sources apart from the water-user fees, the scheme was independently capable of sustaining its finances since it did not incur any management, operation and maintenance cost for the past five years. Thus, farmers assumed various roles to help manage, operate and maintain the scheme. 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.

4.4.4 Environmental Performance

The percentage of the developed irrigable land not impacted or lost as a result of adverse environmental conditions like salinity, erosion, and waterlogging due to the influence of irrigation is referred to as environmental performance. In order to assess how well the projects performed environmentally, the environmental stability index was used.

4.4.4.1 Environmental Stability Index

With reference to salinity, sodicity, erosion, and waterlogging as a result of irrigation's negative effects on the environment, this index was used to evaluate the stability of the developed irrigable areas of the schemes. Measurable soil salinity and sodicity levels helped in determining the environmental stability index. Table 4.12 presents the environmental stability indices of the schemes.

Table 4.12: Environmental Stability Indices of the Functioning Irrigation Schemes (%)

Scheme	Total Developed Area (ha)*	Total Developed Area Affected (ha)*	Type of Environmental Problem in the Scheme*	Total Developed Area Unaffected (ha)*	Environmental Stability Index (%) **
Akumadan	166	0	-	166	100
Kaniago	60	0	-	60	100

Source: * – Scheme Survey and Interview, (2022) ; ** – Desk Calculation, (2022)

The Table 4.12 shows 100 % environmental stability indices recorded for both Akumadan and Kaniago. This means that both schemes were environmentally stable and free from problems of salinity, sodicity, erosion and waterlogging. The environmental stability index of 100 % showed how resilient the irrigable areas of the schemes were regarding environmental threats of salinity and sodicity, erosion and waterlogging.

4.4.4.2 Soil pH in the Irrigable Area of the Irrigation Schemes

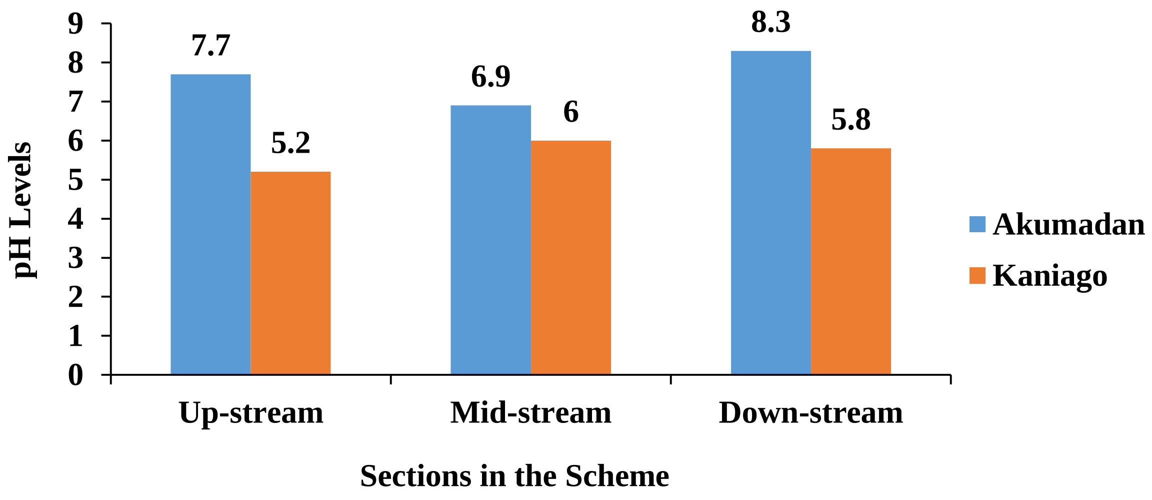


Figure 4.4: Soil pH Levels of Irrigable Areas

The Figure 4.4, shows varying soil pH levels at various sections in the irrigable area of the schemes. The Kaniago scheme recorded average soil pH of 5.7 depicting moderately acidic soils. Soils from Akumadan scheme recorded average pH value of 7.6 indicating slightly alkaline soils in the irrigable area of the scheme The T-test analysis performed on pH of soils in the upstream, midstream and downstream of the irrigable area of the schemes gave P-value of 0.010697 (< 0.05), hence pH for soils at different sections on the schemes were statistically significant. The slightly alkaline nature of the Akumadan scheme soils could be attributed to naturally occuring sodium carbonate (Na_2CO_3) and sodium bicarbonate ($NaHCO_3$) released upon weathering. The presence of moderately acidic soils at Kaniago could be due to: i) rainwater leaching away basic ions of calcium (Ca^{2+}), magnessium (Mg^{2+}), potassium (K^+) and sodium (Na^+); ii) Carbon dioxide (CO_2) from decomposing organic matter and root respiration dissolving in soil water to form a weak organic acid; iii) formation of strong organic and inorganic acids, such as nitric (HNO_3) and sulfuric acid (H_2SO_4) from decaying organic matter and oxidation of ammonium and sulfur fertilizers. Lime is usually added to acidic soils to increase soil pH.

According to USDA (1998), a pH range of 6.0 – 7.0 is ideal for the survival of most crops. However, Liu and Hanlon (2012) reported that a pH range from 5.5 - 7.0 is suitable for most vegetable crops. At soil pH of 8.0 or higher, iron and/or manganese bioavailability cannot satisfy most vegetable crops' requirements. Meanwhile, 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). 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 Akumadan (pH 7.6) and Kaniago (pH 5.7) could potentially decrease microbial activity.

4.4.4.3 Soil Salinity in the Irrigable Area of the Irrigation Schemes

The measured values of electrical conductivity (EC) describes the salinity levels in soils collected from the upstream, midstream and downstream of the irrigable area of the schemes. The Figure 4.5 shows measured values of electrical conductivity (EC) recorded on the schemes.

