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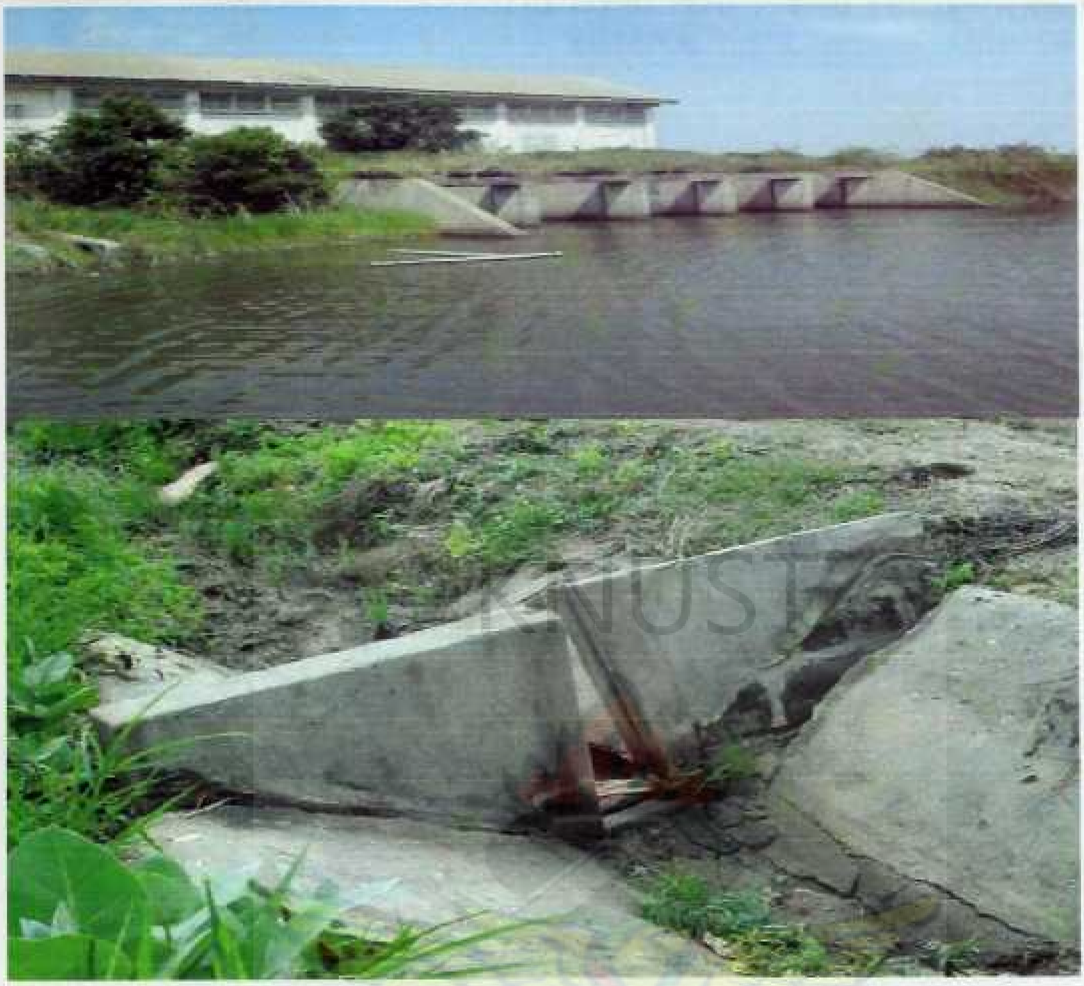

Management of Irrigation Projects in Ghana: Case Study of Dawhenya Irrigation Project

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Management of Irrigation Projects in Ghana: Case Study of the Dawhenya Irrigation Project.

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Master of Science Thesis

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CERTIFICATION

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

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DEDICATION

I dedicate this study to God Almighty who gave me strength throughout this study.

Abstract

The Dawhenya Irrigation Project (DIP) is located on the Accra-Coastal plain approximately 40 km East of Accra-Aflao Highway. The construction of D.I.P had occurred over numerous phases first, as of 1959 to the commissioning of the pump station in 1973 and was mainly for rice production. For these years before the major rehabilitation in 1999-2000, farmers at D.I.P. only cultivates once a year, with low average yield of rice and low average income. After the rehabilitation, the average yield of the farmers increased from 5.5 tons/ha to about 7.8 tons/ha. This means maintenance is a key component in yield increase and management of irrigation projects.

This research was therefore undertaken to study the management and to assess the crop yield of DIP, thereafter to recommend improvement strategies of DIP for the sustainability of the irrigation project, hence increasing the farmer's productivity and their income.

The results indicated that 80% of the farmers currently working at the (DIP) confirmed that access to inputs was difficult, whereas 83% stated that the absence to credit facilities was a limitation to the farming activities. There was low coordination and integration of agricultural activities and poor monitoring of farm activities at project site by the management of Ghana Irrigation Development Authority (GIDA) which brought about failure to achieve project objectives. Moreover, there was poor information flow between project engineers and the farmers on technical guidance in the operation and maintenance activities and also the number of staffs from (GIDA) for the planting periods was on a decline which delayed implementation of decision. Another important findings were the poor maintenance of the irrigation systems and low soil nutrients (organic carbon, total nitrogen, organic matter, phosphorous, potassium), which appeared to be major constraints in sustaining adequate levels of the crop yield. For operation and maintenance of the irrigation systems to be improved, there must be effective co-operation between the farmers' organisation and GIDA. Farmers' organisation must be educated in cooperative management and administration, as well as building on their capacity in management of the project by GIDA extension staff to increase their productivity. The executives of the farmers' organisation must play a leading role for farmers to have direct access to inputs and credit facilities.

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List of Abbreviations and Acronyms

A.P	Accra Plains
D.C.F.F.S	Dawhenya Co-operative Food Farming Society
D.I.P	Dawhenya Irrigation Project
E.C.G	Electricity Co-operation of Ghana
G.I.D.A	Ghana Irrigation Development Authority
I.I.M.I	International Irrigation Management Institute
I.M.C	Irrigation Management Committee
I.M.T	Irrigation Management Transfer
I.S.C	Irrigation Service Charge
MOFA	Ministry of Food and Agriculture
O&M	Operation and Maintenance

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Acknowledgement

Glory and honour be to God Almighty for His grace and mercy that saw me through this work. Indeed it has been His high hand which carried me through.

Notwithstanding all this were done through human vessels of which I cannot than to express my heartfelt gratitude.
I am most grateful to Mr and Mrs Odame-Adams for their financial support that gave me the opportunity to be enrolled as one of the post graduate students, in KNUST.

Again am most grateful to my supervisors, Dr G.K. Anornu and Mr S.Oduro-Kwarteng all of the Civil Engineering Department of KNUST, for their guidance, constructive criticisms and patience to enable me complete this research.

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Thanks goes to all my colleagues who did offer help to make me reach my target, not forgetting Mr and Mrs Arkorful, Mr and Mrs Pastor Simons and all my love ones who did support me in diverse ways to achieve my goal.

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1. INTRODUCTION

1.1 Background of Study

Irrigation projects management has become very vital in achieving flourishing irrigated agriculture, making sustainable operation and maintenance of the irrigation systems (Steven, 2005) very vital. Implies if the provision of irrigation facilities can enhance crop yields, then the management of such facilities must be encouraged (*Sheikh* et *al.*, 2006). Thus in recent years there has been much involvement in the rehabilitation of the existing projects, to increase their performance. Again the management of irrigation projects and transfer to farmers (Johnson III et al, 1995) has prompted considerable research on various aspects of irrigation management reforms, thus the need for alternate strategies for irrigation management and process of creating farmer organizations for successful management (Vermillion, 1997). In Ghana, rain fed agriculture alone is unable to meet domestic food demands. This has caused the government to put in place proposals to develop more small scale irrigation projects wherever feasible and also on significant rehabilitation of most irrigation projects on suspension. This is to reduce the dependency of imported goods and increase productivity (Kranjac-Berisavljevic, 2000). Farmers at Dawhenya Irrigation Project (D.I.P) themselves do maintenance of irrigation structures mostly on the main canals, laterals and sub laterals, bunds and drains, which resulted in the suspension of it (DLDS, 1984). Therefore there is a need to manage the already existing irrigation projects in Ghana which will improve the sustenance of the farmers, as well enhancing the growth in irrigated agriculture.

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1.2 Problem Statement

For several years, nearly every farmer in the Dawhenya Irrigation Project (D.I.P.) crop once in a year, hence have achieved low average income. Pumps, canals and laterals are on continuous deterioration, making facilities partly operational. Thus water use efficiency of facilities is low. Moreover, there is an issue of farmers having difficulty to undertake time consuming management activities, which has affected their maintenance culture. Again challenges in the cropping patterns of farmers before the start of any irrigation season. Consequently, the less managerial skills of the farmers has affected the management of the irrigation facilities, hence the sustainability of the DI.P.

1.3 Objectives of the Study

The main objective of this study is to assess the effects of management of the Dawhenya Irrigation Project in the Greater Accra Region of Ghana on its sustainability and crop yield.

From the above obtained main objective, the following specific objectives must be achieved:

- To assess the management structure of D.I.P.
- To assess the crop yield and soil properties of the study area.
- To identify the water management and maintenance practices of D.I.P.
- To identify the factors that influenced the management of the project.

1.4 Justification of the Study

Most irrigation projects, like D.I.P are sustained, only with the great assistance from governments, external bodies and other supporting agencies. Since irrigation agriculture contributes immensely to the economy of Ghana in the area of (GDP), there is therefore a need to manage irrigation facilities well (Fatcon, 2002), thereby sustaining the projects, also in line with the MDGs it is seen as a tool to eradicate poverty and hunger through improved use of irrigation water, to better the livelihoods of farmers and the nation as a whole, through increase in crop yields. Consequently, this study will contribute knowledge concerning the operation and management of small-scale irrigation projects, as well as their sustainability.

1.5 Scope and Limitation of the Study

This research was conducted to determine the effects of management of the D.I.P in the Greater Accra Region of Ghana on its sustainability and crop yield. Soil samples were taken from (20) rice fields for laboratory analysis. Tests were performed on organic carbon, total nitrogen, electrical conductivity, pH, calcium, magnesium, potassium, phosphorous and sodium. However, this study was subject to the following limitations. Time series information was difficult to collect from the farmers since they were not recording output, as well as the office of Ghana Irrigation Development Authority, not having detailed records of the project due to the suspension of it.

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1.6 Organization of Report

This report is made up of six chapters. Chapter one begins with the introduction which consists of the background of the study, the study objectives and the justification of the study as well as the study limitations. Chapter two also outlines a review of the available literatures on the subjects of management of irrigation projects in Ghana and related topics which comments on issues to achieving sustainable irrigation projects, however attention was also paid to the post performance and management of these designs (irrigation infrastructures). Chapter three describes the background of the study area. Chapter four also describes the research methodology and chapter five presents the data analysis, results of the research and discussion, while chapter six ends the report with conclusions and recommendations of the research.

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2. LITERATURE REVIEW

Irrigation is currently undergoing a serious challenge, even though it has a good record in contributing to food production. Irrigation expansion has dramatically lost momentum since the 1980s due to a considerable slowdown in new investment, losses of irrigated area and salinity problems, and urban encroachment in developing countries. However, irrigated agriculture still remains essential for future food security. The reduction of investments in the irrigation sector is not consistent with the identified needs for future food security, as indicated by numerous model studies on projections of food demand and supply. However poor management of the irrigation facilities may also be a reason why there is decrease trend in the performance of irrigation agriculture. Because these systems are mostly not managed properly, thus this study focuses on the effective and efficient management that is often neglected by decision-makers involved in the development of small-scale irrigation projects (Ankum, 1999). Revisions of the planning process of irrigation projects and the operational procedures have also had impact on the selection and design of water control structures (FAO, 1996).

Irrigation management looks at how the farmers collectively manage the scheme for the sustenance of their livelihoods. Irrigation water management deals with: The organised use of resources (human, physical, financial) for planning, operation and monitoring of tasks and activities related to the water distribution and use for irrigated agriculture, including maintenance, drainage, conflict control and cost recovery, including the organisational structures and communications, all for the realisation of goals and objectives of the organisations and individuals involved.

