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TOPIC: ASSESSMENT OF OPPORTUNITIES FOR SMALL SCALE IRRIGATION IN THE AHAFO-ANO SOUTH DISTRICT

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BY

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CERTIFICATION

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LIST OF ABBREVIATIONS

FAO – Food and Agricultural Organisation

GDP – Gross Domestic Product

GIDA – Ghana Irrigation Development Authority

HYV – High Yielding Varieties

MOFA – Ministry of Food and Agriculture

JICA – Japan International Cooperation Agency

IDC – Irrigation Development Centre

SMCD – Supreme Military Council Decree

IRDD – Irrigation Reclamation Drainage Division

UN – United Nations

USA- United States of America

TAW- Total Available Water

FC- Field Capacity

WP- Wilting Point

ZR- Rooting Dept

UK- United Kingdom

FMIS- Farmer Management Irrigation System

IIMI- International Irrigation Management Institute

SSI- Small Scale Irrigation

AMD- Allowable Moisture Depletion

ADB- African Development Bank

PRA- Participatory Rural Appraisal

JIRCAS- Japan International Research for Agricultural Science

SPSS- Statistical Package for Social Science

NGO- Non–Governmental Organisations

Hp- Horse Power

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DEDICATION

I dedicate this to my son, Nana Wiafe Akenten, and my late brother, Eric Owusu Achaw.

ABSTRACT

The study assessed the opportunities for small-scale irrigation, in the Ahafo-Ano South District. The sustainability, method of water application, major crops grown, water resources and constraints to the development of small-scale irrigation in the District were also assessed. Irrigation development is one of the approaches to addressing problem of poverty which is given significant attention in the economic development programme in the Ahafo-Ano South District. Survey of 100 farmers randomly sampled from five (5) communities was carried out. The study areas are Mankranso, Adugyama, Potrikrom, Barniekrom and Dunyan Nkwanta. Semi-structured questionnaires and focus group discussions were undertaken to assess the opportunities for small-scale irrigation. Parameters such as water application methods, water resources and availability, type of crops cultivated, sustainability of water resources, constraints and opportunities, types of fertilizer used, land management programme were considered in the assessment. Descriptive statistics was used to assess the impact of small-scale irrigation on farmer's livelihood before and after he/she adopts irrigation. The criteria for selection of communities' ability were small-scale irrigation, availability of secondary data and the crops cultivated. The analysis of results and personal observations revealed that farmers face many problems, thus resulting in smaller farm size, poor yields and low marketability of the produce during the season. The research had given specific objectives. These were to ascertain the sustainability of water availability and its application for small-scale irrigation farming and to determine availability and quality of water for small-scale irrigation farming. It was revealed that, the District is endowed with many water resources to sustain any agricultural venture but water management and protection are the main key problems hindering sustainability. The district has two major rivers Mankran and Dunyan. The second objective was to determine water resources, their availability and quality for small-scale irrigation farming. As indicated from secondary data analysis water in the area is of high quality and hence its usefulness. Farmers using traditional river diversions for rice production and diesel pumps for vegetable production had higher mean gross household income than farmers not using irrigation and also to determine the Opportunities and constraints for small-scale irrigation farming. The district has substantial water resource potential. What is constraining production is access to appropriate water management technologies infrastructure and institutional support services including finance, road, market, knowledge and capacity for technology development, pumps breakdowns and enabling the environment for effective private sector involvement.

CHAPTER ONE

INTRODUCTION

1.1 General Introduction

Irrigation is one of the means by which agricultural productivity can be improved to meet the growing food demand (Awulachew *et al*., 2005). The diversion of water for agricultural production often involve the use of formal irrigation schemes with extensive permanent infrastructural facilities as well as traditional flood recession practices under limited water control systems (Underhill, 1990). International agencies like the FAO and the World Bank, as well as national governments of low and middle income countries point at irrigation as an important tool to overcome food security. Such countries make huge investments in the construction, improvement and maintenance of physical infrastructure for efficient capture, distribution and use of water for irrigation

Project evaluations have shown that effective management of irrigation schemes in most cases is an enormous and unsolved problem. Moreover, research has made it clear that many modern irrigation schemes badly affect the socio-economic position of the rural populace. In general, African people face numerous challenges as they struggle to feed themselves and to generate sufficient income to meet their basic needs. These difficulties are often compounded as people are forced to farm on lands which have been degraded due to population pressures.

According to Molden (1998), irrigation in Africa as compared to what is happening in Asia has remained limited especially in Sub-Saharan Africa with a few medium and large scale commercial schemes developed during the colonial period and modest small irrigation sub-sector. At the continental level, it is apparent that Africa has not been able to intensify agricultural production and generate intra-continental trade to feed its growing towns and cities, and buffer the volatility of rainfed production (Sirte, 2008).