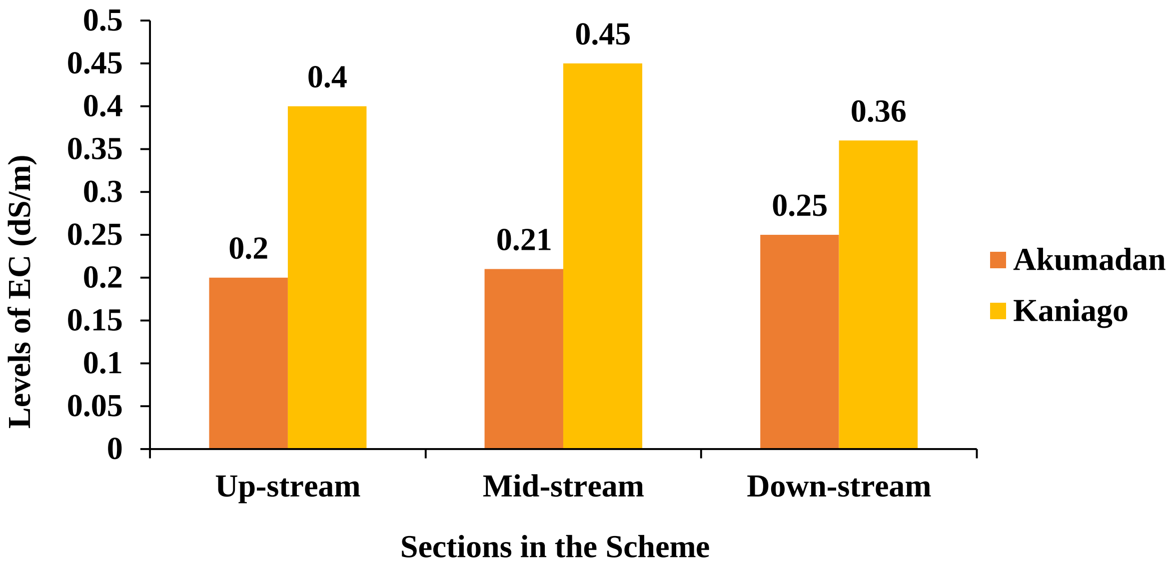


Figure 4.5: Salinity Levels in Soils of the Irrigable areas of the Schemes

The EC values as shown in Figure 4.6 shows permissible levels of EC in the irrigable areas of the schemes. The T-test analysis performed on salinity levels in soils across various streams of the irrigable areas gave P-value of 0.0036 (< 0.05), meaning soil salinity differences among the various sections in the irrigable area of the schemes was statistically highly significant. Hanson and May (2004) stressed that, the allowable EC level in soil of an irrigable area should be equal to or less than 2.5 dS/m (= or < 2.5 dS/m). High soil salinity levels could inhibit plant growth and development by restricting nitrogen uptake from the soil. Horneck *et al.* (2007) reported that salinity in soil can originate from soil parent material; from irrigation water and from fertilizers or other soil amendments. Ijir (1994) reported that the high soil salinity levels in the Wurno scheme were caused by waterlogging due to poor water control and drainage system. According to Horneck *et al.* (2007) and Senon *et al.* (2012), 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 Level in Soils of the Irrigable Areas of the Schemes

The Exchangeable Sodium Percentage (ESP) indicator was used to determine the sodicity levels in soils found in the irrigable areas of the schemes. The measured ESP values are presented in Figure 4.6.

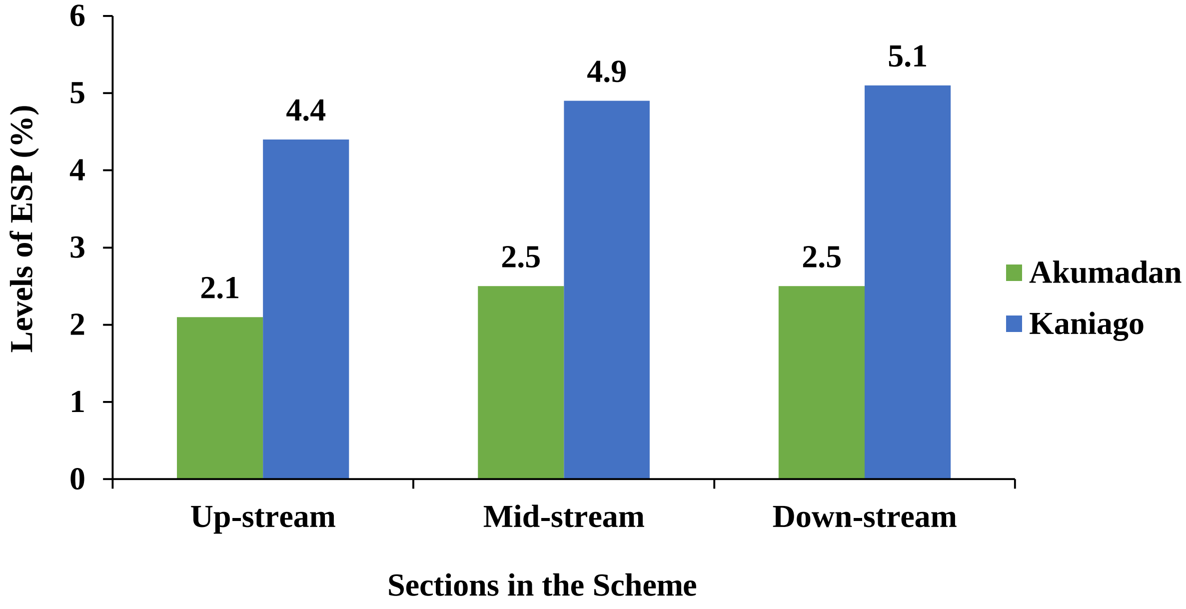


Figure 4.6 : Level of Sodicity in the Soils of the Irrigation Schemes

The average ESP values recorded at Akumadan (2.4 %) and Kaniago (4.8 %) showed differences in proportions of sodium in soils of the irrigable areas of the schemes. The P-value of 0.00641 (< 0.05) from T-test analysis shows a significant difference in sodium levels across the streams of both schemes. It was realised that the ESP of soils within the irrigable areas of the schemes were at acceptable levels that do not interfere with vegetable crop growth and development. As indicated by USDA Natural Resources Conservation Service (2003), soils with ESP less than 15 % are normal soils whereas soils with ESP greater than 15 % are sodic soils. Per the results obtained, it can be ascertained that ESP and EC concentrations in all the studied schemes were low; hence the soils were free of salt-related problems (salinity and sodicity).

According to Senon *et al.* (2012), sodic soils tend to have poor structure (dispersion of soil particles) with physical properties such as poor water infiltration and air exchange, which can reduce plant growth. Warrence *et al.* (2003) stated the principal effects of soil sodicity as reduced infiltration, reduced hydraulic conductivity, surface crusting and reduced crop yield.

4.4.4.5 Soil Texture in the Irrigable Area of the Schemes

Soil texture relates to the relative proportions of sand, silt and clay particles in the soil. Soil texture has the tendency to determine how much water will be able to pass through the soil, how much water the soil can store, and the ability of sodium to bind to the soil. The textural classes of soils present in the various irrigation schemes are shown in Table 4.13.

Table 4.13: Textural Classes of Soils in the Irrigable Areas of the Schemes

Scheme	Location in Field	Textural Classes	Average Textural Class
Akumadan	US	Sandy Clay Loam	Sandy Clay Loam
	MS	Sandy Clay Loam	
	DS	Sandy Loam	
Kaniago	US	Sandy Loam	Silt Loam
	MS	Silt Loam	
	DS	Silt Loam	

US - Up Stream; MS - Mid Stream; DS - Down Stream

Source: - Scheme Survey and Laboratory Analysis (2021)

From Table 4.15; the predominant soil textural classes recorded at Akumadan and Kaniago were sandy clay loam and silt loam respectively. FAO (1990) indicated that, the basic infiltration rate for sandy loam, sandy clay loam and silt loam are within ranges of 20-30, 15-20 and 10-15 mm/hour respectively. Sandy loam soils can hold significant amount of water and nutrients for plants growth. Sandy loams are well aerated which enhances vegetable crop growth and development. Crops cultivated in sandy loam soils require frequent irrigation than that of sandy clay loam because of the high infiltration rate of sandy loam soils. Silt loam soils have moderate infiltration rate and aeration compared to sandy loam soils. Osei *et al.* (2014) indicated that a well-drained sandy loam soil is good for the cultivation of vegetables and significantly impacts yield and production in the irrigation schemes.

4.4.5 Production Performance

The average yield per crop in reference to the average irrigated area was used to assess the production performance of the irrigation schemes. A survey across the irrigation schemes revealed variations in the type of crop cultivation on the schemes. Due to lack of proper production records, evaluations were limited to the 2020/2021 irrigation seasons while referencing past production records as discussed in other published and unpublished researched materials about the schemes.