The three facets of irrigation project management, namely, the water that is delivered to the crops, the structures that control water to (and from) fields, and the organisations that manage these structures and water. The water delivered to the crops forms the supply and control management which looks at acquisition and allocation (supply management), distribution and drainage (control management). Supply management involves getting the required and appropriate amounts of water for the system and then assigning rights thereto. Water control within the scheme is achieved through control structures that have to be designed, constructed, operated and maintained (Uphoff, 1986).

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2.1 Irrigation Systems

The irrigation system consists of a main intake structure or pumping station which is mostly drawn from water source, a conveyance system, a distribution system, a field application system, and a drainage system (FAO and Brouwer 2005). In most African countries, irrigation development usually starts with the creation of small or large water bodies by damming streams or water courses.

2.2 Field Application Systems

There are many methods of applying water to the field. The simplest one consists of bringing water from the source of supply, such as a well, to each plant with a bucket or a water-can. More sophisticated methods of water application are used in larger irrigation systems example sprinkler, drip, surface, etc.

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2.3 Designs of Irrigation Systems

Farm irrigation systems must be designed to apply water at rates, in quantities, at times needed to meet farm irrigation requirements and schedules. They divert water from a source; convey it to cropped area of the farm to apply it over the area being irrigated. Again they facilitate management by proving a means measuring and controlling flow. An important concern for purposes of water-delivery system design and management is the relationship between application rate and application time.

Technical manpower in planning, implementing, and operating irrigated agriculture systems is a major constraint for developing irrigated agriculture in Africa (World Bank, 1987).

2.4 Types of Irrigation Projects in Africa

In many African countries, a polarity exists between a few large-scale government irrigation projects and a number of very small independent irrigators (Moris and Thom, 1987). The large or small scale irrigation projects are usually constructed with government financial support. These projects may be under direct government control or have control allocations by an irrigation authority to small-scale tenant farmers. Most large irrigation projects are surface irrigation systems based on gravity-flow diversion or pumping. They include irrigation based on use of receding or advancing floods in river flood plains, inland valleys and coastal areas, small dams using gravity flow distribution, small river diversions or sometimes pumping water by motorized pumps (Blackie 1984).

2.5 History of Irrigation Management

Following the independence of Ghana (1957) that irrigation project began, where irrigation project management were in the hands of successive governments (Kyei-Baffour and Ofori, 2006). Management of irrigation projects commenced with the Land Planning and Soil Conservation Unit, in the Ministry of Food and Agriculture (MOFA). Afterwards, was put under Irrigation Department of MOFA from 1974-1977. From there after, Ghana Irrigation Development Authority (GIDA) has been at the hem of affairs of all the development and management of irrigation projects.

2.5.1 Irrigation Management

Irrigation management has generally been divided into two, namely normal managerial functions and irrigation water management. Normal managerial function is the overall direction and coordination of the decision-making process which often consist of monitoring certain factors which influence the irrigation system performance namely resources, skills and the motivation of staff. This responsibility is mostly handled by GIDA, who is efficient, maintaining a firm grips over staffing, maintaining adequate technical expertise in all departments of irrigation and also ensuring higher productivity on projects (Kyei-Baffour and Ofori, 2006).

Financing Of Irrigation Associations: Annual budget of any irrigation project maintenance is mostly from membership fees of farmers. In principle, the total amount of membership fees must meet the annual requirements for administrative and personnel expenses as well as operation and maintenance costs (APO, 1980).

Owing to the increase in personnel expenses, labour charge and material prices, the amount of membership fees collected are always insufficient for maintenance and repair of facilities. Thus government subsidies are needed, to enable associations become a self-financing capability, (APO, 1980).

Technical Management: The technical staff controls water delivery at main canals and laterals. From turnout gates through farm ditches to individual fields, water is distributed by irrigation groups under the supervision of the association staff, (APO, 1980). Management division of the association prepares annually an irrigation guide according to production goals and water sources available. This includes the names of the canal system, names of irrigation groups, water from different sources, irrigation methods and intervals, conveyance losses, water requirements of seedbeds and main fields, frequency of irrigation and water delivery schedules. Irrigation Water Management seems to be the most vital of irrigation systems countrywide. (Kyei-Baffour and Ofori, 2006). A very vital water management activity covers the area of water distribution systems, systems maintenance and irrigation extension. The expertise for irrigation water management available at the field level is very poor if not non-existent among most farmers, conveyance water losses are tolerated without due regard, leading to inefficient water application. The absence of a monitoring mechanism creates a weakness in water management, thus raising questions on sustainability (Jurriens and de Jong, 1989). The reasons for the above phenomenon can be due to absence of water management regulations and the absence of water board committee to enforce existing water rights regulations. To attain an improvement in the management of water there must be a detail search on the soil crop water relationship, proper land preparation to ensure efficient water management for the predominant surface irrigation methods (FAO, 2005).

2.6 Water Management and Irrigation Systems

Regardless of system type, the purpose is always to attain a better crop and higher yield. For most smallholder surface irrigation schemes, water allocation is by rotation to blocks or plots to individual farmers, (Tiffen, 1990). Thus the soil moisture should be frequently checked, to avoid too much application of water to the active root zone. Therefore irrigation systems must be repaired to improve system reliability.

- **Scheme Water Management:** Despite the increase in water use by sectors other than agriculture, irrigation continues to be the main water user on a global scale. However, there is an increasing pressure for water to be used more efficiently in agriculture. On the other hand, irrigation agriculture is regarded as one of the main ways to increase food production and rural incomes. It is therefore imperative to improve water management in order to achieve both high water productivity and higher rural income (FAO & AGL, 2006).
- **On-Farm Water Management:** The Water Resources Development and Management Service, offer technical assistance to country members in the design and implementation of on-farm irrigation systems, as well as in the identification and adaptation of irrigation techniques.
- **Institutional Strengthening:** The challenges in water management posed by the increase in population and the pressure to use water resources efficiently mean that the institutions in charge of water management should either be reformed so that countries are able to cope with these new demands. These

institutional reforms might take different forms depending on the local conditions and the specific aims of the reform. For example there can be a draft on guidelines on irrigation management transfer (FAO and INPIM, 2002).

Irrigation advisory services can play an important role in assisting users to adopt new techniques and technologies for more efficient water use and increased production. Such services can be provided by private, public or co-operative agencies. Critical in the promotion of irrigation advisory services is the financial sustainability of such institutes, as in particular in many developing countries, (Ghana) adequate funds not available to finance public services. For effective water use for sustainable crop production, workshops can be organized for capacity building.

- **Training and Capacity Building:** Training and capacity building are identified as key elements in developing the skills, knowledge and means to define, plan and implement the action programmes in integrated water resources development for agriculture. Through a participatory approach in extension, technical staff and other stakeholders put farmers in charge of water management at field and scheme level, promote the adoption of appropriate technologies and establish the necessary local capacity to put farmers in charge of water development and management (FAO – AGLW, 2003). The main thrust of training offered to water users is on aspects of leadership and group organization and on technical aspects of management and maintenance of infrastructure such as canals, furrows, and pumps. Such training will build the capacity of the irrigation communities to run the affairs of irrigation projects without external help from the Government. It will also ensure that all irrigation

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projects under rehabilitation are handed over to the farmers for operation and maintenance (FAO, 2005).

2.7 Operation and Maintenance

The irrigation network is the most costly component of an irrigation project and is designed to last for a long time. However, all too often one find that irrigation project not long constructed bears little resemblance of the original construction and design. Silt deposition, weed infestation, malfunctioning of structures and other undesirable situations make it practically impossible to control flow of water in the canals (SSIAPP, 2001). As a result of that, the system is unable to deliver the necessary water and distribute it equitably. The engineering facilities are properly maintained so as to facilitate irrigation operation. Maintenance work is generally divided into three categories: routine maintenance, annual maintenance and emergency. In routine maintenance, repairs are done immediately on the spot upon discovery of damage. On the other, annual maintenance is performed during the non-irrigation period to ensure proper operation of the facilities in the next irrigation season. Emergency repairs are carried out mainly after flood damage and the facilities must be completed in time for irrigation. Operation and Maintenance (O&M) is crucial for the sustainable running of the scheme leading to better water use and hence improved agricultural output. The two, O&M and agricultural productivity, have a cause effect relationship, that is, the sustenance of one depends on the good performance of the other. Irrigation Management Committee (IMC) does cut all water supplies to the irrigation project when maintenance needs to be done. This has managed to increase the number of farmers attending to maintenance and has been welcomed by most irrigation farmers.

Thus farmers are been advised to attend maintenance meetings, since failure to attend will be met by a fine. The above strategies have been adopted by these (IMCs) to improve on collective actions. (Samakande *et, al* 2000).

2.8 Crop Yield

Crop yields in an individual field could be increased if seepage from the distribution system adversely affects the fields by creating saturated conditions. For unexpected water shortages, it is good to know that, some crops are affected: that is crops do suffer during the growth stages and this will result in severe yield reductions when the water is in short supply. Total yields from the individual farm could be increased if the magnitude of losses in the distribution system were such to cause a loss of cropped land or insufficient irrigations. That is, the water that is saved by achieving this objective might be used to bring more land into production or more effectively irrigate currently-cropped land. Increasing system performance could very well lead to higher yields due when there is less leaching of nitrogen fertilizer, improvement in irrigation uniformity which increases fertilizer use. This contributes to a healthy crop that is able to utilize applied nutrients properly, making it less susceptible to diseases and insects.

2.9 Soil Properties

Soil is the main source of nutrients for crops. Soil also provides support for plant growth in various ways. Knowledge about soil physical condition and its maintenance is critical to sustaining crop productivity. The strength of soils can be assessed by the quality and stand of the crops grown on them. However, that is a general assessment made by farmers. A scientific assessment is possible through detailed physical, chemical and biological analysis of the soils. Essential plant nutrients such as nitrogen

(N), phosphorous (P), potassium (K), calcium (Ca), magnesium (Mg), and sulphur (S) are called macronutrients, while iron (Fe), zinc (Zn), copper (Cu), molybdenum (Mo), manganese (Mn), boron (B) and chlorine (Cl) are micronutrients. Soil may have large amounts of nutrients reserves in them. All or a part of these reserves may not be of any use to crops because they may not be in plant available form. Apart from nutrients, soil pH is also critical in the assessment of soil health. Generally, plants prefer soils that are close to either side of neutrality. However, there are acid-loving crops yields and also crops that can withstand high soil alkalinity. Hence, good crop yields are possible in acid and alkali soils (Motsara and Roy, 2008).

2.10 Influence of Management on Crop Yield

When management is transferred from the government or state to farmers, there arise signs of irrigation project management problems. Some of these problems are poor maintenance which, leads to poor water distribution, hence poor water management. Farmers in management control sometimes bring about weak organization of the farmers cropping programmes and conflicts among individual farmers. Environmental issues such as drainage, planting methods, method of fertilizer application, etc. are sometimes well done by the government agency in charge, but receive not full attention when farmers are in charge. Under the government management the responsibility to function economically productive agriculture on a sustainable basis is far broader than when is under farmers' cooperatives. More importantly because the farmers' organization becomes financially incapable after turn out of management; high cost of inputs, less assistance to rehabilitation programmes, and proper maintenance is not done on irrigation facilities. These intend affects farmers farming activities, cropping programmes from the beginning of each season to the harvest.

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Thus the growing stages of the plant are affected thereby decreasing the crop yield. Hence the sustainability of the irrigation project may be affected (Groenfeldt and Sun, 1994).

2.11 Influence of Soil Properties on Yield

The role of plant nutrients in crop production is well established. The following essential plant nutrients are available; C, H, O, N, P, K, Ca, Mg, Fe, S, Zn, Mn, Cu, B, Mo and Cl. These nutrients elements have to be available to the crops in quantities as required for a yield target. Any limiting or deficient nutrient will limit crop growth. The required nutrients may come from various sources, such as the atmosphere, soil, irrigation water, fertilizers, etc. integrated plant nutrient supply depends on various factors including the type of crop, soils, availability of various resources and ultimately on economic considerations, such as the level of production and the costs of inputs and outputs (Motsara and Roy, 2008). Integrated nutrient management is well accepted approach for the sustainable management of soil productivity and increased crop production. Soil pH has a considerable influence on the activity of soil micro flora on the availability of soil nutrients to crops. Physical properties such as soil texture and soil structure do affect the crop yield.