Most irrigation in Africa involves non- pressurised irrigation systems. The proportion of area with full or partial water control that is irrigated with surface systems ranges from 37% in the southern part to nearly

100% in the Sudano-Sahelian regions. In most parts, the proportion is greater than 80%. Sprinkler irrigation has been developed extensively in the southern region, where pressurised systems are found on 52% of the area with full or partial water control. Localised irrigation which includes drip and trickle irrigation system is not widely adopted in Africa. The largest areas are found in the Northern and Southern regions but rainfall is limited and some of the countries are more prosperous than in the other regions (Frenken, 2005).

In West Africa alone, 34% of the existing irrigation potentials has been developed so far, utilizing to a large extent 94% of surface water (Grimm & Richter, 2006). If a substantial increase in irrigated area is to be achieved on the continent, several limitations must be addressed. In this light, traditional irrigation that has thrived in the past, e.g., Democratic Republic of Congo (formerly Zaire) and Zimbabwe should be revived (FAO, 1993).

Agriculture is the main economic sector in Ghana, accounting for about 36% of its gross domestic product (GDP) (Sirte, 2008). It is predominantly practiced on small scale holder family operated farms using rudimentary technology to produce about 80% of Ghana's total agricultural output (Sirte, 2008). Even though it has been realized that irrigation holds the key to ensuring sustained food availability in the face of climate change, irrigation development has lacked investment at the appropriate level. Out of the known 1.9 million hectare irrigation potential, less than 2% has been developed and put to use (Sirte, 2008).

In the Ahafo-Ano South District of the Ashanti Region of Ghana, small scale farmers are in the majority. Among the many challenges confronting them is the erratic rainfall pattern. In addition to the high rainfall variability for agriculture, inputs such as fertiliser and insecticides are also not easily accessible to the farmer. In the quest to satisfy their food and cash needs, farmers practice small scale irrigation during the dry season from December to March each year. Vegetable crops mainly cabbage (*Brassica aleracea var Capitata*), lettuce (*Latuca Sativa*), tomato (*Lycopersicum esculentum*), Okro (*Abelmoschum esculentus or Hibiscus esculentus*), garden egg (*Solanum melongena*), carrot (*Daucus carota*), French beans (*Phaseolus vulgaris*), water melon (*Citrullus vulgaris*), hot pepper (*Capsicum *frutescens*), shallots (Allium ascalonicum) and onion (*Allium cepa)* are cultivated. The sources of water usefor irrigation in the district include streams, rivers, boreholes, dugouts and wells.

1.2 The Place of Small-Scale Irrigation in the Development of the Ahafo - Ano South District

Ever since the start of settled agriculture, irrigation has fascinated humankind with its possibilities of challenging the harshness and vagaries of the climate by artificially controlling the plants most vital needs of water supply. And so from prehistoric times up to the present, irrigation has been practiced by peasant farmers throughout the whole world. Small-scale irrigation is therefore hardly a new idea (Underhill, 1990).

The opportunities for expanding small scale irrigation in the Ahafo-Ano South District and in Mankranso and Adugyama in particular are considerable. There are vast unused lands that could be converted into irrigable lands. Water could be tapped from the rivers such as Mankran and Duyan, streams, wells, dugouts and harvested rain and stored in reservoirs or river basins for use during the dry season. This development will contribute to the solution of the food production problem through its major role in rural development, by mobilizing indigenous knowledge and skills at low investment level to encourage self-help activities, supported by judicious investments and technical assistance from the Ghana Irrigation Development Authority (GIDA), research and academic institutions such as Department of Agricultural Engineering, KNUST will be of tremendous benefit to farmers.

However, studies have shown that the self-reliance and motivation of indigenous management groups can easily be undermined by too much external assistance and that this is a real danger in the present situation of growing international interest in small scale farms. For this reason, care must be taken since too much help will prevent peasant farmers from taking charge and being responsible for their own lives.

1.3 Problem Statement and Justification

Ghana, as a nation, has twenty-two public irrigation schemes spread across the length and breadth of the country. According to the 2010 population and housing census, Ghana has a population of 24,223,431 with an annual growth rate of 1.7%. It has a total land area of 238,540km^2 of which cultivable area is estimated to be 42% (10 million ha) of the total land area (FAO, 2005), yet it cannot produce enough food to feed its inhabitants.

Large schemes have more psychological prestige and appeal of value to policy planners, donors or politicians than small scale schemes. In the past, most irrigation planning at the national level has been concerned with large schemes. There are several reasons, one being that planning, designing, appraisal, funding, construction and finally operation, management and maintenance are more efficiently done, in terms of cost per ha for large schemes. The large scale irrigation schemes require high input and management, accurate water supply system, and drainage control system, proper application of fertilizer, timing of all agricultural practices and a good marketing system. These requirements can only be met if inputs are readily available and the scheme is properly managed and worked by trained and skilled officials or experts and disciplined farmers.