Akumadan Irrigation Scheme: According to management, cultivation on the scheme had for the past three years being limited to three crop types; tomato (*Solanum lycopersicum*), bell pepper (*Capsicum annuum*)and okra (*Abelmoschus esculentus*). Akumadan irrigation scheme was mainly noted for the cultivation of tomatoes. According to Odamtten *et al.* (2016), Tomatoes recorded a yield value of 10.4 t/ha as against the expected yield of 20 t/ha in the year 2013 at Akumadan. In the same year, 30.0 ha of the irrigable area was expected to be cultivated but the actual cultivated land area was 25.0 for tomatoes. Odamtten *et al.* (2016) further reported that, pepper had an actual yield of 9.5 t/ha in the year 2013. However, in the 2020 growing season, an average yield of 12 t/ha was recorded for tomato. Pepper and Okra also recorded yield values of 9 t/ha and 10.5 t/ha respectively. According to MoFA (2020), the average achievable yield for tomato, pepper and okra were 15 t/ha, 32 t/ha and 15 t/ha respectively. Shown in Table 4.14 are yield values recorded from the Akumadan scheme for years 2013 and 2020.

Table 4.14: Yield Values Recorded at the Akumadan Scheme for Years 2013 & 2020

Crop	Average Yield (t/ha) 2013	Average Yield (t/ha) 2020	Achievable Yield (t/ha)
Tomato	10.4	12	15
Pepper	9.5	9	32
Okra	-	10.5	15

Source: MoFA (2020) and Management Records (2020)

The yield values obtained in the scheme shows an increase using 2013 records as baseline. The yield values for the year 2020 showed an increase of 1.6 t/ha in tomato production and a decrease of 0.5 t/ha for pepper production. Comparing the recorded yield values to the expected yields, pepper showed a huge decline of about 23 tonnes in yield. Tomato recorded a yield value of 12 t/ha with a yield gap of 3 t/ha of the expected yield. Okra recorded a yield value of 10.5 t/ha with 4.5 t/ha yield gap of the expected yield. Studies however indicated a reduction in the irrigated area size over the years which had affected production performance on the scheme.

Kaniago Irrigation Scheme: The plot-holders in the scheme cultivated mainly cabbage (*Brassica oleracea var. capitata*), garden eggs (*Solanum melongena*) and maize (*Zea mays*). In the year 2021, yield values of 27.6 t/ha, 11.3 t/ha and 0.95 t/ha for cabbage, garden eggs and maize respectively. However, MoFA (2011) and MoFA (2020) reported achievable yields of 15 t/ha for garden eggs and 3.5 t/ha for maize. Thus, MoFA had no yield records on cabbage production. Nevertheless, the Farmdreams Guide (2021) cited an achievable yield value of 70 t/ha on cabbage production. Conclusively, yield values recorded in Kaniago were low as a result of poor agronomic practices coupled with poor water conveyance and distribution especially at the downstream of the scheme. These challenges led to the decrease in the cultivable area size of the scheme.

4.5 Catch Can Water Collection, Absolute Deviation, Distribution Uniformity and Uniformity Coefficient of the Sprinkler System in Akumadan

The Table 4.15 presents the results of measured volumes (ml) and depth (mm) of water collection by catch cans in the given experimental area.

Table 4.15: Collected Catch Can Volumes (mL), Depth (mm) and Absolute Deviation Results for the Upstream and Downstream Sections of the Akumadan Scheme

Upstream				**Downstream**			
Catch Can number	**Depth (mm)**	**Volume (ml)**	**X(z-m)**	**Catch Can number**	**Depth (mm)**	**Volume (ml)**	**X(z-m)**
1	46	160	3.8	1	55	190	5.3
2	45	155	2.8	2	52	180	2.3
3	38	130	4.2	3	52	180	2.3
4	30	105	12.2	**4**	**35**	**120**	**14.7**
5	29	100	13.2	5	43	150	6.7
6	43	150	0.8	6	45	155	4.7
7	49	170	6.8	7	55	190	5.3
8	48	165	5.8	8	54	185	4.3
9	48	165	5.8	**9**	**58**	**200**	**8.3**
10	46	160	3.8	10	54	185	4.3
11	42	145	0.2	11	51	175	1.3
12	**28**	**95**	**14.2**	12	41	140	8.7
13	30	105	12.2	13	39	135	10.7
14	33	115	9.2	14	49	170	0.7
15	41	140	1.2	15	52	180	2.3
16	45	155	2.8	16	55	190	5.3
17	**52**	**180**	**9.8**	17	56	195	6.3
18	49	170	6.8	18	51	175	1.3
19	48	165	5.8	19	51	175	1.3
20	43	150	0.8	20	46	160	3.7
21	29	100	13.2	21	42	145	7.7
22	39	135	3.2	22	49	170	0.7
23	49	170	6.8	23	55	190	5.3
24	48	165	5.8	24	54	185	4.3
25	**52**	**180**	**9.8**	25	49	170	0.7
26	43	150	0.8	26	52	180	2.3
27	46	160	3.8	27	49	155	0.7
28	35	120	7.2	28	43	150	6.7
29	32	110	10.2	29	43	150	6.7
30	48	165	5.8	30	51	175	1.3
31	45	155	2.8	31	55	190	5.3

32	51	175	8.8	32	54	185	4.3
Sum	**1350**	**4665**	**200.4**	**Sum**	**1590**	**5475**	**145.8**
Average	**42.2**	**145.8**		**Average**	**49.7**	**171.1**	

The results from Table 4.15 showed that all thirty-two (32) catch can arrangements for the uptream and downstream sections of the irrigable area received water from sprinklers A and B. After one hour (1hr) of irrigation, the catch cans for sprinkler A received an accumulated depth of 1350 mm of water with an average of 42.2 mm.The catch can collection volume for sprinkler A at the upstream ranged from 95 ml to 180 ml. The catch cans numbered 17 and 25 collected the highest volume (180 ml) of water representing 3.86 % of the total volume of water collected whilst catch can numbered 12 collected the least volume (95 ml) of water representing 2 % of the total volume of water. This indicates that water distribution was not uniform making some sections of the soil received more volume of water than the others. This may be due to the wind effects at that time of the field experiment. The pressure of water flow and the distance of throw of water could also affect the distribution uniformity of the sprinkler. Sometimes structural issues due to inconsistent and/or older equipment could as well lead to low distribution uniformity.

From sprinkler B (down-stream), an accumulated depth of 1590 mm and average depth of 49.7 mm were collected by the catch cans. The catch can numbered 9 received the highest volume (200 ml) of water while the catch can numbered 4 received the lowest volume (120 ml) of water. It was observed that the distribution of water on the soil by sprinkler B (down-stream) was more uniform than sprinkler A (up-stream). This occurrence could be due to the pressure differences at the sprinkler heads and the distance of conveyance of water to the field, as the water source was more closer to the sprinkler B (down- stream) than the sprinkler A (up-stream). The absolute deviation values (z-m) for the depth of water was used to calculate the uniformity coefficient (UC) , and the average of the lowest quartile of the catch cans, 8 out of the 32 cans were used to determine distribution uniformity (DU). The table 4.17 displays UC and DU results for sprinkler A (up-stream) and sprinkler B (down-stream).

Table 4.16: Values for DU, UC and Average Catch Depth for Sprinkler Area Coverage of 30m by 30m in the Akumadan Scheme

Experimental Area (30m × 30m)	Average Low-quarter (mm)	Average catch depth (mm)	Distribution Uniformity (DU) %	Uniformity Coefficient (UC) %
Sprinkler A (Up-stream)	30.8	42.2	73	85.2
Sprinkler B (Down-stream)	41.4	49.7	83.3	90.8

From Table 4.16, the average distribution uniformity (DU) of sprinkler A at the upstream was 73 % whiles sprinkler B recorded an average DU of 83.3 %. Makki *et al.* (2019) indicated that, an excellent performance impact-sprinkler should have DU of 80% or above. This indicates that the DU at the upstream was low. Wigginton and Raine (2001) reported that, the decrease in DU value was as a result of changes in the uniform application of water within an irrigated area. As stated earlier, wind effects in the field, pressure differences and structural defects due to older equipment might have affected the DU of a system.