3. BACKGROUND OF STUDY AREA

3.1 Overview of Study Area

Studies in the 1960's identified the Dawhenya area as appropriate for irrigation development to improve the local production of rice and other food crops in Ghana. This is located east of Accra and is under the Ga East District, lying on the plains between two hills boarded by two streams. The inhabitants are mainly from Dawhenya and Tema, others from different parts of the country. Lying close to the major port of Tema, various occupations for the community are created, which makes irrigated agriculture in the area very difficult, compared to the other irrigation projects in the country coupled with low irregular rainfall pattern.

Figure 3.1 Ghana map showing the location of the study area

The Dawhenya Irrigation Project is located on the Accra Plains (A.P). The main components of the scheme are the Dam with a maximum height of 9.1 m, Dawhenya Reservoir located on the Dechidaw River, pump station. The project was designed primarily for the production of rice by smallholders using a double cropping system of cultivation. The original construction of the Dawhenya dam was undertaken in 1962, but the provision of the irrigation facilities did not commence on a significant scale until about 1974, which was to serve an area of about 450 ha, but initial funding was restricted, and the first phase construction was limited to the main pump station and a canal system for 200 ha.

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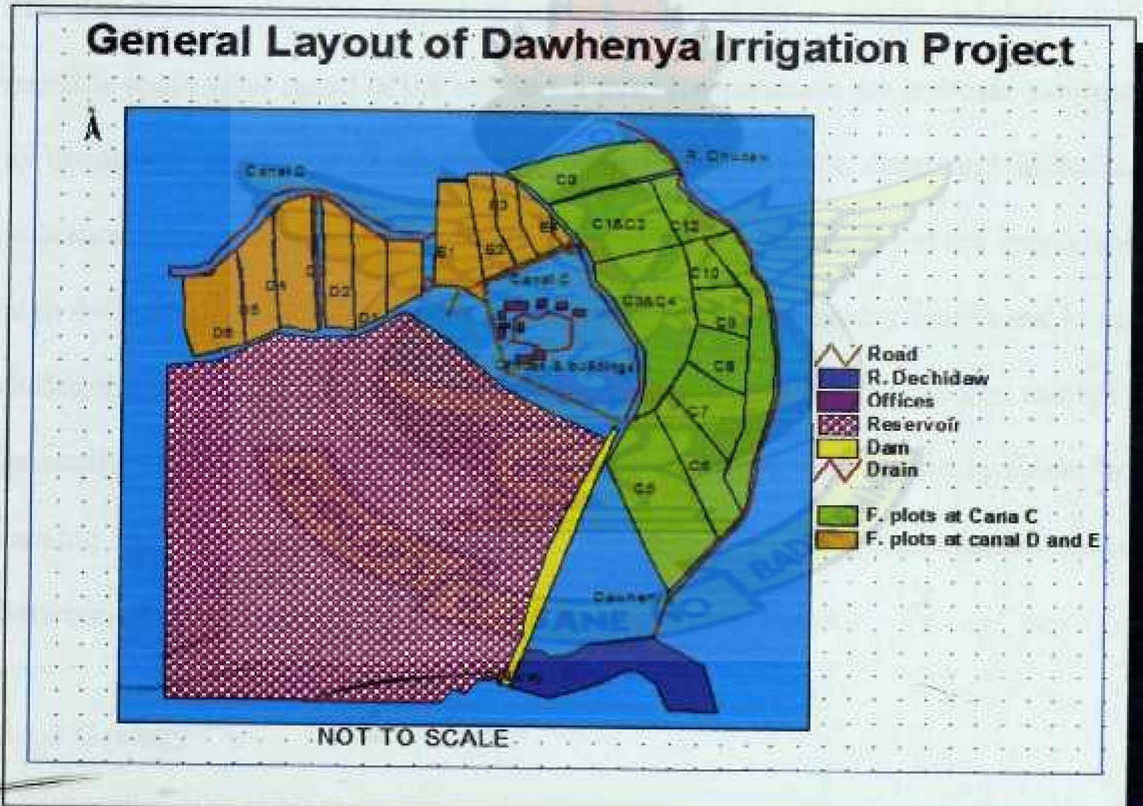

Figure 3.2 General Layout of the Dawhenya Irrigation Project

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3.1.1 Location

The study area is located at longitude 0° 03` E and latitude 5° 46` N, at an altitude of 15m above sea level and 9.5 km inland from the coastal town of Prampram. It lies 40 km from Accra, north of the Accra- Aflao road. The study site and the catchment for the reservoir is part of the (A.P), which form a strip, 25 km to 40 km wide, parallel to the coast and to the south-east of the Akuapim mountain escarpment, approximately 25 km from the study area (DLDS, 1984).

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3.1.2 Climate

The Dawhenya Irrigation Project at an elevation of 15 m above sea level, with monthly mean wind speed of 0.6 m/s to 1.3 m/s. Temperatures are however subjected to occasional and minimal moderating influences along the coast and altitudinal influences affected by the Akwapim Range (AR) in the northwest and are appreciably high for most parts of the year with the highest during the main dry season and lowest during the short dry season. The monthly mean temperature is 32° C, whiles rainfall is generally very low (March-July) with most of the rains, very erratic in nature and coming mostly between September and November. Mean annual rainfall ranges between 641mm/year and 1185 mm/year in the catchment area.

3.1.3 Geology

The project site which forms part of (A.P) consists essentially of Precambrian Rocks (PR) with lesser occurrences of Togo Quartzite and tertiary sediments. According to (Kesse, 1985) the (PR) are represented by the Dahomeyan formation, which consists of alternating acidic and basic bonds of massive gneiss, with subordinate schists and migmatites. The area is highly weathered, with deep, slightly permeable to impermeable calcareous clays covering the rocks depths of about 25 m.

3.1.4 Soil characteristics

Generally most of the soils in the study area are from the Dahomeyan Rock formation, which are heavy black and clay soils, known as plastic montmorillonite clays which are highly expansive when wet, but crack deeply when dry. Some of the existing linings of laterals and canals show symptoms of damage due to this soil movement. Soil is shallow which overlies a coarse formation and have comparatively low fertility levels. Clay cracking is a problem why hydraulic conductivity is high, also there is phosphorous deficiency, low iron and zinc levels and some parts having salinity problem where crop growth is patchy or totally inhibited (DLDS, 1984).

3.1.5 Vegetation

The predominant vegetation type of the study site is of the short grass savannah interspersed with shrubs and short trees, a characteristic of the Sub- Sahelin type. A large portion of vegetation remains dry for most parts of the year particularly towards the south except for the short rainy season. Along some stream courses, however, higher vegetation type ranging from thickets to light forest is common. Some light forest with tall trees is also found along the foothills of the AR especially around Dodowa, Ayikuma and Agomeda areas. There is a Forest and Game and Wildlife Reserve around the Shai-hills. Isolated stands of baobab trees are common all over the plain and in the Volta flood plain areas, tall swampy grass and tall grass savannah with isolated patches of thicket and trees represent the main vegetation type.

4. RESEARCH METHODOLOGY

Generally the data that was used for the study objectives were gathered through the following; desk study and literature reviewed, data collection from G.I.D.A individual farmers (questionnaire administration, focus group discussion, interviews with key informants and from secondary sources), field's studies: sampling of soils for physical and chemical properties to ascertain their relationship with crop yield.

4.1 Desk Study

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Reports on the Dawhenya Irrigation Project, Irrigations Projects in Ghana and their operations and management, Guidelines and Operations and Maintenance were obtained and studied for information on the area of study. This was done to have an understanding of the research and helped in information gathering. This also helped in finding out solutions to the above problem statement.

4.2 Field Studies

Reconnaissance of study area was done for analysis of soil sample. This was done to compare the output of the management options, in relation to their crop yield.

4.2.1 Soil Sampling

Sampling points were selected to cover the entire functional irrigation facilities at Dawhenya Irrigation Project. Soil samples were taken from twenty (20) rice fields at a depth of 15 cm. Sampling procedures and analysis used are as follows:

- Soil samples were collected for physico-chemical analyses in well clean and unused polythene.

- Analyses of the soil sample were commenced within forty-eight hours. Analytical methods used were in accordance with the Guide to laboratory establishment for plant nutrient analysis, by the Food and Agriculture Organization of the United Nation (Motsara and Roy, 2008).
- The parameters analysed are as follows pH, Electrical conductivity (EC), Organic Carbon, Organic Matter, N, P, K, Ca, Mg, and Na.

4.3 Primary Data Collection

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Primary data was collected by the use of formal and informal survey methods. Formal surveys were also carried out with the help of standard questionnaire designed to obtain information from farmers. Discussions were also made with key informants such as the farm manager, cross-section of people who were farmers at the start of the project, and now have rented their lands, head of the co-operative society and some technical men of the Dawhenya Irrigation Project.

4.4 Secondary Data Collection

In addition to the primary data that was collected through questionnaire administration. Crop yield of D.I.P, reports on rehabilitation of irrigation projects and reports on D.I.P were collected from G.I.D.A, Nelson and Sons Limited (private farmer), office if the D.I.P, journals and news papers

4.5 Focus Group Discussion and Key Informants

Primary data was collected from farmers' at the DIP through questionnaire administration and information on the successive managements of D.I.P. were attained through focus group discussion, with some past Leaders of the Dawhenya Co-operative Food Farming Society, Nelson and Son's Limited and GIDA.

4.6 Data Analysis

Data collected (both qualitative and quantitative) was categorized into different components and the analysis was carried out after fieldwork. A compilation of the responses from the farmers through questionnaire administration, laboratory results of the soil analysis, crop yield records from the G.I.D.A were carried out (formulation of data into graphics and tables), to assess the management of irrigation systems and to determine the factors for sustainable operation and management of irrigation projects.

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5. RESULTS AND DISCUSSION

This chapter outlines the results of the study at D.I.P. The findings are part of the study aimed at assessing the effects of management of the D.I.P. in the Greater Accra Region of Ghana on its sustainability and crop yield. The analysis was done for different rice fields at the study area.

5.1 Social and Economic Profile of the Study Area

The social background of farmers at D.I.P had influence on adoption of technology, organisation of farmers and farm management behaviour. The farmers are of mixed origins, but the majority are from the local Dawhenya area. Out of the 30 farmers interviewed, 20% have alternative occupations because of their low returns, also difficulty in management, lack of funds and resources affected their minimum required cultivation activities. From the above results production and management of the systems, should not be affected too much, but for lack of funds and minimum extension services offered, management of the project was affected. Thus management must ensure that minimum responsibilities are properly carried out. Difficulty to market farmers' product had also affected management of the project.

5.1.1 Education

The educational status of the farmers at D.I.P. is shown in Table 4.2 below. Out of 30 farmers interviewed, 50% of the farmers had basic education, while 36.67% of them had second cycle education. From the analysis it may be that the low educational level of the farmers may contribute to the poor recording of data (end of season farming activity) which can affect the operation and management of co-operative society.

Table 5.1 Educational Status of the Farmers

LEVEL OF EDUCATION	PERCENTAGE (%)
None	6.67
Basic	50
Secondary/Technical	36.67
Tertiary	3.33
Others	3.33

Source: Survey Results, 2008

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5.2 Management and Institutional Issues of D.I.P

G.I.D.A of M.O.F.A was in charge of the management of D.I.P including all irrigation projects in Ghana before the implementation of government policy, where farmers' organisation took over. From the data analysis, 63% out of the 30 farmers interviewed answered that poor management of the project did contribute to the suspension of it. From the 30 farmers, there are no associations between the various divisions of canals network, as well as ineffective communication between the farmers' organisations and G.I.D.A. In the multiple plot system as can be found in the study area, farm activities must be monitored to ensure smooth running of the system (Stern, 1998). Efficient operation and maintenance of the systems largely depends on the services at the disposal of the farmers, such as training, supply of inputs, marketing, credit, etc. But these were poorly provided by co-operative society. It was realized that cooperative had no linkage with other irrigation agencies for support and the absence of irrigation associations might have affected farmers yield. This may reduce the effective operation of the on-farm facilities; this can reduce farmers' participation in management of D.I.P.

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Again co-operative pre-existing indebtedness to E.C.G led to the deterioration in the operation and maintenance of the systems, since they were not in use. When government shifted the requirements of organization and management, to the farmers; they were then constrained by limited funds, lack of strong leadership, lack of training for the executives, lack of administrative procedures, poor linkages, etc to manage the system. However this affected farmers' productivity reducing each year the area of cultivation since farmers vacate their farm holdings. Analysis showed two different forms of management, which are the individual farmer and a privately owned (Nelson and Sons). Due to the absence of support mechanisms by way of institutional arrangements, D.I.P is showing signs of decline, decrease in the performance of productivity and increase in the deterioration of structures. Thus farmers' association and approval of any operational plan can be a vital tool for the sustainability of D.I.P.