Ghana is not self-sufficient in food production and it has been difficult to ensure food availability in sufficient quantities all year round (FAO, 2005). With the trend of population growth in the Ahafo-Ano South District, irrigation schemes must be properly managed to ensure maximum output to sustain the population. The need for more food should not be over-looked, since fertile land for farming is declining since much of the lands are now reserved for residential infrastructure leaving smaller plots at the outskirts of the towns, communities/villages and some at the backyards of houses for agriculture.

In view of the increasing population, increase pressure on land and rainfall variability, there is the need for intensification of small scale agricultural schemes in the district to provide food during the dry season. The benefits and nutritional values of fresh vegetables to the increasing population are considerable. Emphasis on the supply of quality water for the performance of efficient vegetable production in the district needed to be evaluated and assessed for various opportunities for small scale irrigation schemes in the district.

1.4 General Research Objective

The main objective of this research was to assess the opportunities for small scale irrigation in the Ahafo-Ano South District in the Ashanti Region of Ghana.

1.5 Specific Objectives

The specific objectives pertaining to this research were to:

- Ascertain the sustainability of water availability and its application for small scale irrigation
- Identify the water resources, their availability and quality for small scale irrigation
- Determine the constraints and opportunities of small scale irrigation for vegetable and arable crop production
- Carry out a comparative analysis of the various water application methods for improving vegetable and arable crop production and

1.6 Research Hypothesis

The research hypothesis is that food security and safety in the Ahafo-Ano South District is a function of regular supply of adequate quality water for small scale irrigation during the dry seasons.

CHAPTER TWO

LITERATURE REVIEW

2.1 Historical Importance of Irrigation

Historically, irrigation originated as a method for improving natural production by increasing the productivity of available land and thereby expanding total agricultural production, especially in arid and semi-arid regions of the world. Availability and access to irrigation was considered essential for crop production, asset creation and expansion of development frontiers. Rapid expansion of irrigated areas in the recent past, coupled with availability and access to new technology, high yielding varieties (HYV), fertilizers water and water extraction mechanisms in the late 1960s and 1970s were major underlining factors for the success of the green revolution in Asia. Better access to irrigation infrastructure facilitated intensification of cropping practices and inputs used, thus, paving the way for the modernization of the agricultural sector (Bhattaria *et al*., 2002).

Irrigation has long been seen as an option to improve and sustain rural livelihoods by increasing crop production. Irrigation can reduce dependency on rain-fed agriculture in drought prone areas and increase cropping intensities in humid and tropical zones by extending the wet season and introducing an effective means of water control. In the 1970s and 1980s, international agencies and national governments invested heavily in irrigation to intensify agriculture and reap the benefits of high yield potential of irrigated agriculture. The nature of donor sponsored development favoured large- scale projects rather than small ones and the majority of funding went into large scale irrigation schemes (Kay, 2001).

Water is a valuable resource for agricultural production. Scarcity and misuse of water pose a serious and growing threat to life and sustainable development. As water is the limiting factor in most of the world agricultural production increasing yield and sustaining food production depend mainly on irrigation. Therefore, protection and development of water resources are crucial for irrigation facilities (Degirmenci *et al.*, 2003). According to Guerra *et al.*, (1998), agricultures share of water will decline at an even faster rate because of the increasing competition for available water from the urban and industrial sector.

To achieve sustainable production from irrigated agriculture, it is obvious that utilization of the important resources in irrigated agriculture, water and land, must be improved. The question then is how is irrigated agriculture performing with limited water and land resources? This question has not been satisfactorily answered. This is because we are not able to compare irrigated land and water used to learn how irrigation systems are performing relative to each other and what the appropriate target achievements are (Behailu *et al*., 2005).

Improving water utilization of schemes, which require improving the management skills of the user, is one challenge to be tackled to ensure sustainability of schemes (Behailu *et al*., 2005). According to Small and Svendsen (1992), the assessment of irrigation performance is clearly important to managers of irrigation projects, but it has been seriously neglected by those who allocate public funds for irrigation and by researchers. Frequent monitoring of the performance of irrigation systems will assist to distinguish whether the targets and objectives are being met or not. It also provides system managers, farmers and policy makers a better understanding of how a system operates. It helps to identify the strengths and weaknesses, consequently alternatives that may be effective and feasible in improving system performance to achieve maximum efficiency. The important resources in irrigated agriculture, land and water, are the ones that should be considered and sustained in their productivity in order to meet the targets, (Behailu *et al*., 2005).

Rice is the most widely grown of all the crops under irrigation. More than 80% of the developed fresh water resources in Asia are used for irrigation purposes and about half of the irrigation water is used for rice production (Guerra *et al.*, 1998). Rice is the staple food for nearly half of the world's population, most of who live in developing countries. The crop occupies one third of the world's total area planted to cereals and provide 35-60% of the calories consumed by 2.7 billion people. More than 90% of the world's rice is produced and consumed in Asia.