For the uniformity coefficient (UC), sprinklers A and B had estimated values of 85.2 % and 90.8 % respectively. ASAE Standard EP458 (1996) classified uniformity of a sprinkler irrigation system as unacceptable, poor, fair, very good and excellent if the UC value is less than 60 %, from 60 % to 70 %, 70 % to 80 %, 80 % to 90 % and 90 % or greater respectively. This means that the UC value of sprinkler A at the upstream was very good whiles the value from sprinkler B at the downstream was excellent.

4.6 Flow Velocity, Depth of flow and Discharge Measurements in the Main Canal at Kaniago

Presented in Table 4.17 are measured values of velocity of flow (m/s), depth of canal flow (m), canal discharge (m^3/s) of the main canal in Kaniago. These values helped to determine the efficiency of water conveyance through the canal system of the scheme.

Table 4.17: Measured Values of Flow Velocity (m/s), Depth of Flow (m) and Discharge (m^3/s) of the Main Canal in Kaniago

Parameter	**Point of Measurement**						
	Source	**Up-stream**		**Mid-stream**		**Down-stream**	
-Velocity of flow (m/s)	0.345	0.343	0.3I8	0.262	0.253	0.202	0.182
-Mean velocity (V) (m/s)	0.276	0.274	0.254	0.21	0.20	0.162	0.146
-Depth of flow (m)	0.16	0.16	0.17	0.19	0.21	0.12	0.08
-Canal flow area (A) (m^2)	0.16	0.16	0.17	0.19	0.21	0.12	0.08
-Discharge (V*A) (m^3/s)	0.044	0.044	0.043	0.04	0.042	0.019	0.012
-Average discharge (m^3/s)	0.044	0.044		0.041		0.016	
-Conveyance Efficiency (%)		**100**		**93**		**36**	

From the Table 4.17, the recorded average discharges for the up-stream, mid-stream and down-stream sections of the canal were found to be 0.044 m^3/s, 0.041 m^3/s and 0.016 m^3/s respectively. The differences in discharge might be attributed to the non-uniform canal slope in the scheme. A reference discharge of 0.044 m^3/s was also measured in the canal at the source of water supply. Comparing discharges to the reference discharge, the conveyance efficiencies recorded at the up-stream, mid-stream and down-stream of the canal were found to be 100 %, 93 % and 36 % respectively. This means the efficiency of water conveyance in the Kaniago scheme was high at the source of water supply but reduced as flow progressed through the canal. The downstream of the canal recorded the lowest efficiency value of 36 % which showed a limitation in water delivery in the downstream of the irrigable area, hence affecting production in the scheme. Mati (2011) reported a standard conveyance efficiency value of 95 % for canal systems.

4.7 Challenges Encountered in the Functioning Irrigation Schemes

The study on the irrigation schemes revealed certain major infrastructure and managerial constraints. According to management of both schemes, some farmers were reluctant in the payment of irrigation service charges which affected maintenance and repair works on the schemes. Allocation and utilization of irrigation services income was problematic especially on the Kaniago scheme since there was no clear-cut plan by the WUA executives on usage of irrigation services income.

Regarding the condition of infrastructure, the Akumadan scheme was confronted with challenges of many faulty sprinkler heads, inadequate laterals with un-fit coupling and hydrants having broken valves. These challenges affected conveyance and uniform distribution of water on the scheme. At Kaniago, the infrastructure challenges were that of faulty hydrants and poorly designed canal slope that resulted in low gravity flow in the main canal hence affecting water conveyance to the downstream of the scheme. Shown in Plates 4.2 and 4.3 are photographs of poorly functioning infrastructure in the Akumadan and Kaniago schemes.

a) Leaking Pipe lateral with Unfit Coupling

b) Hydrant with Broken Valve

c) Faulty Hydrant Abandoned in the Scheme

d) Faulty and Abandoned Sprinkler

Plate 4.2: Pictures showing the Deplorable State of Structures in the Akumadan Scheme

a) **A Faulty Hydrant**

b) **Evidence of Low Gravity Flow in the Downstream of the Scheme**

Plate 4.3: Pictures showing the Challenges in the Kaniago Scheme

4.7 Challenges of the Defunct Irrigation Schemes in the Transition Agro-ecological Zone

Defunct schemes refers to schemes that are no longer in operation or service. A scheme becomes defunct when it develops major faults resulting from lack of maintenance which inturn obstruct operations on the scheme. Sometimes certain management challenges could lead to the breakdown of an irrigation scheme. Example; For a pumped irrigation scheme, poor irrigation service charge recovery significantly affects operations since it is cost intensive due to energy utilization. For this study, the defunct schemes are the Tanoso and Subinja irrigation schemes.

4.7.1 State of the Defunct Schemes Prior to Breakdown

4.7.1.1 Management of the Schemes

The Tanoso and Subinja schemes were managed jointly by personnel from GIDA and MoFA with assistance of the WUA executives of the schemes. The Figure 4.7 shows the management structure that was implemented in the Tanoso scheme until breakdown of the facility.

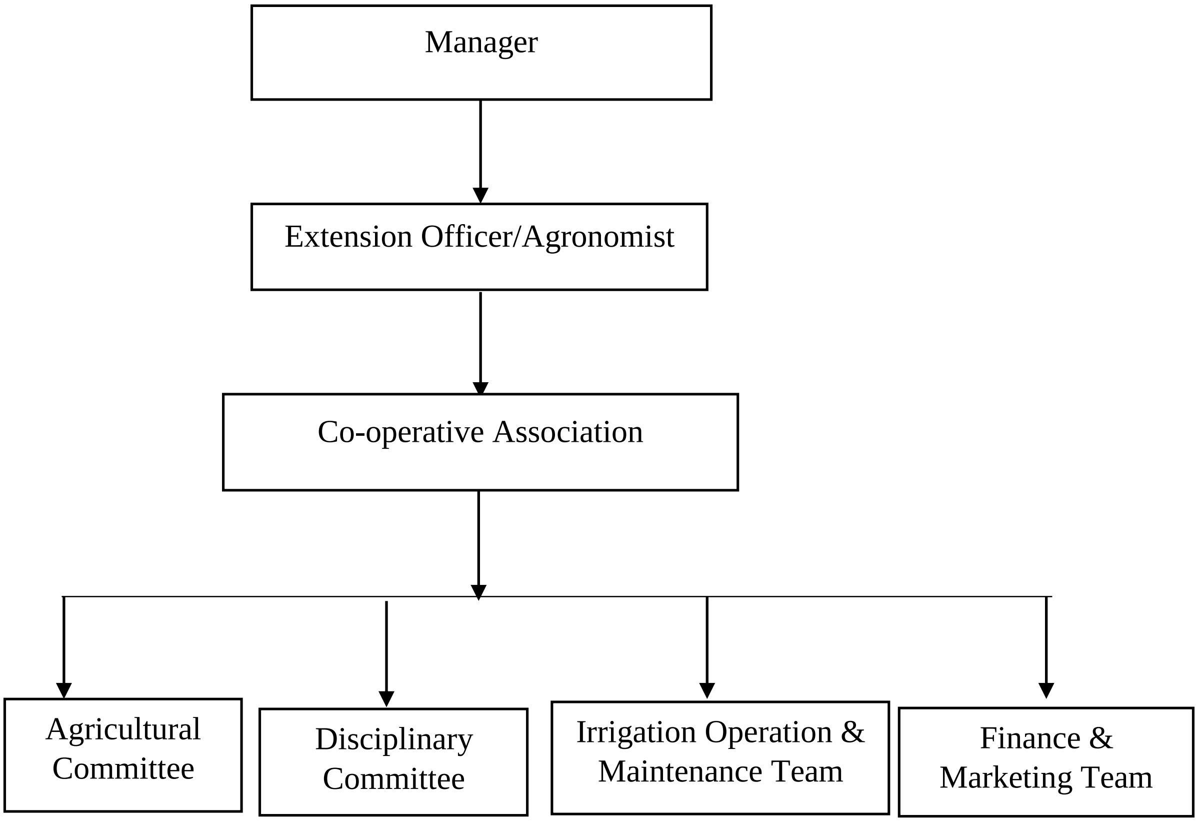


Figure 4.7 : Schematic Diagram of the Management Structure at the Tanoso Scheme

According to the manager of the scheme, there was no irrigation technician during those periods of operation and that some farmers volunteered to ensure water conveyance and distribution to the farmlands. This may have affected irrigation scheduling hence resulting in over or under irrigation.