5.2.1 Management of Irrigation Infrastructure

From the farmers 30, even though they became in charge of the management of the irrigation facilities; the turnover was not fully acknowledged by them. The method of water application is through pumping and natural gravity. The management of the irrigation system reposes on a number of inter-related functions carried out by the farmers in the system. The functions are driven by the flow of information and resources. The performance of these functions can be affected, if not conditioned. The functions are water management function, agricultural production and organizational function. Currently all the farmers use motorised pumps to lift water to the fields. The significant difficulty with the full function of the irrigation systems is the inadequate operation and maintenance of them: this can be attributed to the insufficient irrigation service fee collected from farmers, the often breakdown of the pumps and lack of training. For the irrigation systems to be effectively managed by the farmers' organization they must accept the full responsibility that involves some kind of organizational and management mechanisms that will agree to ensure efficiency, thus there must be capacity building of the farmers co-operative. This will help evaluate possible constraints that can arise due to policy, institutional and social factors in the implementation and operation of other irrigation projects.

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5.2.2 Irrigation Management Issues of D.I.P

The farmers (30) responded that personnel's from G.I.D.A had visited the project site few times to see what actually is happening on the ground. The self-sufficiency policy adopted in 1970's in Ghana resulted in the creation of G.I.D.A of the Ministry of Food and Agriculture, as a semi-autonomous organization in 1977. G.I.D.A. was established for the systematic planning and development of irrigation projects in the country. The organizational structure (refer to Appendix A2) has the representatives of GIDA at the hem of affairs, with the following functions; to manage the affairs of D.I.P including the farmers and ensure higher productivity on the D.I.P, monitors the performance of the irrigation systems, and maintains a firm grips over staffing and in charge of provision of adequate technical expertise. It was realised from field study that there exist less coordination and integration of agricultural activities, limited funds and personnel for technical guidance. More seriously there is no strong communication between GIDA and the project manager as well as the farmers. There is also exist inadequate managerial support from GIDA.

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Project Manager: he is charge of the implementation of the decision taken by GIDA, with the assistance from the other team of committees under him. With them, there must be coordination of farmers' activities and control of D.I.P programme. Upon the interview with him, there exist difficulty in the implementation of the programme plan from GIDA, as well as less supervision and control of projects activities.

Department of Cooperatives: this is under Ministry of Social Welfare and Employment, where farmers on all irrigation projects, example D.I.P are assisted on organizing themselves into a cooperative society. The department registers and issues certificate to them. It also has training officers who trains the cooperative society. From the interviews, it was known that not enough training was given to farmers, as well as failing to assign them on a mini project, to report on the results attained. The executives of the cooperative were not equipped with much managerial issues to continue with the organization of the individual farmers.

Farmers Cooperative: they comprise of all registered farmers by the Department of Cooperatives and their functions are as follows; to arrange for the sale of produce, provide facilities for the processing of produce, arrange for supply of farming inputs and to educate members on the cooperative rules and regulations. During the field study observation made was that, there is difficulty in assessing inputs, equipment for processing was in bad condition and also cooperative executive had no effective control on the individual farmer's activity. Below is the management structure of the farmers' cooperative society.

Figure 5. 1 Organizational structure of the cooperative society

Management Committee: This comprised of (7) elected committee members: the extension officer, co-operative training officer and three (3) employed staff by the society, headed by the president of the society with the business manager as the secretary. Their responsibilities are sanitation work on the project, preparation of cropping programme, budget for that year and land preparation services and their pricing. The society had five staff members, headed by the Business Manager, who were to implement decisions taken by management and to report to the president. There were also many sub-committees formed under the Management Committee to assist in the operations of the irrigation project: they are lateral leaders, canal inspectors, etc. Their overall responsibility is to monitor the activities of the farmers whether they are operating in accordance with the rules and regulations. Farmers' organization obtained assistance from supporting agencies during the periods of joint management through the European Development Fund, for rehabilitation of the project, revolving fund, etc. where Agricultural Development Bank manages it farmers. The revealed that all the sub-committees under co-operative officer are all not in existence. This may reduce the efficiency in the operation and management of the project and the maintenance of facilities, services needed by individual farmers, are inadequate. Thus through their own efforts raise funds to carry out their cropping programmes and management work necessary that meets their financial ability. Therefore there is a need to improve the management capabilities of the farmers and the capacity of farmers' organization in co-operative management and administration for increased productivity and income.

Administration and Finance: as a five member staff, they are to implement decisions taken by management and to report to the project manager. Also they see to the day to day activities in the office, such as data processing, credit management and funds. Upon the discussion with the book keeper, there is poor record keeping and absence of credit service, which can affect the sustainability of the project.

Agronomy Department: they are in charge of extension services for the smooth running of D.I.P. The department has extension officers who offered technical guidance to the individual farmers and farm workers. Also training works were been organized for the water bailiff person, as well helping them in the planning of the projects programme. It was clear that the extension system was weak: no constant in-service training for field staff and individual farmers.

5.2.3 Agricultural Extension

According to the 30 farmers only two (2) extension officers were given them after the turn over for extension purposes, which had other responsibilities. The core plan of extension course is to instigate change to bring about sound agricultural development. This provides technical knowledge and supplies necessary inputs and services. The farmers practice irrigation without essential technical know-how on crop water management, water application methods, etc. which can lead to water shortage and production losses due to farm level mismanagement and mishandling after harvest, hence decrease in yield. Farmers lacking of proper knowledge on irrigation water management can result in water loss and water logging problems (Van Den Ban and Hawkins, 1988) on fields. The co-operative society is now non functional due to limited funds and inadequate leadership and administrative skill. This has influenced the improvement of the farming system, thereby reducing their yield. From the analysis it was understood that lack of adequate credit, appropriate market and inadequate farm machinery, also had influence on yield.

The following points were realized during the discussion with the farmers;

- The irrigation engineers have rarely been involved in the management of the system, thus cannot incorporate feedback facilities operations and their assumptions about management.
- Poor information flow between management.
- There is low coordination and integration of agricultural activities by management, as well as poor monitoring of farm activities.
- The type of irrigation system been practiced, which needs elemental cost for each of the components involved in the operation of the scheme.
- High cost of electricity tariffs and inputs.
- The use of inexperience people for the operation of certain key components of the scheme (pump station) and the continuous use of lean staff at the station.
- Inadequate technical staff from G.I.D.A to offer technical assistance to the farmers.

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The costs of organization and management at Dawhenya had negative impact on some farmers' income thus the inability to contribute towards the sudden high costs of energy and maintenance on time. Currently all the institutional mechanisms are disintegrated, making operation and management of the project very difficult. Moreover cooperative which played a pivotal role in the running of the project had several of its equipments in worst state, which affected the management of the project and crop yield. To attain sustainable farmers' organization for D.I.P management, implementation of credit scheme can be established as a means of strengthening the organization financially as well routine organization of training workshops.

5.2.4 Inputs

Out of the 30 farmers attended to, 80% of them responded that the access to inputs is difficult, thus have affected their crop yield. At DI.P cropped areas have decreased few years after government withdrawal, simply because plot holders were unable to organize the working capital needed to hire tractors, buy seeds and fertilizers, and to obtain services. When farmers do obtain the necessary capital, they often do not have ready access to good quality seeds and fertilizers, also difficulty to market their produce. Because co-operative society is no more in existence, subsidized fertilizers takes a long time reaching farmers. There is therefore a need to bring back the cooperative society as soon as possible, also there be a plan to establish a centre for farmers to have direct access farms inputs, as well as to attract government support.

5.2.5 Credit Facilities

Of all the thirty (30) farmers interviewed 83% attributed the absence of credit service to be a contributing factor of the limitations to the farming system improvement.

Irrigation farm management requires more financial input than rain fed agriculture. Farmers at D.I.P are not capable to meet capital requirements needed for the production activity, which did affect the operation and management of the project. However almost all the farmers (97%) said lack of government support previously through adequate credit services has gradually disappeared and affected continuous production. There is no micro-financial institution that provides loan to farmers in the study area. In the absence of formal credit service, informal credit sources can be used as an option to generate capital that can help to invest in a productive activity though it demands high rate of interest.

5.2.6 Training in Irrigation Management

From analysis 53% out the thirty (30) farmers attended to, answered they have had training in irrigation, whiles 47% said they have had no training. From the trained farmers, it was only in pest management and once when the project was government managed. For D.I.P to be sustainable, training should be a continuous process.

5.3 Average Yield of D.I.P. and Crop Yield of the Farmers

The assessment of the average yield of farmers at D.I.P (refer to Appendix A3) was done to help promote irrigated agriculture, since the rain fed was unable to meet domestic food demands. The D.I.P basically practices mono cropping, the main type of crop been is rice. When the farmers are beaten by time, they either plant a short term rice variety, coupled with different planting methods, the reason been that, they do not want to enter into the dry season during harvesting period.

From 1995 to 2003, there were poor yield records, showing inconsistencies in the farmer's crop yield, under both government and farmers managed; the farmers fail to either maintain or improve on their productivity. Using first season column, since there is insufficient data recorded in the second season due to bad timing of season, inadequate funds, not ready access to market at the end of first season to begin with the next season. Poor record keeping by the farmers as an indicator of bad management can affect their individual farming system improvement, thereby decreasing their crop yield. It can be seen that the farmers performed poorly to keep up with that good sign of increase from the year 2000. It may be also, there were meagre environmental practices by the farmers, as well as the magnitude of water losses in the leaky distribution systems, which means some fields receives less amount of water where plant growth may be affected. Moreover the act of mono-cropping might have depleted the soil nutrient, thereby decreasing crop yield. It was realised that withdrawal of the former management affected cooperative links with the extension personnel's. This reduced farmers' development in the appropriate technology for increased and stable agricultural productivity in farming systems. The following conditions may be essential for crop yield improvement: crop diversification, establishment of appropriate cropping patterns, improvement in the cultural practices and farm management capabilities.

The average yield record (refer to Appendix A4) was obtained during field study, from an individual farmer. This shows that some individual farmers had good yield records, but the average yield of the project is low, which may be due to low yields records of certain farmers. Such a farmer must be encouraged to increase in productivity. This strengthens farmers to cultivate each season, hence sustaining the project. The yield record of the individual farmer can also be attributed to soil characteristics, varying environmental practices, type of seed variety.

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5.3.1 Type of Rice Varieties Cultivated and Seed Selection

From the analysis all the farmers (30) plants local perfume rice, with maturity days of 120. On Appendix A5; shows rice variety types with yield records obtained in the past. Requirements were to select several high yielding rice varieties, with short maturity periods to allow for double cropping, resistance to lodging and known pests.

On Appendix A6; shows the results of two groups of farm ownership realised during the analysis. It can be seen from the table that the private organization, had better yield records than that of the individual farmers, thus the government can encourage such firms to get into irrigation agriculture, to help promote sustainability. This is because the land holding of the private organization is approximately 55 ha currently which encouraged certain farmers to come back after the suspension of the D.I.P.

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From figures 5.2 to 5.4 below, shows the plot of the average yield of farmers at their respective locations.

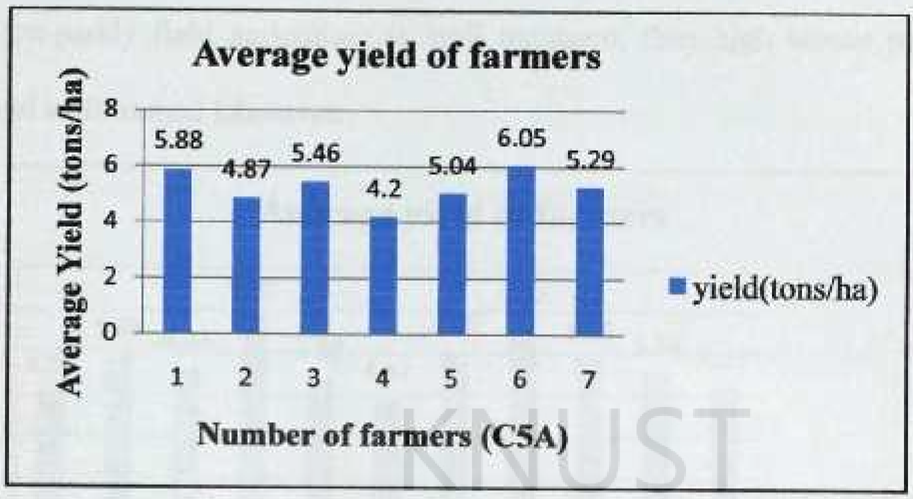

Figure 5.2 Average yield of the farmers (C5A) served by lateral C

In table 5.6, the private person had the highest yield at 'C5B' and from field study better management practices where practical on his farm compared to individual farmers.