The future of rice production will therefore depend heavily on developing and adopting strategies and practices that will use water efficiently in irrigation schemes. Such strategies and practices are also important for other part of the world, particularly in parts of Africa where demand for rice is high and water is less abundant than in Asia (Guerra *et al.*, 1998). For improve production as well as efficient utilization of water, it is suggested that the introduction of very small water fees will help in enhancing the irrigation practices to the desired level. This also helps to sustain the practice if it is operated and maintained by the beneficiaries (Behailu *et al*., 2005).

The performance of many irrigation systems is significantly below their potential due to a number of shortcomings, including poor design, construction, operation and maintenance (Degirmenci *et al.*, 2003).

With many variables that influence performance of irrigated agriculture, including infrastructure, design management, climate conditions and socio-economic setting, the task of comparing performance of system is formidable. However, if the focus is on communalities of irrigated agriculture water, land, finance and crop production, it should be possible to see, in the gross sense, how irrigated agriculture is performing with various settings (Behailu *et al*., 2005).

2.2 Brief History of Irrigation Development in Ghana

According to FAO estimates, corroborated by the World Bank in its "Ghana Irrigation Sub-Sector Review", 1986, Ghana has an irrigation potential of 120,000ha (World Bank, 1986). Although cultivation of vegetables using hand dug wells dates as far back as pre-independence era, modern irrigated agriculture started in Ghana under the Land Planning Unit of the Ministry of Food and Agriculture in 1955. The function of the above mentioned unit was mainly land planning for future development and successful agricultural use. In addition, land conservation was another of its prime targets. In 1962, the Land Planning Unit expanded to a divisional level in the Ministry of Food and Agriculture and named the Irrigation, Reclamation and Drainage Division.

In 1974, the Irrigation Department was established. This department had broad responsibilities for promoting irrigation, including technical studies and infrastructure development. The Ghana Government recognized the need to integrate the agricultural and engineering functions to achieve irrigation development in the country, and thus established in April 1977, an institution named the Irrigation Development Authority (IDA). Today, the Ghana Irrigation Development Authority (GIDA), a statutory organization in the country responsible for irrigation.

Over the past years, about 22 irrigation schemes of various sizes have been initiated in Ghana. By 1989, about 8850ha of irrigable area had been completed and handed over to farmers. More still remain uncompleted, owing to funding limitations.

In 1985 - 1986, the Government of Ghana, with the World Bank assistance, carried out a review of the irrigation sub-sector. A major finding of this review was that previous large irrigation projects in the country have had a poor record of success. They have been handicapped by many factors. Some of them had high investment costs, land tenure problems, high operation and maintenance cost, insufficient extension and input supply services. Other problems include: low level of community support (financial and otherwise) for the construction and maintenance of the schemes, conflict with traditional rain-fed farming and over-estimated yields. The review therefore suggested that the focus of future irrigation development should be on small scale community based schemes.

Current activities (since 1990) of Ministry of Food and Agriculture (MoFA) in cooperation with other relevant organizations, include the promotion of small and micro-scale irrigation, provision of water for livestock (especially in Northern Ghana) and the exploitation of coastal and inland fresh water for fish culture. The emphases are on the construction and rehabilitation of dugouts in the drier parts of the country. This trend is accompanied with the development of other rural infrastructure mainly in the area of drinking water supply for the convenience and health of the rural work force, majority of which are engaged in agriculture.

Most of the small scale farmer-managed irrigation schemes in catchments management involved the establishment of an agro forestry plantation up stream of the reservoir. Agro forestry plantation had the objective of reduction of sediment inflow to the reservoir, as well as decrease of evaporation from open water surfaces.

To facilitate GIDA'S improved performance, a research wing was initiated at Ashaiman, near Tema in 1991, with assistance from the Japan International Cooperation Agency (JICA). The research section is known as the Irrigation Development Centre (IDC) and it presently concentrates on studies mainly related to the agronomy of irrigated rice which is the main product of many Ghanaian irrigation schemes (Kranjac-Berisavljevic, 1998). GIDA was formed with the broad objective of multi-disciplinary irrigation development outlook with a vision to explore all water resource for livelihood option in agriculture at the appropriate scale for all communities. The mission of GIDA is to formulate and execute plans to promote the development of water and land resources in Ghana for crop production, livestock watering, agriculture, agriculture related industries and institutions within a suitable environment (GIDA, 2008).

2.3 Small- Scale Irrigation Developments in Ghana

The development of irrigation in Ghana is a priority in Ghana's efforts to meet the country's food needs and production of industrial raw materials (Keita *et al.*, 2007). The rehabilitation or construction of small scale irrigation schemes is guided by compliance with a series of strict technical criteria, in-depth site, technical studies and designs and cost effectiveness (US$ 10000-12000 per ha) (Keita *et al.*, 2007).