At Subinja, the scheme lacked the services of both irrigation technician and extension officer. This might have impacted decisions on good farming practices and water supply on the scheme. The management structure at Subinja is shown in Figure 4.8.

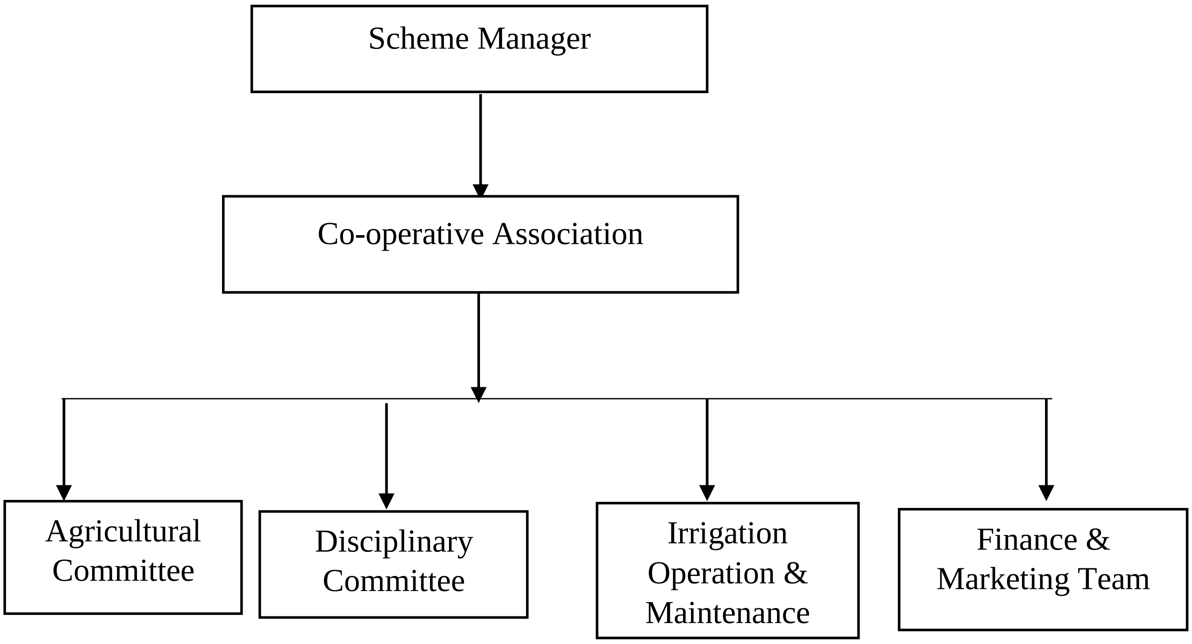


Figure 4.8 : Schematic Diagram of the Management Structure at the Subinja Scheme

4.7.1.2 Irrigable Areas in the Schemes

The irrigable areas of the irrigation schemes comprises the potential cultivable areas, the total developed irrigable areas and the actual cultivable areas. In the case of the defunct schemes, the actual irrigable area in the scheme prior to the scheme's breakdown was considered.

Tanoso Irrigation Scheme: The scheme had a total developed irrigable area of 64 hectares of which 16 hectares were actually put to cultivation until the scheme closed down. Regarding the potential area for irrigation, the scheme had an area size of 130 hectares.The minimal actual irrigable area size was due to the insufficient water supply on the scheme resulting from a broken dam wall. The broken dam wall made it difficult for the reservoir to hold enough water for irrigation. The presence of rocky patches in the irrigable area restricted irrigation development in certain areas of the farmlands. Moreover, faulty hydrants and sprinkler heads contributed to the reduction in the actual irrigable area. Abdul-Ganiyu *et al.* (2016) reported an average soil textural class of loamy-sand in the scheme. Crops cultivated under the scheme were okra (*Abelmoschus esculentus*), chili pepper (*Capsicum annuum*), cabbage (*Brassica oleracea var. capitata*), tomatoes (*Solanum lycopersicum*) and watermelon (*Citrullus lanatus*).

Subinja Irrigation Scheme: The scheme operated on 18 hectares of land of a total developed irrigable area of 60 hectares. The reduction in size of the actual irrigable area was attributed to the inadequacy of surface materials coupled with low irrigation service charges recovery that affected operations and development on the scheme. Operation of an overhead system is immensely affected by low irrigation service charges recovery due to the huge operational-costs as a result of energy utilization. As indicated by management, major crops cultivated on the scheme were garden eggs (*Solanum melongena*), chili pepper (*Capsicum annuum*), tomatoes (*Solanum lycopersicum*) and okra (*Abelmoschus esculentus*). According to Odamtten *et al.*, (2016), the widespread soil textural class in the irrigable area of the scheme was sandy-loam. The scheme had a potential irrigable area of 121 hectares.

4.7.1.3 Irrigation Service Charges on the Schemes

The irrigation service charges (Water Tax) refers to the amount of money levied on the farmers for the utilization of irrigation water. ISC often covers water and land usage fees on the scheme. The ISC of the schemes were estimated based on a fixed rate for a hectare of land use.

According to erstwhile managements, farmers on the Tanoso and Subinja schemes were charged flat irrigation service fees of GH¢ 3,250 and GH¢ 2,100 per hectare in a season respectively. However, the irrigation service charges recovery was low in the irrigation schemes since many farmers were unable to pay their irrigation services charge. This made it difficult for management to meet operations and maintenance costs on the schemes which subsequently led to the closure of the Subinja scheme.

4.7.2 The Current State of Infrastructure in the Defunct Irrigation Schemes

Photographs taken on the schemes showed the deplorable state of certain important structural components. The current physical condition of structures in the defunct irrigation schemes are presented in Plates 4.4 and 4.5.

4.7.2.1 Tanoso Irrigation Scheme

Infrastructure	Condition
 a) **Broken Dam Wall in the Scheme**	The major problem identified on the Tanoso scheme was that of a broken dam wall. This made it difficult for the reservoir to hold water for irrigation. The problem initially began with cracks on the dam wall and later aggravated to the complete collapse of the wall.