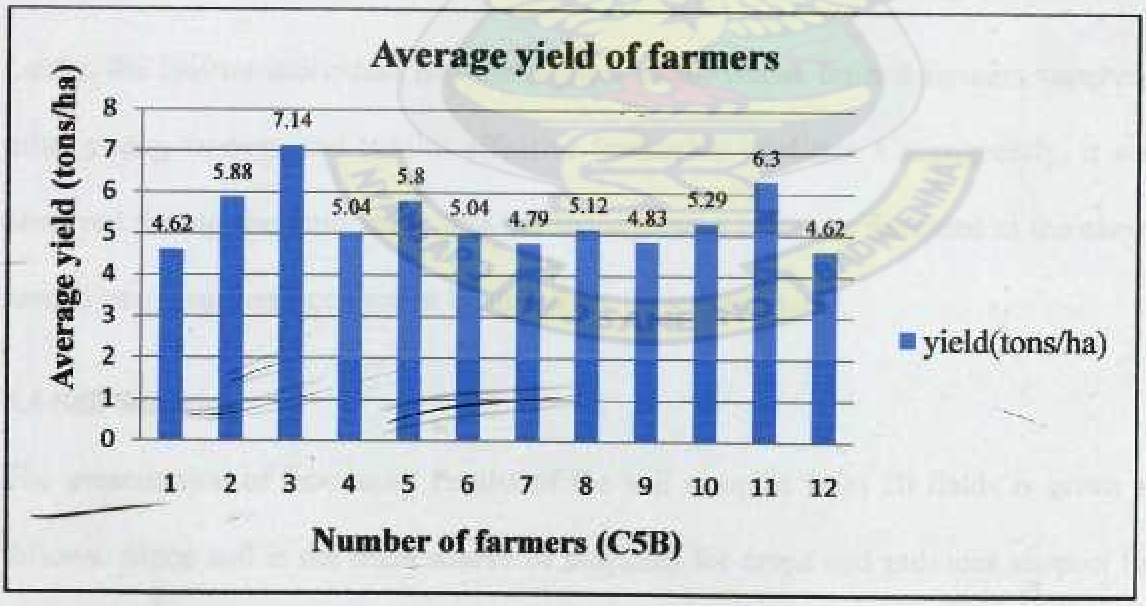

Figure 5.3 Average yields of the farmers (C5B) served by lateral C

Again the private farmer had the highest yield in the figure above, which may be as a result of the observed better management practices. Also the essential physical element for paddy field agriculture is well managed, thus high labour productive, reliable and well trained labourers.

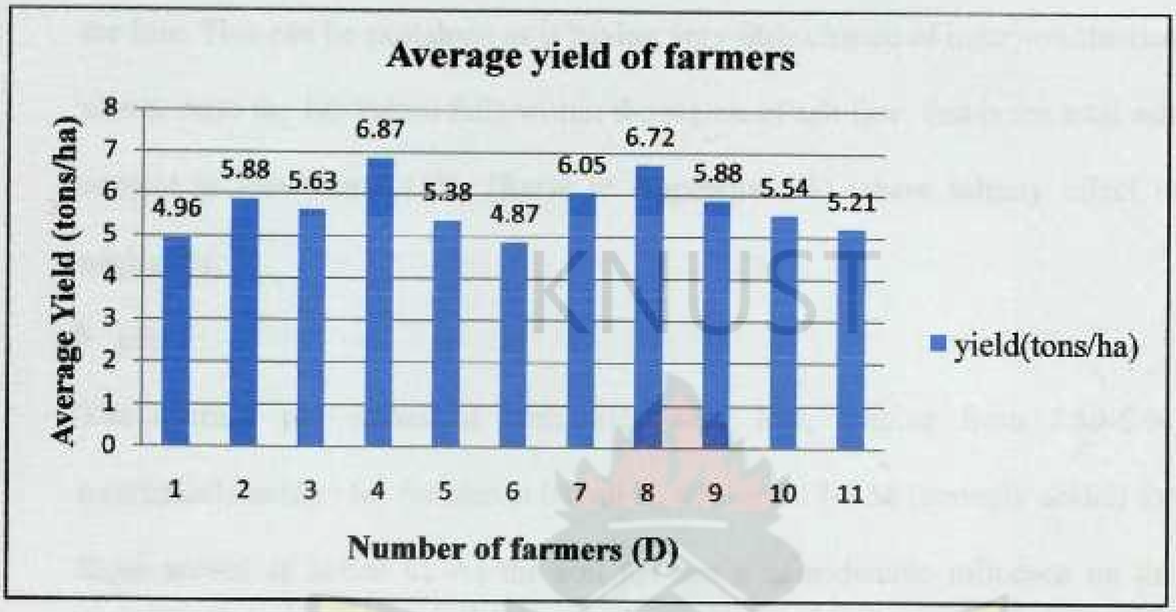

Figure 5.4 Average yields of the farmers served by lateral D

Lastly, the private individual had the highest yield, whose trained farmers supervise other young farmers and exhibit effective leadership qualities. Consequently, it was observed during the field study that the management practices executed at the above named two locations occurred at D also, thus better crop yield.

5.4 Soil Samples

The presentation of laboratory results of the soil samples from 20 fields is given as follows. Since soil is the main source of nutrients for crops and provides support for plant growth. For proper assessment of the crop yield, it was necessary to assess the capacity of the soil that supplies nutrients to the soil, thus the measuring of the soil properties at D.I.P.

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❖ **Electrical Conductivity (EC)**

The average EC values ranges from (105-159 us/cm) for the farmers been served by lateral D, whiles (40-140 us/cm) for those at lateral C. Generally the EC values of the soil are low, that is to say the soluble salts concentration in the soil are low. This can be explained as it having very little chance of injury on the rice plants. Also the EC values falls within the region of salt free, that is the total salt content is less than 0.15%. (Refer to Appendix D3) where salinity effect is negligible.

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❖ **pH**

The average pH values of both sites were low, ranging from 5.60-6.01 (moderately acidic) for farmers at lateral D, whiles 5.17-5.58 (strongly acidic) for those served at lateral C. As the soil pH has a considerable influence on the availability of nutrients to crops. Even though the pH ranges is two, moderately acidic and strongly acidic, they both lies within the range were most nutrients elements are available for plants, using their unit point values digits (refer Appendix E1).

❖ **Organic Carbon (OC)**

From soil analysis the average values of the OC obtained for the farmers served by laterals C and D are ; 0.83% and 0.98% respectively, that is within the low range, which means that the available organic matter for the plant uptake will be minimal for plant growth (refer to Appendix E3) which can affect productivity. The amount of available nutrients in the soil is of utmost importance to plant growth. If the available nutrients are more the uptake of it by the plants increases, which leads to increase yield. Thus knowing the composition of these nutrients reducing the crop yield, like in the case of the soil at lateral C. On a whole the soil suitability is averagely low, thus for optimum yields due regards should be given to the soil, plant and water relationship through management of water.

5.5 Water Management Systems

Water management is defined as the integrated processes of diversion, conveyance, regulation, measurement, distribution and application of the rational amount of water at the proper time and removal of excess water from the farms to promote increased production in conjunction with improved cultural practices. For the successes of introduction of double cropping, improvement in cultural practices, farm management. There is a need to improve upon the water management practices of D.I.P. Thus the following were identified at the D.I.P during the field study.

5.5.1 Checking of Bunds

93% out of the 30 farmers responded that they do check their bunds at the field regularly, since leakage of bunds complicates water management of plots in the lateral system. Therefore bunds are well maintained for effective use of irrigation water.

5.5.2 On-Farm Water Management Practices

On-farm water-saving practices is been done by the farmers at D.I.P to reduce irrigation application requirements and to improve the growing conditions, thereby increasing yield. The following were results were realized.

- From the data analysis, all the farmers (30) admitted they do capture all rainfall possible and only drain it if the rainfall is very high. When this is realised, the irrigation schedule is very well adjusted to this capturing of rainfall and the farmers rarely irrigate directly after rainfall.

- All the farmers (30) do go round to check the broken bunds immediately to fix them back after heavy rainfall. This is done to check any leakage before irrigation is done.
- The thirty (30) farmers' responded proper land levelling of fields is done during land preparation, not to create ponding on certain aspects of the field which maximizes the role of water management as well as uniform growth.
- Out of the 30 farmers 80% said they repair dikes before land preparation to impound water in the field, this is done manually with hoes.
- The 30 farmers responded that ponding depth in the paddy fields is maintained to be shallow to avoid excessive percolation and seepage losses.
- Only 10 out of the 30 farmers said they do hand weeding during the growing stages of the rice to reduce the amount of water use for a plant growth, and not only that but will also reduce nutrients uptake, thereby increasing crop yield.
- The soil is allowed to dry out for about 7 to 10 days, until cracks appear; this is done to check over application, also allows for oxygenation of the soil from the air and accelerates the decomposition of nitrogen, said the 30 farmers.
- 20 out of 30 the farmers in the dry season, do cultivate other crops which requires less water intake for plant growth, on some portions of the plot.
- 23 of the total farmers in the first season, do resort to a rice variety which uses less number of days to mature compared to the first season cropping seed, i.e. instead of 120 days, 90 days or less is realized.

- The field channels and irrigation supplies reaching farmers plot is maintained, to check wastage diversion, by all the farmers.
- All the farmers ensure availability of irrigation water and drainage facilities at on farm level which is essential for effective water management.

5.5.3 Intermittent Irrigation

From the analysis, the 30 farmers practice intermittent irrigation, where ponding of the paddy is reduced for weed control. This brings about improvement of irrigation water management, which leads to increase in rice cultivation, because it can be grown under diverse conditions without affecting yields.

5.5.4 Chemical Control

From analysis all the farmers' 30 uses herbicides as a good weed control for their rice cultivation. Farmers do scout regularly for new weed flushes after previous treatments, since weeds will germinate and emerge throughout the growing season. This may be very vital since less water will be used during application.

5.6 Maintenance Practices of D.I.P

With the expansion of Irrigated Agriculture, by the government of Ghana, sustainable operation and maintenance of the irrigation systems is prerequisite for performing a profitable agriculture harmonized with land and water conservation in irrigation projects. Thus there is a need to plan adequately on maintenance matters on projects, to improve productivity and sustainability of irrigation projects: D.I.P.

5.6.1 Operation and Maintenance Situation Report before Suspension

Maintenance of the Project: According to all the farmers, this became the duty of the D.C.F.F.S. after the turn over, thus individual farmers do the operation and maintenance of the project themselves, that is maintenance of pumps, canals, weed and de-silting, sub laterals, head-itches and dam wall. The maintenance was done with the Irrigation Service Charges (ISC) collected from farmers.

5.6.2 Operation and Maintenance on Dam

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Routine dam maintenance operations was defined by the co-operative society and carried out by all the farmers, which were the very essential part of the ongoing activities to ensure continuous safe operation of the dam. They include: tree and bush clearance on the dam, destroying ant and termite colonies on the dam, to prevent undermining and damaging of the dam structure. The upstream side of the dam is also protected from the combined erosive action of wind and waves, also floating grass and bulrushes are planted to minimize wave erosion.

5.6.3 Operation and Maintenance of the Reservoir

The farmers responded that nobody is responsible for the management of the reservoir, even though the executive had committee for such. This had serious implications for operation of irrigation project, since cropping culture depends very much on the volume of the water stored.

Automatic Level Recorder: this recorder is meant to measure reservoir levels and has been installed at the pump house sump but no personnel pays attention to the levels. Summary of the main operations and maintenance activities undertaken before the suspension of D.I.P; canal and lateral maintenance, cleaning, weeding, repairing, de-silting, pump maintenance, storage reservoir maintenance, renovation of fields and earthworks, road maintenance. From the field study the cause of poor maintenance of D.I.P. may be as a result of insufficient funds available for repairs and servicing.