The potential for irrigation schemes in Ghana is very good although the experience in irrigated agriculture is relatively limited. Ghana's irrigation potential is estimated at 1.9 million hectare. Valley bottoms and flood plains could add another 1.0 million hectares that could be cultivated mostly to rice by employing water management technologies such as bunding, levelling and puddling. It is believed that overall about 27900ha of the total of 30900ha developed area or 90% were actually irrigated in 2000, while in the 22 public irrigation schemes, only 5600ha of the 8587ha developed area or 65%, were actually irrigated. This is due to the deterioration of the infrastructure because of lack of sufficient funds for maintenance (Sirte, 2008).

2.4 Small Scale Irrigation in Sub-Saharan Africa

The average rate of agricultural development for the countries of Sub-Saharan Africa from 1988-2000 was 43600 ha/yr bringing an additional one million hectares into irrigated production by the year 2005. Programme to achieve the UN millennium development goals will increase availability of funding for irrigation projects that would improve food production and security. The World Bank estimates that water infrastructure investment in the order of $180 billion per year are needed until 2025. While it is true that large scale irrigation systems have been constructed in this region, their performance records indicate failure with regards to their anticipated benefits. As a result of the shortcomings of these large scale systems, small scale irrigation were subsequently advocated (Faulkner, 2008).

Although, hardly noticed by the main aid donors until recently, small scale irrigation already plays a significant role in Ghana and other African countries. In Nigeria the *"fadama",* or seasonally flooded plains, cover hundreds of thousands of hectares. The development of these areas by small scale farmers has been rapid, assisted in some places by the World Bank (Carter *et al.*, 1984).

Inland swamps and flood plains are also widely used for small scale irrigation with partial water control. The oldest production technique in Mali is the flooded systems in the delta of the Niger and Bani rivers around the city of Mopti along the flood plains of the Niger towards Segou and to the Bani towards San. The only water control is the construction of earth dykes to prevent too rapid entry of water onto fields of young plants. In the more deeply flooded fields, floating rice varieties are grown and may be harvested from boats (Underhill *et al.*, 1990).

Similar areas of rice production are common in Guinea, Mali, Burkina Faso, Ivory Coast and Ghana. Similar to the *bolilands* of West Africa is the *dambos* of Central and Southern Africa, where they occupy around 10% of the total land surface (Bell *et al.*, 1987). They are thought to act as hydrological reservoirs, storing water in the rainy season and releasing it for evapotranspiration on the *dambo* surface and for dry season stream flow.

Coastal swamps and estuaries suitable for rice production exist around the West African coast from the Gambia River to Liberia, to a less extent further east, to Togo and Benin Republic. Production is most commonly in the hands of small scale holders using traditional methods but a substantial contribution is made to national rice production in the Gambia, Senegal, Guinea and Sierra Leone (Underhill *et al.*, 1990).

Small streams have been developed for local irrigation by peasant farmers throughout the continent. In Ivory Coast, nearly 19,000ha of valley bottom lands are irrigated by diversion water from small streams, in some cases with construction of small dams. Furrow irrigation from rivers has long been practiced by the Wa-Chagga on the slopes of Mount Kilimanjaro. Similar cases are also found in Zambia.

An alternative method exploiting seasonal river flow is by pumping or by hand shad of or mechanically. Shad of irrigation from surface water sources is still common in many parts of Africa and has the advantage of depending on local materials and labour only. Small mechanical pumps are now, however, becoming very common, purchased by the farmers on their own initiative or through government aided schemes. An example of mechanical pumps in use in Ghana can be found in the Upper East Region. Production of tomato along the tributaries of the Volta River using these pumps is common.

Shallow ground water is also exploited in many areas for small scale irrigation. Examples can be found in many communities in Northern Ghana (Navrongo, Kulaa and Lawra in the Upper West Region) and many other countries of Africa.

2.5 Advantages of Small Scale Irrigation

Small scale irrigation has several advantages which could be summarized as follows:

- Initiating a development process rather than planning a development action. This means stimulating dynamic and continuing process, rather than one-off change from one stable state to another though more advanced one.
- Little infrastructure is needed for small scale irrigation. It is of course likely that improved road and other communications or the provision of other services will increase irrigation productivity (as well as human welfare). Improved marketing facilities may be necessary if farmers are to profitably dispose of perishable crops such as irrigated vegetables. However, whereas investment in such social overheads is an essential element of large scale irrigated settlement schemes, small scale projects may prove viable with the existing infrastructure, to which step by step improvements may be part of a wider approach to rural development.
- Low take-off point or success threshold. Initially, a low technical efficiency, but this may be combined with a high economic efficiency as inputs are also low. Since development of this kind is a step by step process, the initial target is very modest, being an incremental improvement on the previous situation.
- No migration or resettlement of labour with all the associated costs is required for most small scale projects. They are usually established on existing farms often in association with, and complementing, rain-fed cropping. In these circumstances, irrigation may represent only a marginal change to a given agricultural system. The situation is different for large scale schemes which require large scale social transformations.
- Self reliance. Technology is based on the farmers' existing knowledge. Development is seen as a learning process, with pace of development dictated by the farmers themselves. This may initially be slow, though in fact probably no slower than in many large schemes where cost and time overruns are common. An advantage is greater robustness due to a large measure of independence from imported inputs: fuel, machinery, fertilizers and sophisticated skills, etc.