The main pipeline had been left surrounded by bushes due to closure of operations on the scheme**.**

b) Section of the Main Pipeline

The Suction end of the pumphouse was left unkept and covered by bushes. The caretaker of the scheme revealed that this condition had existed since the year 2019.

c) Suction End of the Pumphouse

These sprinklers were faulty, hence abandoned at the warehouse of the scheme.

d) Faulty Sprinklers Deposited at the Scheme's Warehouse

This photograph shows a bunch of dismantled pipe laterals deposited at the warehouse of the scheme.

e) Pipe Laterals

0.21 km of the total road length of 2.4 km in the scheme had been eroded by running water as a result of heavy rains.

f) Eroded Road Network

It was observed that the floor of the control room was covered by remnants of sand due to the constant flooding of the place. This could lead to greater damage in future if flood control measures are not put in place on the scheme.

g) Pump Control Room

Plate 4.4: The Current Condition of Infrastructure in the Tanoso Scheme

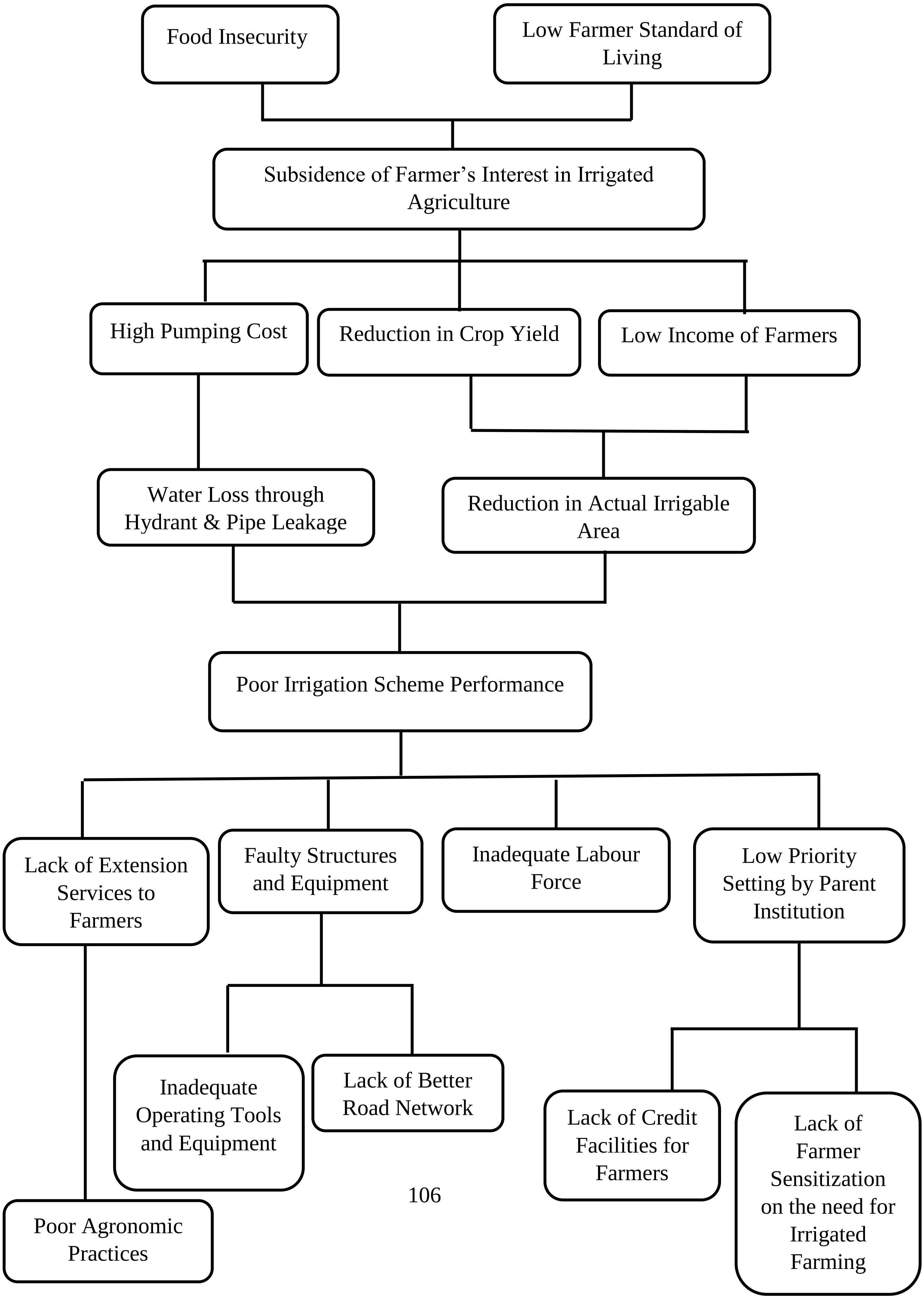
4.7.2.2 Subinja Irrigation Scheme

Infrastructure	Condition
 **a) Abandoned Pumphouse**	The pumphouse being an important component of the scheme had broken down because the scheme was over-burdened with huge electricity costs. This resulted in the disconnection of power supply from the national electricity grid thereby rendering the pumphouse defunct.
 **b) Faulty Power Panel**	An important component of the pumphouse is the power panel which regulates the electric voltage as required by the pumps for their operation. It serves as the engine-starter of the pump. According to the manager of the scheme, the panels had being left dilapidated following closure of operations for the past seven (7) years.

Plate 4.5: The Current Condition of Infrastructure in the Subinja Irrigation Scheme

4.8 Cause – Effect Analysis of Poor Scheme Performance

Figure 4.9: Cause – Effect Analysis of Poor Performance and Condition across the Schemes



CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The study revealed that:

- The majority of farmers (56 %) at Kaniago had no form of formal education whiles 20 % of farmers at Akumadan were formally uneducated. This showed a high level of illiteracy in the Kaniago scheme.
- The youthful (21 – 50 years) participation in irrigated farming across the irrigation schemes was encouraging.
- Landholding at Akumadan and Kaniago ranged from 0.2 – 0.4ha and 0.4 – 0.8ha respectively. Farmers at Akumadan could not afford very large landhold sizes due to the high irrigation service charges on the scheme.
- The major source of labour on the irrigation schemes was family labour. This was due to the high cost of hired labour.
- The developed irrigable areas at Akumadan and Kaniago were under-utilised; thus with recorded average irrigation rates of 22 % and 41 % respectively.
- The sustainability of irrigated area indices of Akumadan (31 %) and Kaniago (28 %) were low indicating a decline in irrigated agriculture on the schemes.
- Akumadan recorded 100 % maximum pipe flow length whiles Kaniago recorded a low canal flow length of 64 %.
- Irrigation structures were in deplorable condition due to worn-out parts, broken parts or outlived lifespan. Thus, the schemes lacked maintenance and rehabilitation.

- Considering the efficiency of road network passability, the road network at Akumadan was accessible all year round. However, Kaniago had no major road network in the scheme.
- All irrigation schemes were environmentally stable and resilient with regards to problems of salinity and sodicity.
- All irrigation schemes had poor irrigation service charge recovery rates which affected operations and maintenance activities on the schemes. This particular situation led to the shutdown of the Subinja Irrigation scheme.
- Akumadan experienced low degree of financial autonomy since only 6 % of the irrigation services income was retained by management whiles 24 % was passed to the central government. However, Kaniago being managed by WUA recorded high degree of financial autonomy.
- Crop production on the schemes was generally low due to the constant decrease in size of the cultivable areas. Inadequate surface materials at Akumadan and water distribution challenges at Kaniago contributed to the decrease in size of the cultivable areas on the schemes.
- The Impact-sprinklers located at the upstream and downstream sections of the Akumadan scheme recorded DU values of 73 % and 83.3 % respectively. At the same time, the UC values of the sprinklers were found to be 85.2 % at the upstream and 90.8 % at the downstream.
- At Kaniago, the water conveyance efficiencies measured in the upstream, midstream and downstream of the canal were found to be 100 %, 93 % and 36 % respectively.