5.6.4 Operation and Maintenance Report after the Suspension

There is total collapse of the cooperative society; which means the committees under them will all be non-functional, making all irrigation activities not effectively planned and practiced. The major maintenance activities undertaken by the 30 farmers presently are as follows:

- ❖ Maintenance of diesel pumps and repairs: (greasing, oiling the bolts and nuts)

  Currently all the farmers are using motorized pumps, because the pump station is not in operation, due to the deterioration and loss of certain key components.

- ❖ Lateral maintenance: The (30) farmers attend to the minor cracks found on some of the lined laterals, also clears off the natural weeds that do grow around the earth-lined field channels.

- ❖ Maintenance of distribution controlled structures (division box, checks, etc)

  Painting, repairs are done to the wooden and metal gates by the 30 farmers, which are used in the division box, only when they are in bad shape, to direct water to the rice fields of the farmers. For improvement in the maintenance of facilities at D.I.P there is a need for government to support the farmers' organization with funds for maintenance activities, also farmers must be educated to see themselves as owners of the project. This will enable them to fully participate in maintenance activities. Most importantly the project staff must plan adequately on maintenance issues, for by doing this increase in productivity and sustainability of D.I.P can be achieved.

5.6.4.1 Summary of the Conditions and Maintenance of Irrigation Facilities

Currently the existing structures like the canals and lined laterals are in bad conditions due to poor maintenance practices, soil movement, etc. Thus they provide little control on water deliveries and excessive weed growth, which lead to high rates of water loss. Thus data on irrigation facilities maintenance were obtained from field study, to measure the maintenance culture of the farmers; because proper maintenance of facilities is a prerequisite for efficient operation of irrigation projects D.I.P. Below shows a figure of the responses of the farmers interviewed on certain variables on maintenance. Routine maintenance activities which has to be repeated throughout the lifetime of D.I.P to keep it functioning, is on a decline. Thus long services of the facilities were not assured and that resulted in intermittent faults or break downs.

Not much routine maintenance is done on the structures and that has reduced the working power of the equipments (refer to Appendix B5). This may be as a result of increase in farmers' expenses, labour charges and material prices, coupled with the insufficient ISC for maintenance and repairs of the facilities. Again it may be because farmers were previously farming at Dawhenya in a manner which had many resemblances to upland rice production, rather than the paddy rice production which is necessary to produce high yields. The production system does not require such intensive and carefully timed operations, together with careful monitoring to ensure that operations and management activities are properly done.

5.7 Factors that Influenced the Management of D.I.P

After the planning and design of an irrigation project (D.I.P), there are control structures that must constantly be functioning to make D.I.P functional and sustainable. For this to be achieved, the management of D.I.P must be very efficient and effective.

5.7.1 Shrinkage and Swelling of Soils

At D.I.P, the soil structure in the field changes with the water conditions. Because most of the soils in the area are plastic montmorillonite clays which are highly expansive when wet but crack deeply when dry. However the above behaviour has affected some existing lateral linings, which do show symptoms of damage due to this soil movement. To obtain a high crop yield and suitable field environment for farming, good water management is vital. Thus understanding the effects of shrinkage and swelling of the soil is essential since the soil structure influences the permeability.

5.7.2 Farmers Reluctance to Diversified Cropping

Water is a limiting resource in most situations and its scarcity is expected to be increasingly acute in the future, due to the low irregular rainfall at Dawhenya. There are inherent differences among crops in relation to water needs, for example grain crops. Like rice production consumes much water, unlike vegetables. For several years farmers normally crop once in a year, due to production cost and bad timing of season, and have achieved low average income and low yield. Upon the interview with the farmers, they easily process their seeds from the harvested paddy, thus becomes reluctant in diversifying cropping. D.I.P farmers must be encouraged to do such to promote higher water use efficiency and income from farming. These farmers should also be flexible in crop choice especially in the dry season, and also must accept the provision of the cropping system and crop rotation programme from management which will enhance and maintain soil fertility.

5.7.3 Financing of the Rehabilitation Programmes

The financing of rehabilitation programmes may be the determinant factor in the rate of implementation. The government of Ghana and other supporting agency (European Union) have participated in the cost-sharing programme to rehabilitate the irrigation delivery infrastructure, without the farmers' contribution. Thus in 1996 when there was a forced shift of management according to the farmers (30), this brought about the withdrawal of the supporting agencies. Therefore because D.C.F.F.S was not financially capable to continue with the rehabilitation programmes, it affected the irrigation facilities, thus decreasing their rate of efficiency, since not adequate maintenance was done on these facilities.

5.7.4 Inadequate Credit, Inputs and Output Markets

Difficulties in obtaining credit have proved a major obstacle to viable, agriculture. At D.I.P, cropped areas did decrease sharply in every year, after government and the other supporting agencies withdrew their supports. Because of the farmer's low average income, co-operative society was unable to organize the working capital needed to hire tractors, buy seeds and fertilizers, and to obtain services. In addition, the project is located a little far away from towns and cities, which affected their linkages with other supporting agencies. Whiles few farmers (10) can obtain the working capital, they often do not have ready access to good quality seeds and fertilizers, to market their produce, etc. Thus the untimely withdrawal of government has brought about serious destruction of the past efforts of the farmers organization.

5.7.5 Type of Irrigation System

D.I.P practice both pumping and gravity method, where a lot of money is needed in the running of this system. The cost of electricity for lifting water from the reservoir to the rice fields is very expensive. Again these systems both have elemental cost which makes proper maintenance very difficult. Successful operation of D.I.P depends on proper management of these systems. Because maintenance is not properly done it did affect farmer's yield, therefore this might have contributed to the hastening in the implementation of government policy.

5.7.6 Transfer of Management

It was the government policy to transfer the management of all the irrigation projects to the farmers, in Ghana. In view of that, the government handed over the management of all the irrigation facilities to the farmers at D.I.P in the year 1996, but according to the farmers (30) interviewed, during the negotiations they resisted because they were not at that time fully adequate to manage D.I.P. Because there was not full acceptance on the side of the farmer's, the intended purpose of the management transfer was not realized: that is to improve the financial and physical sustainability of the project, agricultural productivity and water management. Transfer of management does not automatically result in such improvements. Thus there must be a need to understand the constraints and opportunities that goes with the transfer.

6. CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

The following general conclusions were drawn from the analysis of the results:

- The results indicated that 80% of the farmers currently working at the D.I.P. confirmed that access to inputs is difficult, whereas 83% stated that absence to credit facilities is a limitation to farming activities and 97% out of the 30 farmers stated that lack of government support affected their productivity.
- There is poor information flow between project engineers and the farmers on technical guidance in the operation and maintenance activities and also the availability of staffs from Ghana Irrigation Development Authority (G.I.D.A) for the planting periods is on a decline which delays implementation of decision.
- 52% out of the 30 farmers stated that routine maintenance is not done on the irrigation facilities which are due to farmers' low average income and inadequate planning. This signifies poor maintenance.
- Soil analysis results show that the soil conditions at Dawhenya are generally of low (organic carbon, total nitrogen, available potassium and phosphorous are all low 0.83%, 0.08%, 78 ppm and 3.80 ppm respectively according FAO standards.

6.2 Recommendations

- Management of D.I.P. must ensure common access be created for both inputs and credit facilities, to enhance farmers' activities. They must also attach importance to the routine maintenance, supervision and monitoring of farmers activities.
- Communication between farmers' organization and the management of D.I.P must be improved to enhance the management of the project.
- Irrigation trainings and management can be intensified to improve the maintenance culture of the irrigation infrastructures.
- Soil conditions can be improved, through crop diversification to enhance crop yield.

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APPENDICES

APPENDIX A1: FARMERS SURVEY QUESTIONNAIRE

I- Project and Farmer Characteristics

IA Background Information

1.1. Name ________________

1.2. Locality/Suburb ____________

1.3. Sex= M/F

1.4. Age = ____________

1.5. Education level of the respondent 1= none 2= basic 3= secondary/tech. 4= tertiary

1.6. Occupation of the respondent, 1= unemployed 2= trading 3= self employed 4= agriculture/ farming 5= others

1.7. What benefits do you get from the farmers produce? 1= food 2= money (through buying and selling) 3= others (specify)

1.8. Do you get all that you need from the crop that you produce? 1= yes 2= no

1.9. What are some of the benefits the community is receiving from the scheme?
1= decrease in unemployment 2= increase in food security
3= others (specify)________________

1.10. Specify the type of benefit you receive directly or indirectly from the scheme personally? ____________

IB. **Project participation and farmer training**

1.11. Do you have any specialized training on irrigation? 1= yes 2= no

1.12. For how long have you practiced irrigation? _________

1.13. Was the scheme constructed with the consent and full participation of the target beneficiaries? 1= yes 2= no

1.14. If yes, in what aspect did you participate?
1= simply attending discussion assemblies about the project
2= attending discussion assemblies and actively expressing feelings, ideas, views, etc.
3= others (specify) ________________

II. Crop Yield and Irrigation Water Management Practices

A. Crop yield

2.1. Location _______________

2.2. Farm size (ha) _______________

2.3. What area under irrigation do you normally harvest (ha)?__________

2.3.1 What crop you harvest? _______________

2.4. How much produce (kg) do you normally obtain from your irrigated area? ____

2.5. How many hectares of your cultivated land are accessible for irrigation? ______

2.6. Do you have a water bailiff? 1= yes 2= no

2.7. Does he go round to check how the water gets to the farm plots? 1= yes 2= no

2.8. What are some of the water management practices put in place?
1=checking of bunds every day, whether there are some holes created by grass cutters
2= not regular checking of bunds after every heavy down pour.
3= not regular checking of wooden check box.

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2.8.1 Tick the following water management practices that you normally observe.

Water management practice	yes	no
Do you irrigate after rainfall		
Fix of bunds after rainfall		
Proper levelling of rice fields		
Repairs of dikes during land preparation		
Maintains desired water depth using bunds height		
Hand weeding after tillering		
Soil allowed to dry until cracks appear		
Do you cultivate all your irrigable land in the dry season		
Change of rice variety during the dry season		
Are field channels well maintained		
Do you practice intermittent irrigation		
Use of herbicides as weed control		

B. Water availability and management

2.9. Do you irrigate all of your irrigable land? 1= yes 2= no

2.10. If not, why? (Circle as many as apply)

1= shortage of water 2= low productivity
3= getting sufficient produce by rain feed agriculture
4= poor quality of irrigation 5= poor maintenance 6= others, (specify)…………..

2.11. What source of water do you use?

1= river/stream 2= shallow dug out 3= others (specify) 4= natural pool/pond
5= artificial pond/dam 6= others (specify)

2.12. What type of water delivery system is used from the source?

1= motor pumps using electric power 2 = motor pumps using diesel power
3= diversion using gravity 4= others (specify) ____________

2.13. Who operates water devices or structures and distribute water to farmers?

1=IDA staff________
2=Farmers' association operator ________
3= Individual farmers ________
4= Others specify ________

2.14. Is there a mechanism of water pricing for facility users? 1 =Yes 2= No

2.15. If yes what is the price per year (or per ha)? ________
2.16. How much do you produce in a year? ________

III. Maintenance Practices and Designs

A. Maintenance practices

3.1. Who weeds and /or desilt the canals/drains?
1=IDA staff ________
2=Farmers' association operator ________
3=Individual farmers ________
4=Others, specify ________

3.2. Who repairs a crack in a canal bank? 1= Individual farmer 2= Hired labourers 3 =staff from the management 4 = Others, (specify) ________

3.3. Who inspects the canal systems? 1=the individual farmers 2= irrigation committee 3=IDA staff member 4= others, (specify) ________

3.4. Is there a regular check on the bunds? 1 =Yes 2= No

3.5. Is there a routine greasing on the gates? 1 =Yes 2= No

3.6. If yes it's been done by who? 1= hired labourer 2= individual farmer 3= operational field staff 4= others, (specify) ________

3.7. Do you have the following structures in place? 1= gate and measuring structures 2= Steel structures 3= water level gauges 4= pumps

3.8 Is there a routine maintenance work on the above stated structures?

- gate and measuring structures; 1 =Yes 2= No
- Steel structures; 1 =Yes 2= No
- water level gauges; 1 =Yes 2= No
- pumps 1 =Yes 2= No

3.9. Who removes weeds from embankments and canals?
1=IDA staff ________
2=Farmers' association operator ________
3=Individual farmers ________
4=Others, specify ________

3.10 Is there regular check on field channels before water is applied to plots?1=Yes2= No

3.11 In your view what do you think may be the causes to the failure of structures? 1=Poor design construction, 2=Poor routine maintenance work, 3=lack of field experts 4=lack of irrigation facilities for maintenance work, 5= poor management of the scheme, 4=others, (specify) ________

3.12 Is there a regular check on repairs of damages on structures? 1=Yes 2= No

3.13. If yes, who normally does it?
1= A mason ________
2= one of the scares ________
3=Individual farmers ________
4=others, specify ________

B. Designs

3.14 Which of the structures have cracks or defects in them?
1= canals, 2= laterals, 3=field channels

3.15 From the above stated answer(s) how many can be found in the affected structures.

1= canals………… 2= laterals…………3= field channels………

3.16 What is the defect that can be likened to the water control structure?

1= not well fitted to the spacing in the division box

2= rotten/rusted

3= others, specify……….