which are usually in unreliable or short supply and sometimes completely unobtainable. The small scale approach is therefore most suitable in countries with an acute shortage of foreign currency, shortage of skilled man power (technical and managerial), weak infrastructure, and a suspicion of authority by the peasants. The degree of self reliance or its opposite, dependence- will vary greatly according to circumstances.

- Mobilization of the human resources. Local skills – technical, managerial and entrepreneurial – are used more fully since the project belongs to the local people, they are involved in all stages of project development, and it is they who reap the benefits.
- Low external inputs.
- Small scale irrigation can provide vegetables and other food staples to the door steps of the consumers in the urban areas.

2.6 Problems Associated with Irrigation

- Irrigation development is not free from controversies. It has been argued that irrigation development in various regions has displaced marginal and poor farmers and has made them landless labourers and ultimately driven them to become urban dwellers (Chambers, 1998).
- Likewise, the social disruption of rural poor due to large scale irrigation systems and reservoirs construction, payment of inadequate compensation to displaced persons and increased incidence of water borne diseases in irrigation commands are other potential negative impacts associated with irrigation development (Bhattaria *et al.*, 2002).
- Increased water logging and soil salinity build-up due to poor provision of drainage facilities in irrigation systems are also often cited as negative environmental impact of irrigation (Bhattaria *et al.*, 2002).

2.7 Socio-Economic Impact and Poverty Alleviation Linkage with Irrigation

In addition to increasing crop production, farm and family income, improved irrigation access significantly contributes to rural poverty reduction through provision of employment and livelihood (Bhattarai *et al*., 2002). Irrigation farming is one of the most important rural development investments that can have direct and indirect impact on poverty and food security in semi-arid tropical countries (Nedumaran and Berger, 2009). The level of decrease in world food prices is the result of the higher rate of expansion of world food supply compared to rate of increase of food demand caused by population growth (Bhattarai *et al*., 2002). During the period from 1960 to 1990, global cereal production has expanded by more than 100%, whereas global population has increased by 70% (FAO, 1998).

According to Bhattaria *et al.*, (2002), the total beneficial impact of irrigation development can be summarized as follows;

- Increased crop production (yield improvement) can increase farm income
- Increased cropping intensities and crop diversification opportunities and the feasibility of year round crop production activities
- Increased farm employment- more employment opportunities for farming families as well as for hired labourers in the locality
- Increased farm consumption and increased permanent wealth (permanent asserts accumulation due to irrigation). This has significant implication for reducing intrinsic food insecurity in a region
- Reduced food (crop) price allowing access to food for all. This is more beneficial to landless and subsistent families by providing better nutrition intake. This is also beneficial to urban poor and city dwellers, since they spend more than 50% of their income on food items
- Reduce friction in the rural economy and reduced transaction cost including reduced farm marketing costs due to increased access to farm link roads and to other improved farm and non-farm related services in the region
- Multiple uses of water for bathing, washing, livestock and home gardens

- Increased recharge of ground water, easy access to groundwater into less drudgery for women in fetching water for daily household needs
- Aesthetic and recreational benefit accrued out of irrigation facilities
- Increased farm income (for farmers) and increased farm and off farm employment opportunities for rural landless labourers and improved social capital in society. This is due to the income effect of irrigation since education is still a luxury compared to other basic needs: food, cloth, shelter, health, etc
- Export tax revenue accruing to government coffers. This is important particularly for the major agricultural (rice) exporting countries like Thailand, Vietnam, USA, etc.

2.8 Physical and Socio-Economic Factors in Irrigation

The physical and socio-economic factors in irrigation according to Underhill (1990) are presented:

1. Climate zone (arid to humid)
2. Land use before irrigation (none to intensive form)
3. Source of water (surface or groundwater)
4. Physical control of water (almost none to complete)
5. Size of the scheme in ha (very small, 1ha or less to very large, hundreds of thousands of ha)
6. Size of the plot (from a few m^2 to a few ha)