5.2 Recommendations

5.2.1 Recommendations for Policy

Based on the findings of the study, the following recommendations were made for facility management and policy considerations to enhance the performance of the irrigation schemes:

- GIDA in collaboration with MoFA and GoG should ensure rehabilitaion of the defunct schemes so as to promote agriculture and ensure food security in the transition agro-ecological zone and Ghana at large.
- Management should ensure that there is periodic and regular repairs and maintenance of the infrastructure in the schemes.
- Management should ensure the availability of enough surface materials (sprinklers and laterals) on the pumped schemes to enhance efficiency and effectiveness in operations.
- Payment of irrigation service charges (ISC) before cropping should be adopted by the management of the irrigation schemes to ensure high recovery rates.
- Management should adopt the culture of proper record keeping so as to keep track of operations and activities on the schemes.
- The Scheme Managers should fully involve farmers in the operation and management of the schemes, which would consequently improve performance.
- The WUA managed schemes (Kaniago) should periodically seek professional advice on proper agronomic practices so as to enhance production.
- Public Private Partnership (PPP) in the management of irrigation schemes should be encouraged to ensure proper management and good performance.
- MoFA in collaboration with GoG should prioritise irrigated agriculture so as to improve agriculture and ensure food security.
- MoFA in collaboration with GoG should sensitise farmers on the need to engage in irrigated farming.

5.2.2 Recommendations for Future Research

- A comparative performance indicator like “Irrigation water potential” should be considered for future study.
- Assessment of the irrigation water quality in the irrigation schemes should be considered for future study.

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APPENDICES

Appendix A1a: Comparison of Performance Indicators between Actual and Notional Normal Values for the Irrigation Schemes

Performance Indicator	Notional Normal Value (%)	Scheme	Actual Values for the Schemes (%)				
			2018	2019	2020	2021	2022
Irrigation rate (%)	90 - 100	Akumadan	36	33	25	-	15
		Kaniago	53	57	43	32	18
Efficiency of irrigation service charges recovery (%)	90 - 100	Akumadan	85	88	80	-	82
		Kaniago	59	50	34	32	25
Financial self sufficiency factor (%)	> or = 100	Akumadan			132		
		Kaniago			> 100		
Scheme financial autonomy factor (%)	> or = 50	Akumadan			25		
		Kaniago			100		
Extent of main canals/pipe flow lengths (%)	100	Akumadan			100		
		Kaniago			64		
Poor structure index (%)	0	Akumadan			27		
		Kaniago			14		

Appendix A1$_b$: Comparison of Performance Indicators between Actual and Notional Normal Values for the Irrigation Schemes

Performance Indicator	Notional Normal Value (%)	Scheme	Actual Values for the Schemes (%)				
			2018	2019	2020	2021	2022
Sustainability of irrigated area index (%)	90 - 100	Akumadan			31		
		Kaniago			28		
Efficiency of roads passibility (%)	100	Akumadan			100		
		Kaniago			0		
Environmental stability index (%)	90 - 100	Akumadan			100		
		Kaniago			100		

Appendix A2ₐ: Qualitative Checklist of Performance Indicator Measurements on the Irrigation Schemes

Performance Indicator	Type of Performance Measure	Scheme	Performance Ranking 2018	2019	2020	2021	2022
Irrigation rate	Output	Akumadan	VP	VP	VP	-	VP
		Kaniago	P	P	VP	VP	VP
Efficiency of irrigation service charges recovery	Output	Akumadan	A	A	A	-	A
		Kaniago	P	P	VP	VP	VP
Financial self sufficiency factor	Process	Akumadan			Good		
		Kaniago			Good		
Scheme financial autonomy factor	Process	Akumadan			Very poor		
		Kaniago			Good		
Extent of main canal/pipe flow lengths	Input	Akumadan			Good		
		Kaniago			Poor		
Poor structure index	Input	Akumadan			Very poor		
		Kaniago			Very poor		

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

Appendix $A2_b$: Qualitative Checklist of Performance Indicator Measurements on the Irrigation Schemes

Performance Indicator	Type of Performance Measure	Scheme	Performance Ranking				
			2018	2019	2020	2021	2022
Sustainability of irrigated area index (%)	Output	Akumadan			Very poor		
		Kaniago			Very poor		
Efficiency of roads passibility (%)	Input, Output	Akumadan			Good		
		Kaniago			Very poor		
Environmental stability index (%)	Output	Akumadan			Good		
		Kaniago			Good		

Appendix A3: Indicator Measurement Ranges and their Corresponding Remark

Measurement Range (%)	Remark
< 50	Very poor
50 - 79	Poor
80 - 89	Acceptable
= > 90	Good

Appendix A4: Laboratory Results for the Physico-chemical Characteristics of Soils in the Irrigable Areas of the Schemes

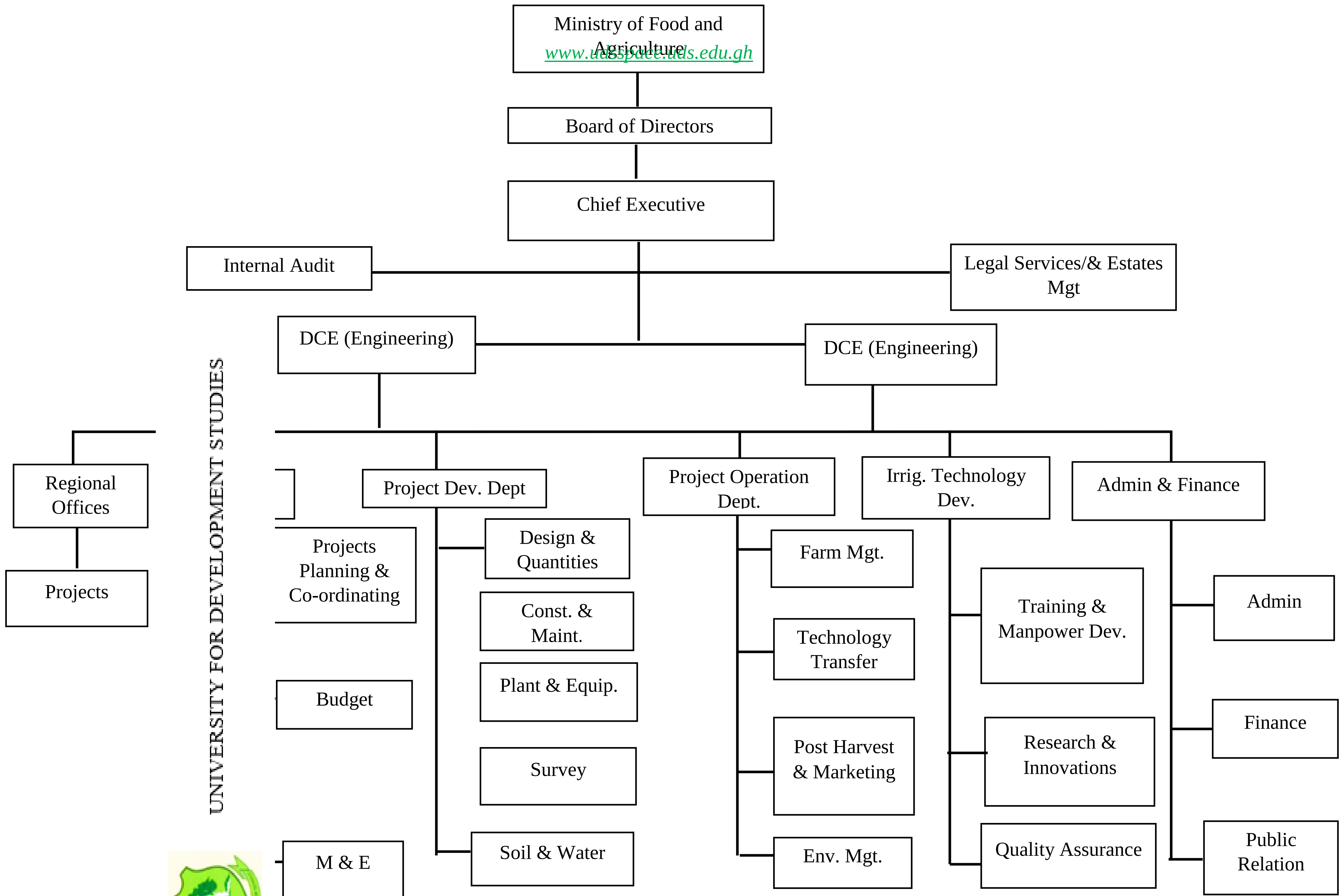
Akumadan Scheme					
Parameter	Up-stream	Mid-stream	Down-stream	Mean value	Acceptable Mean value
pH	7.7	6.9	8.3	7.6	6.0 – 7.0
EC (dS/m)	0.2	0.21	0.25	0.22	= or < 2.5
ESP (%)	2.1	2.5	2.5	2.4	< 15
Texture	Sandy clay loam	Sandy clay loam	Sandy loam	Sandy clay loam	Loamy sand
Kaniago Scheme					
Parameter	Up-stream	Mid-stream	Down-stream	Mean value	Acceptable Mean value
pH	5.2	6.0	5.8	5.7	6.0 – 7.0
EC (dS/m)	0.4	0.45	0.36	0.4	= or < 2.5
ESP (%)	4.4	4.9	5.1	4.8	< 15
Texture	Sandy loam	Silt loam	Silt loam	Silt loam	Loamy sand