3.17 In which of the structures can we find leakages around them.

1= canals: specify the number………

2= water control structures: specify the number………

3= laterals: specify the number………

4= field channels: specify the number………

3.18 At what depth has the above listed structures been silted.

1= less or equal to 1 cm 2= in between 1 and 3 cm

3= in between 3 and 5cm 4= others, specify

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IV. Labour availability, land preparation and crop management

4.1. **What type of labour do you use for the following Irrigation activities?**
(Please indicate all types used)

Activity	Self	Spouse	Other household members	Hire Labour	Other
Land Preparation					
Planting/Transplanting					
Weeding					
Applying Agro-Chemicals					
Watering					
Harvesting					
Transporting & Storing					
Others (specify)					

4.2. **If you hire labour fill in the following.**

Activity	NO. of Men (Days)	Cost/Day (GH¢)	Total Cost
Land Preparation			
Planting/Transplanting			
Weeding			
Applying Agro-Chemicals			
Watering			
Harvesting			
Transporting & Storing			
Others (specify)			

4.3. Did the payment for hired labour increased because of irrigation? 1= yes 2= no

4.4. If you do not hire labour why?

1= have enough family labour 2= too expensive 3= not available labour to hire

4= others (specify) ___________________________________

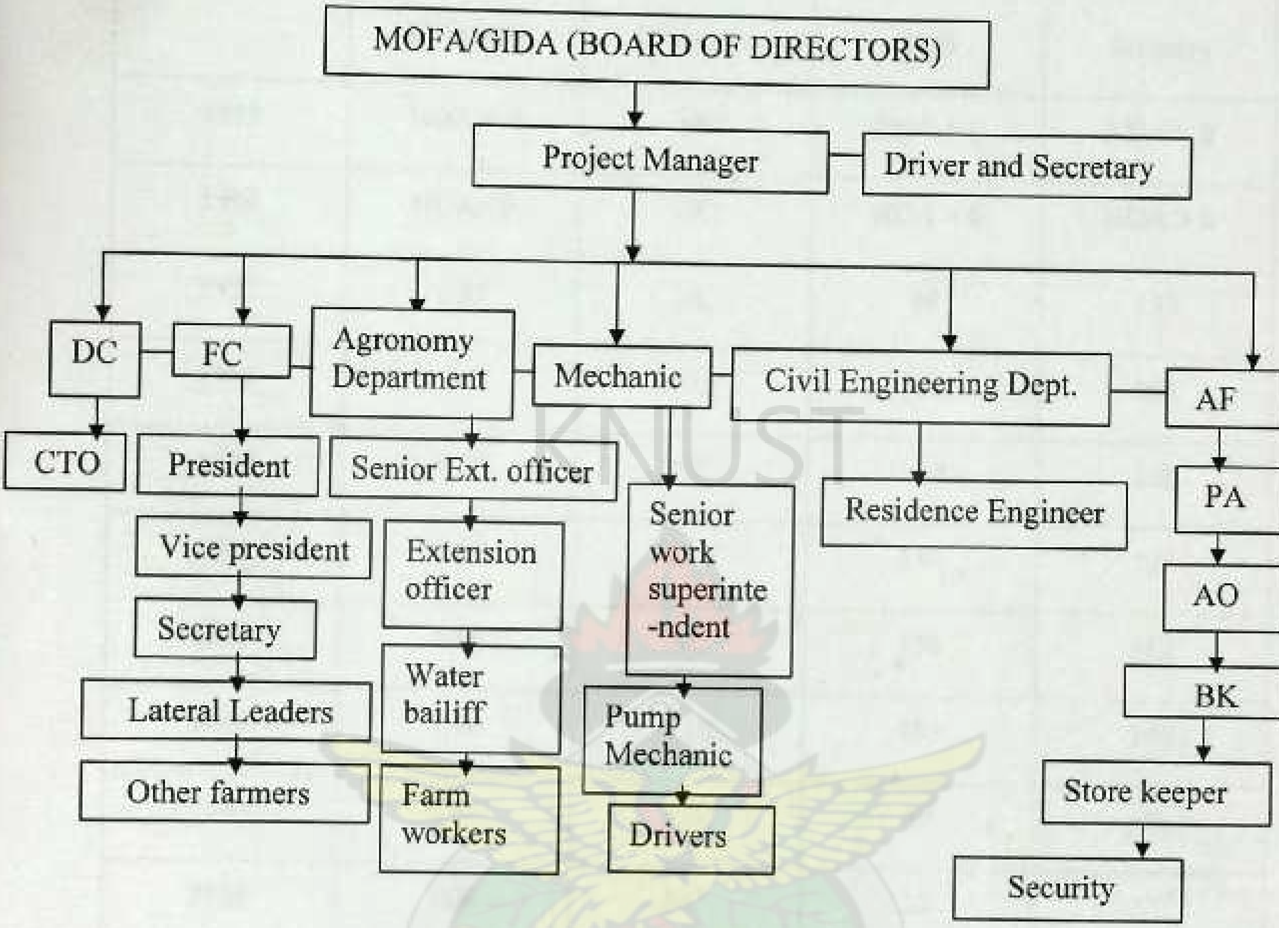
4.5. Outline some of the positive impacts of irrigation observed? (rank in order of importance).

1= change in the number of meals eaten per day
2= change in the type and variety of food eaten
3= change in the amount of money spent on education, health, clothing, etc.
4= change in the ability to cope with draught
5= change in coping strategies during times of food shortage
6= diminish in crop failure and increase production
7= change in the amount of products sold for income
8= enhance employment opportunity during irrigation season
9= diversification of crop grown
10= others (specify) ____________________________

4.6. Rank the following important factors which affect your output (yield).

Factors	**Rank**	**Extent of the problem**		
Water		**Severe**	**Not Severe**	**Considerable**
Land				
Input				
Credit				
Market				
Transport				
Crop damage				
Competition				
Absence of government support				
Lack of skill				

APPENDIX A2: Organizational Structure of D.I.P



AF... Administrative and Finance; AO ... Account Officers; BK...Book Keeper

CTO ... Cooperative Training Officer; DC... Department of Cooperative

FC ... Farmers Cooperative; PA ... Project Account

APPENDIX A3: Statistics of Rice in the DIP (unit: ton/ha).

YEAR	AVE. YIELD, 1st Season	AVE. Yield, 2nd Season	Area in use (ha)	Number of farmers
1995	NDA > 0	NC	NDA > 0	NDA > 0
1996	NDA> 0	NC	NDA > 0	NDA > 0
1997	6.67	NC	80	130
1998	5.42	NC	155	204
1999	5.50	NC	160	218
2000	7.80	4.80	140	155
2001	4.63	NC	150	182
2002	3.41	5.10	143	140
2003	2.87	3.10	87	90
2004	5.00	NC	20	15
2005	5.20	NC	30	15
2006	5.30	4.3	NDA >0	NDA > 0
2007	5.20	3.9	NDA > 0	NDA > 0

Source: Report on evaluation of the impact of the project of farmers' participation in farming, 2000. 'NDA'= no data available, 'NC'=no cropping

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APPENDIX A4: Rice yield of an individual farmer at D.I.P (unit in tons/ha).

YEAR	1st Season Yield	2nd Season Yield	Seed Variety
1998	6.69	NC	ITA 222
1999	6.67	NC	"
2000	6.91	5.10	ITA 406
2001	6.30	NC	Local perfume rice
2002	6.80	5.05	"
2003	4.94	3.11	"
2004	7.07	NC	"
2005	6.44	NC	"
2006	5.71	5.80	G.K. rice
2007	6.27	4.03	Local perfume rice

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APPENDIX A5: Rice variety types

Variety	Maturity Days	Yield (tons/ha)
DS3	114	6.21
IETS 6279	143	5.88
ITA 312	132	6.86
ITA 306	129	7.18
BW 348-1	126	6.52
ITA 123	110	5.66
BR 316-15-4-4-1	110	6.11
Si Pi 692033	110	6.52
S 499B-28	118	6.29
UPL Ri 4	114	5.29
1990	126	6.29
TOX 1835-8-1	118	4.71
IR 22082-41-2	118	6.70

Source: Second Six Monthly Reports, July to December 1990.

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APPENDIX A6: Average yield of the two groups of farm ownership

Farm Ownership	Yield (ton/ha)	Farm Location	Farm Ownership	Yield (ton/ha)	Farm Location
Individual	4.20	C5A	Private	5.29	C5A
Individual	4.87	C5A	Private	5.88	C5A
Individual	5.04	C5A	Private	6.05	C5A
Individual	5.46	C5A			
Individual	4.83	C5B	Private	4.62	C5B
Individual	5.12	C5B	Private	5.29	C5B
Individual	6.30	C5B	Private	7.14	C5B
Individual	6.72	D2	Private	6.87	D2
Individual	5.63	D3	Private	5.88	D3

Source: Survey Results, 2008

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APPENDIX B1: Rank the following important factors which affect your yield.

Factors	Severe (count)	(%)	Not Severe (count)	(%)	Considerable (count)	(%)
Water	7	23.3	8	26.7	15	50
Land	3	10.0	7	23.3	20	66.7
Input	24	80	4	13.3	2	6.7
Credit	9	30	16	53.3	5	16.7
Market	16	53.3	10	33.3	4	13.3
Transport	1	3.3	7	23.3	22	73.3
Crop damage	2	6.7	19	63.3	9	30
Competition	14	46.7	9	30	7	23.3
Absence of government support	29	96.7	1	3.3		
Lack of skill	11	36.7	12	40	7	23.3

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APPENDIX B2: Project participation and farmer training.

Training in Irrigation	Frequency	Percent	Valid Percent	Cumulative Percent
Yes	16	53.3	53.3	53.3
No	14	46.7	46.7	100.0
Total	30	100.0	100.0	

Years of Experience in Irrigation	Frequency	Percent	Valid Percent	Cumulative Percent
from 1 - 5 years	9	30.0	30.0	30.0
between 6 - 10 years	6	20.0	20.0	50.0
from 10 - 15 years	5	16.7	16.7	66.7
from 16 - 20 years	3	10.0	10.0	76.7
from 21years and above	7	23.3	23.3	100.0
Total	30	100.0	100.0	

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APPENDIX B3: Average yield of farmers for the various farm locations.

Farm location	No of farmers	Yield(tons/ha)
C5B	1	4.62
C5B	2	5.88
C5B	3	7.14
C5B	4	5.04
C5B	5	5.80
C5B	6	5.04
C7	7	4.79
C5B	8	5.12
C5B	9	4.83
C5B	10	5.29
C5B	11	6.30
C5B	12	4.62

Farm location	No of farmers	Yield(tons/ha)
C5A	1	5.88
C5A	2	4.87
C5A	3	5.46
C5A	4	4.20
C5A	5	5.04
C5A	6	6.05
C5A	7	5.29

Farm location	No of farmers	Yield(tons/ha)
D4	1	4.96
D1	2	5.88
D3	3	5.63
D2	4	6.87
D1	5	5.38
D1	6	4.87
D6	7	6.05
D2	8	6.72
D3	9	5.88
D1	10	5.54
D1	11	5.21

APPENDIX B4: Summary of maintenance of the irrigation facilities at D.I.P.