2.8.1 Socio-Economic Factors are:

1 Historical (old or new).

2 Technology (simple to complex).

3 External intervention (none to very large).

4 Management control (single farmer to government agency).

5 Dependency on external forces (very small to very large).

6 Previous irrigation experience (high to zero).

2.9 Soil water availability

Soil water availability refers to the capacity of a soil to retain water available to plants. After heavy rainfall or irrigation the soil will drain until field capacity is reached. Field capacity is the amount of water that a drained soil should hold against gravitational forces or the amount of water remaining when downward drainage has markedly decreased. The total available water in the root zone is the difference between the water content at field capacity and wilting point (Allen *et al*, 1998).

$$TAW = 1000\ (\theta fc - \theta wp)\ Zr$$

Where: TAW – the total available soil water in the root zone (mm)

Θ_{fc} – the water content at field capacity (m^3m^{-3})

Θ_{wp} – the water content at wilting point (m^3m^{-3})

Z_r – the rooting depth (m)

TAW is the amount of water that a crop can extract from its root zone and its magnitude depends on the type of soil and the rooting depth.

2.10 Water and Agriculture

Water, soil, air and sunshine are the four main determinants for plant growth. Therefore, water is essential to plant growth and crop production (Widtose, 2001). All sectors depend on water. Water is important for agriculture, household consumption, industry, hydropower, fisheries, recreation, navigation and ecosystem. When there is adequate supply of water, crops grow best and produce most. Water is a basic need for human beings and animals. It is essential for their metabolic processes. Livestock water requirements are mainly provided by direct water intake and partly by the moisture content of their forage. According to Dupriez and De Leener (2002), the sources of water for crop production is rainfall and irrigation water. The two types of agriculture seen from the perspective of water management are:

- Rain fed cultivation is crop production depending entirely on the rainfall. It relies on the rainfall timing and distribution. Rainfed farming is mostly practised during the growing season.

- Irrigated cultivation is agricultural production using irrigation water in addition to rainfall. Irrigated crops benefit from man-made watering with the help of water pipes, canals, reservoirs and pumps. The source of irrigation water is surface water or ground water.

2.11 Perspectives and Objectives of Irrigation

A reliable and suitable irrigation water supply can result in vast improvements in agricultural production and ensure the economic vitality of the region. Many civilizations have been dependent on irrigated agriculture to provide the basis of their society and enhance the security of their people. It is estimated that as little as 15-20% of the worldwide total cultivated area is irrigated. Based irrigated to non-irrigated yields in some areas, the relatively small fraction of irrigated agriculture may be contributing as much as 30-40% of gross agricultural output (FAO, 1989). Many countries depend on surface irrigation to grow crops for food and fibre. Without surface irrigation their agricultural production would be drastically lower and problems of unreliable food supply, insufficient rural income and unemployment would be widespread. Although precise data are lacking, estimation of surface irrigation accounts for some 80 - 90% of the total 260 million hectares of irrigated land worldwide, mainly in developing countries in the tropics and sub-tropics, where hundreds of millions of farmers depend on surface irrigation to grow their crops (Jurriens et al, 2001).

The method, frequency and duration of irrigation have significant effects on crop yield and farm productivity. For instance, annual crops may not germinate when the surface is inundated causing a crust over the seedbed.

After emergence, inadequate soil moisture can often reduce yields, particularly if the stress occurs during critical periods. Even though the most important objective of irrigation is to maintain the soil moisture reservoir, how this is accomplished is an important consideration. The technology of irrigation is more complex than many appreciate. It is important that the scope of irrigation science is not limited to diversion and conveyance systems, or solely to the irrigated field, or only to the drainage pathways.

Irrigation is a system extending across many technical and non-technical disciplines. It only works efficiently and continually when all the components are integrated smoothly (FAO, 1989).

FAO (1989) outlined the problems irrigated agriculture may face in the future. One of the major concerns is the generally poor efficiency with which water resources have been used for irrigation. A relatively safe estimate is that 40**%** or more of the water diverted for irrigation is wasted at the farm level through either deep percolation or surface runoff. Irrigation in arid areas of the world provides two essential agricultural requirements:

- A moisture supply for plant growth which also transports essential nutrients; and
- A flow of water to leach or dilute salts in the soil. Irrigation also benefits croplands through cooling the soil and the atmosphere to create a more favourable environment for plant growth (FAO, 1989).

2.12 Definition of small scale and Large scale Irrigation

The first question in any discussion of irrigation, as stated by Turner (1994) is the definition. Certainly the application of water to plants is irrigation. There could be great differences between countries and agencies over what is meant by "small". In fact, small according to the Indian definition is regarded as large in Africa. Turner (1994) points out that irrigation system can be classified according to size, source of water, management style, and degree of water control, source of innovation, landscape niche or type of technology. Most authors, however, agree that concepts of local management and simple technology should be combined with size, and the best working definition seems to be that used by the UK Working group on Small Scale Irrigation (SSI): small scale irrigation is 'irrigation, usually on small plots, in which farmers have the major controlling influence and using a level of technology which the farmers can effectively operate and maintain'. There is also a case for using the term 'farmer-managed irrigation systems' (FMIS), as used by the International Irrigation Management Institute (IIMI), which removes the confusion with authority-managed small-scale irrigation.