Appendix A5: Values for Distribution Uniformity (DU) and Uniformity Coefficient (UC) of the Overhead System at Akumadan

Sprinkler A (up-stream)			
Indicator	**Measured value (%)**	**Acceptable standard (%)**	**Remark**
DU	73	= or > 80	Fair
UC	85.2	> 80	Very good
Sprinkler B (down-stream)			
Indicator	**Measured value (%)**	**Acceptable standard (%)**	**Remark**
DU	83.3	= or > 80	Very good
UC	90.8	> 80	Excellent

DU – Distribution Uniformity; UC – Uniformity Coefficient

Appendix B: Proposed Re-Structure of GIDA



Appendix C1: The Ratio of Good Irrigation Structures to the Total Number of Structures in the Schemes

Irrigation Structure	Total No. of Structures	No. of Structures in Good Condition	No. of Structures in Bad Condition	$\frac{\text{Good struc.}}{\text{Total No. of struc.}}$
Akumadan Scheme				
Pump(s)	4	4	0	1.0
Power distribution panel	1	1	0	1.0
Motor starting panel	4	4	0	1.0
Main pipe	1	1	0	1.0
Spillway	1	1	0	1.0
Sprinkler(s)	88	21	67	0.2
Pipe lateral(s)	72	34	38	0.5
Hydrant(s)	156	82	74	0.5
Valve(s)	2	2	0	1.0
Kaniago Scheme				
Main canal	1	1	0	1.0
Weir	1	1	0	1.0
Flume	3	3	0	1.0
Gate structure(s)	9	8	1	0.9
Valve(s)	2	2	0	1.0
Diversion boxes	8	8	0	1.0
Hydrant(s)	32	19	13	0.6

Appendix C2a: Existing Structures and Facilities in the Akumadan Scheme

a) Pumphouse

b) Pump

c) Power distribution panel

d) Motor starting panel

e) Reservoir and its catchment

f) Spillway

Appendix C2b: Existing Structures and Facilities in the Kaniago Scheme

a) **Weir**

b) **Flume**

c) **Reservoir**

d) **Main valve**

e) **Diversion box**

f) **Canal**

Appendix D1a: Research Questionnaire for Irrigation Scheme Farmers

Mphil Research Questionnaire

1. Name of Scheme ___________________________________ Date of interview ____________

2. Town/village of residence____

3. Sex. M [ ] F [ ]

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

5. Marital status. Married [ ] Unmarried [ ] Widowed [ ] Divorced [ ]

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? < 1 acre [ ] 1 acre [ ] 2 acres [ ] 3 acres [ ] 4 acres [ ] 5 - 1 0 acres [ ] other____________

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

9. How many years have you practised irrigated farming in the scheme? _________Years

10a. What are your objectives for engaging in irrigated farming during the dry season?____

10b. Have the objectives for irrigated farming been achieved over the years? Yes[ ] No[ ]

If No, state reason(s)_____________________

11. How is the irrigation done? Gravity flow from canals [ ] Lifting by bucket/calabash from canal [ ] Pumping from the canals [ ] Pumping from hand dug well [ ] Pumping through a sprinkler system [ ] Other means____________________

12a. How many times in a week are the canals opened for irrigation?

12b. How long do you irrigate your crops in a day?

13a. Is maintenance and repair works undertaken on the scheme periodically? Yes [ ] No [ ]

13b.What is the frequency of maintenance and repair works? Daily[ ] weekly[ ] monthly[ ] yearly[ ]

13c. Maintenance and repair works are done by who? ____________________________

13d. Indicate clearly the sections or areas of the scheme where maintenance and repair works are undertaken. ____

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

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

14. Do you have water users association? Yes [ ] No [ ]

15a. Do irrigation water fees and land-usage fees exist in the scheme? Yes [ ] No [ ]

15b. How much is paid for irrigation water fees and land-usage fees (GH¢):

Water fees (Gh¢) per acre	Land-usage fees (Gh¢)-acre

15c. What is the method of charge for irrigation water usage? (flat rate, volumetric rate, per cropped area) ____

15d. Are all farmers in the scheme required to pay the established fees and charges? Yes [ ] No [ ]

16. What is the funding source for farming ? Loan [ ] Personal [ ] Family [ ]

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

17b. If yes, name it/them ____

17c.What are their roles and responsibilities? _______________________________________

18. Please indicate the area, crops cultivated, yield and revenue for the last growing season.

Crop	Year	Area cultivated (acres)	Total yield (kg, bags or boxes)	Income from sales per kg/bag of produce

19a. What is the drainage and soil condition of your land? Waterlogged [ ] No waterlogging[ ] Occasionally waterlogged [ ]

19b. If waterlogged, when does it normally occur?________________________________

20. What are/were the major problems or challenges encountered in the scheme?___________________________

21. Could you please suggest the critical areas in the operation and management of the irrigation scheme that you think need/needed improvement to enhance performance of the scheme?____

Appendix D1b: Research Questionnaire for Transition-Zonal GIDA Office

Mphil Research Questionnaire

1. Name of Interviewee_________________________________ Date of interview ___________

2. Position of Interviewee____

3. Sex. M [ ] F [ ]

4. What is the general performance of irrigation schemes within the transition agro-ecological zone? Good [ ] Averagely Good [ ] Poor [ ] Very Poor [ ]

5a. Are there periodic maintenance works on the schemes ? Yes [ ] No [ ]

5b. If Yes, how often ?___________________

6. Has the government's objective of ensuring all year round food production being realised over the years ? Yes [ ] No [ ]

7a. Is GIDA aware of the breakdown of major irrigation schemes in the transition agro-ecological zone ? Yes [ ] No [ ]

7b. Is there any idea of the cause(s) of breakdown of the irrigation schemes ? Yes [ ] No [ ]

8a. What has prolonged rehabilitation of the defunct schemes ?______________________

8b. Is there any rehabilitation plan by MoFA and GIDA for the defunct irrigation schemes ? Yes [ ] No [ ]

8c. If Yes, what is the plan ?______________________________

9. Is GIDA resourced enough to carry out its duties ? Yes [ ] No [ ]

10. What are the challenges of GIDA ? ___________________________