Aspect of maintenance	Yes: Variable (Frequency)	Percentage	No: Variable (Frequency)	Percentage
Bunds checking	28	93.3	2	67
Routine greasing of gates (metal)	10	33.3	20	66.7
Routine maintenance on measuring structures	14	46.7	16	53.3
Routine maintenance on structures with metals	2	6.7	28	93.3
Routine maintenance on water level gauge	2	6.7	28	93.3
Routine maintenance on pumps	17	56.7	13	43.3
Regular check on field channels	25	83.3	5	16.7
Regular checks on repaired structures	18	60	12	40

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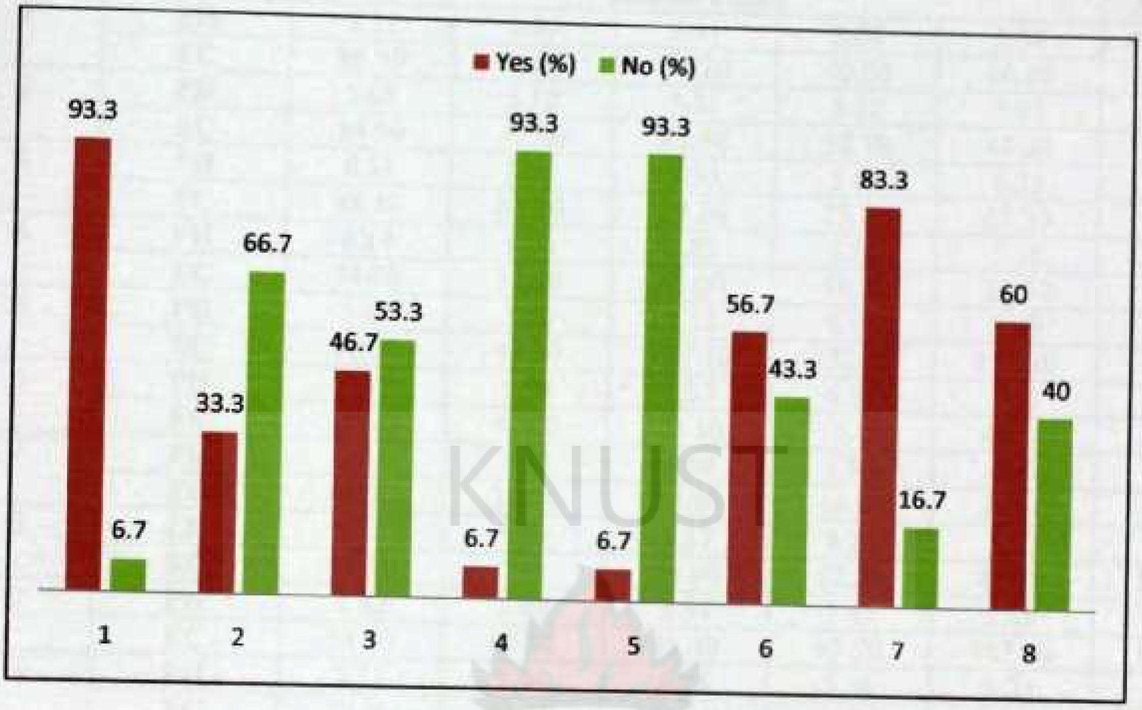
APPENDIX B5: General view of maintenance at Dawhenya Irrigation Project



1 Bunds checking
2 Routine greasing of gates
3 Routine maintenance on measuring structures
4 Routine maintenance on structures with metals
5 Routine maintenance on water level gauge
6 Routine maintenance on pumps
7 Regular check on field channels
8 Regular checks on repaired structures

APPENDIX C1: Results of physical properties of the soil at Lateral C

Fields	Parameter	Sample Points					Average
1	PH	5.11	5.99	6.11	5.08	5.38	5.53
	EC	86.90	81.50	77.20	70.90	60.80	75.46
2	PH	5.68	5.12	5.21	5.32	5.07	5.28
	EC	34.90	42.40	83.90	52.10	42.30	51.12
3	PH	6.31	5.31	5.35	5.08	5.35	5.48
	EC	88.80	83.10	78.30	73.80	67.30	78.26
4	PH	6.14	5.55	5.83	5.21	5.16	5.578
	EC	74.20	51.20	62.00	51.20	28.50	53.42
5	PH	5.63	5.55	5.12	6.01	5.49	5.56
	EC	52.00	42.30	137.10	132.20	132.30	99.18
6	PH	5.47	5.94	5.33	6.02	5.03	5.56
	EC	82.20	41.40	73.10	76.00	41.20	62.78
7	PH	5.65	5.48	5.59	5.99	4.97	5.54
	EC	49.70	34.00	34.60	44.90	39.50	40.54
8	PH	5.05	6.03	5.17	5.77	5.13	5.43
	EC	69.30	352	55.90	52.20	41.70	114.22
9	PH	5.82	5.08	5.97	5.45	5.49	5.56
	EC	54.10	69.80	35.40	63.70	483.00	141.20
10	PH	5.11	5.04	5.26	5.16	5.31	5.18
	EC	37.00	43.60	65.10	43.70	41.50	46.18

APPENDIX C2: Results of physical properties of the soil at Lateral D

Fields	Parameter	Sample Points					Average
1	PH	5.01	5.84	5.32	6.12	5.80	5.62
	EC	123.50	94.60	138.50	110.50	99.70	113.36
2	PH	5.91	6.40	5.55	5.41	6.00	5.85
	EC	134.00	69.10	193.60	89.70	120.90	121.46
3	PH	5.43	4.91	6.36	5.47	6.11	5.66
	EC	77.30	425.00	81.60	128.50	85.60	159.60
4	PH	5.51	5.54	6.38	6.77	5.77	5.99
	EC	134.50	104.90	116.20	159.70	147.10	132.48
5	PH	5.51	5.88	5.85	5.99	5.89	5.82
	EC	142.20	289.00	68.30	183.80	106.30	157.92
6	PH	5.98	5.11	5.95	6.14	6.88	6.01
	EC	109.00	211.00	88.20	128.70	82.90	123.96
7	PH	6.06	5.79	5.09	6.01	5.98	5.78
	EC	101.20	131.60	156	158.00	153.20	140.00
8	PH	5.43	5.87	6.76	5.85	5.94	5.97
	EC	69.80	128.00	123.70	138.90	157.40	123.56
9	PH	5.01	5.86	6.19	5.84	5.13	5.60
	EC	108.30	66.20	86.20	173.00	95.00	105.10
10	PH	5.41	5.74	5.37	5.79	5.90	5.64
	EC	100.10	179.9	171.10	108.50	79.80	127.88

APPENDIX C3: Content of available brays

Lateral C	
P (ppm)	K (ppm)
3.87	75.00
3.74	79.00
3.80	73.00
3.84	81.00
3.85	77.00
Average = 3.82	**Average = 77.00**
Lateral D	
2.91	93.75
2.98	93.59
2.93	93.64
2.97	93.84
2.96	93.88
Average = 2.95	**Average = 93.74**

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APPENDIX C4:Summary of the major chemical and physical soil characteristics

Property	Unit	Range: Lat C	Overall rating	Range: Lat D	Overall rating
Organic C.	% weight	0.79-0.87	Very low	0.96-0.99	Low
Total nitrogen	% weight	0.06-0.10	Very Low	0.08-0.13	Low
Organic Matter	% weight	1.40-1.46	Very low	1.67-1.72	Very low
Available K	ppm	75.00-81.00	Moderate	93.59– 93.88	Moderate
Available P	ppm	3.74 – 3.87	Low	2.91- 2.98	Low
Exchangeable Cations					
Ca	(me/100g)	9.01- 9.17	Moderate	10.35-10.53	High
Mg	(me/100g)	5.77-5.99	Moderate	17.75-18.09	High
K	(me/100g)	0.41- 0.47	Moderate	0.47- 0.69	High
Na	(me/100g)	0.39- 0.45	Moderate	0.55- 0.75	Moderate

APPENDIX C5: Summary of water management practices

Water management practice	Yes Count	(%)	No Count	(%)
Do you irrigate after heavy rainfall	0	0	30	100
Fix of bunds after rainfall	30	100	0	0
Proper levelling of rice fields before land preparation	30	100	0	0
Repairs of dikes during land preparation	24	80	6	20
Maintains desired water depth using bunds height	30	100	0	0
Hand weeding after tillering	30	100	0	0
Soil allowed to dry until cracks appear	30	100	0	0
Do you cultivate all your irrigable land in the dry season	20	66.7	10	33.3
Change of rice variety during the dry season	23	76.7	7	23.3
Are field channels well maintained	30	100	0	0
Do you practice intermittent irrigation	30	100	0	0
Use of herbicides as weed control	30	100	0	0

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APPENDIX D1: Values of Laboratory results of the selected soil sites at the Dawhenya Irrigation Project. (Lateral C)

Organic Carbon (%)	Total Nitrogen (%)	Organic Matter (%)	Exchangeable Cations (me/100g)				Total Exchangeable Base (T.E.B)	Exchangeable Acidity (Al + H)	E.C.E.C (me/100g)	Base Saturation (%)
			Ca	Mg	K	Na				
0.85	0.06	1.45	9.01	5.77	0.41	0.40	15.59	0.28	15.87	98.23
0.81	0.10	1.43	9.17	5.79	0.43	0.43	15.82	0.24	16.06	98.50
0.83	0.07	1.40	9.16	5.82	0.42	0.39	15.79	0.22	16.01	98.62
0.79	0.09	1.46	9.00	5.99	0.47	0.45	15.91	0.28	16.19	98.27
0.87	0.08	1.41	9.08	5.97	0.46	0.43	15.94	0.23	16.17	98.58
0.83	**0.08**	**1.43**	**9.08**	**5.87**	**0.44**	**0.42**	**15.81**	**0.25**	**16.06**	**98.44**

APPENDIX D2: Values of Laboratory results of the selected soil sites at the Dawhenya Irrigation Project. (Lateral D)

Organic Carbon (%)	Total Nitrogen (%)	Organic Matter (%)	Exchangeable Cations (me/100g)				Total Exchangeable Base (T.E.B)	Exchangeable Acidity (Al + H)	E.C.E.C (me/100g)	Base Saturation (%)
			Ca	Mg	K	Na				
0.98	0.10	1.68	10.36	17.80	0.47	0.68	29.31	0.13	29.44	99.56
0.96	0.08	1.72	10.35	17.75	0.58	0.63	29.31	0.14	29.45	99.52
0.99	0.12	1.67	10.53	17.85	0.69	0.75	29.82	0.16	29.98	99.46
0.99	0.09	1.69	10.45	18.09	0.50	0.64	29.68	0.17	29.85	99.43
0.97	0.13	1.68	10.38	17.78	0.64	0.55	29.55	0.15	29.70	99.49
0.98	**0.10**	**1.69**	**10.41**	**17.89**	**0.58**	**0.65**	**29.53**	**0.15**	**29.68**	**99.49**

The last rows values of the above two tables are averages.

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APPENDIX D3: General interpretation of electrical conductivity (EC) values.

Soil	Electrical conductivity (EC) (µS/cm)	Total salt content	Crop reaction
Salt free	(0 – 2)	(< 0.15)	Salinity effect negligible, except for more sensitive crops
Slightly saline	(4 – 8)	(0.15 – 0.35)	Yield of many crops restricted
Moderately saline	(8 – 15)	(0.35 – 0.65)	Only tolerant crops yield satisfactorily
Highly saline	(>15)	(>0.65)	Only very tolerant crops yield satisfactorily

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APPENDIX E1: Soil reaction ratings

pH range	Soil reaction rating
<4.6	Extremely acidic
4.6 – 5.5	Strongly acidic
5.6 – 6.5	Moderately acidic
6.6 – 6.9	Slightly acidic
7.0	Neutral
7.1 – 8.5	Moderately alkaline
>8.5	Strongly alkaline

APPENDIX E2: Available brays rating

Available – Brays (K)	Rating
< 50 ppm	Low
50 -100 ppm	Moderate
> 100 ppm	High
Available – Brays (P)	**Rating**
<10 ppm	Low
10 – 20 ppm	Moderate
> 20 ppm	High

APPENDIX E3: Exchangeable cations and organic constituent's ratings

Exchangeable Cations (me/100g)	Very low	Low	Moderate	High
Ca		< 5	5 - 10	> 10
Mg		<5	5 - 10	> 10
K		< 0.2	0.2 – 0.4	> 0.4
Na		0.1 – 2.0	2.0 – 6.0	> 6
Organic Constituents (% weight)				
Organic carbon/matter		0 – 0.09	0.1 – 0.2	> 0.3
Total Nitrogen		< 1.5	1.5 - 3	> 3

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Plate 5.1 Use of the salinity meter to measure salinity, pH, EC of the soil sample

Plate 5.2 The measurement of 25 g of the soil sample to mix with distilled using the mechanical shaker to have the supernatant been filtered.