According to Jorge (1993) irrigation systems fall into two broad categories: those in which the principal management responsibility is exercised by government agencies with the farmers playing a subsidiary role, and those in which most management activities are carried out and decision made by the farmers themselves with the government providing periodic technical or logistical support. The latter category in which farmers assume the dominant role is referred to as Farmer-Managed Irrigation Systems (FMIS). In general, an important characteristic of FMIS is that the farmers also control and manage the water abstraction from its source. Governments often classify these systems as "small-scale irrigation system" or "minor irrigation systems," although examples of FMIS may be found with command areas of hectares. FMIS are also known as traditional, indigenous, communal or people's systems. The precise set of activities and functions that the farmers and their organizations perform varies from country to country and from system to system.

2.13 Farmer Managed Irrigation System (FMIS) Changing Trends

Irrigation has been practiced for at least 5000 years in Egypt and China, 4000 years in India and the Tigris-Euphrates basin and 2,500 years in the central Andes. Large-scale systems were developed under state or royal patronage where there were well-organized social systems and long-term stability prevailed. But small-scale irrigation must be even older. In more recent times, major schemes were developed in India in the late 19th century, followed by other parts of Asia, Egypt and Sudan. These schemes were often seen as an ideal way to increase food production and reduce dependence on the variability of rainfall. They were also prestige developments, and later similar schemes appealed particularly to newly independent countries and attracted large amounts of foreign aid, especially in the 1960s and 1970s (Jorma, 1999).

Turner (1994) also described other reasons for the appeal of such schemes to governments and to donors. However, many problems became apparent when these large-scale schemes failed to live up to expectations, costing far more and producing much lower crop yields than estimated and introducing many new problems while alienating the majority of farmers.

In recent years, there has been an emphasis on the concept of sustainable development, which is often incompatible with increasing river regulation. There is also now a tendency to decentralize management and encourage FMIS by rehabilitating old schemes and handing over control to the farmers involved (Jorma, 1999).

2.14 Importance of Farmers' Managed Irrigation System

Despite the lack of available statistics, there is no doubt about the importance of small-scale irrigation (SSI) in many developing countries. For many farmers, irrigation is only part of their livelihood but often a very important part. Irrigated fields are usually valued very highly. Turner (1994) gave the following reasons for the importance of such FMIS: it can be used to extend the length of the growing season; and as a form of insurance so that when rains start late and upland crops are at risk, crops planted in the valley bottoms or those which receive supplementary irrigation are often the only ones to reach maturity.

Farmers are empowered since they are able to apply water when and where they need it. Capital costs are lower and local labour and skills are employed. In many cases, smallholders can be more productive with their yields and more efficient in water use than larger irrigation schemes (Jorma, 1999).

Irrigation is thus a valuable insurance. Several crops, such as tomatoes and leafy vegetable, grow far better in the dry season when they do not suffer attacks of mildew or pests prevalent in the wet season, and other crops require the lower temperatures of the dry season. There is also a major advantage in combining dry season and wet season cultivation. The latter is used for staple crops but the area a family can cultivate is often limited by the labour required during operations like weeding. Dry season cultivation makes deficient use of labour at a less busy time of year. Much FMIS is for subsistence cultivation and improves the diet by providing a supply of fresh vegetable throughout the year. But it is also important as a source of high value crops, providing income when access to roads and markets is possible (Turner, 1994).

There is much evidence that farmer-controlled small-scale irrigation has better performance than government-controlled small-scale systems. The substantial farmer-controlled small-scale irrigation sector that exists in many countries in Africa, often without government support, indicates that these systems are economically viable. Areas under farmer-controlled small-scale irrigation systems have grown rapidly over the past decades, and account for large and growing share of irrigated area in Sub Saharan Africa (McCornick *et al*, 2003).

For the most part, by passed by the green revolution and other successful innovations in agriculture production, smallholders live at or below the poverty level and are highly averse to risk; their very livelihoods are focused on keeping the margin for error as small as possible. At the same time, smallholders are capable of managing irrigation systems efficiently provided they have access to affordable technologies that are easy to operate, maintain and repair. Small-scale systems and technologies are attractive since they put the operation, maintenance and management of systems directly in the hands of the individual farmers, thus eliminating any need for centralized control or management (Jorma, 1999).

In general, according to McCornick *et al* (2003) all small-scale systems may have advantages over large-scale systems. These advantages include small-scale technology that can be based on farmers existing knowledge; local technical, managerial and entrepreneurial skills can be used; migration or resettlement of labour is not usually required; planning can be more flexible; social infrastructure requirements are reduced; and external input.

2.15 Irrigation water use efficiencies

Irrigation efficiency is the ratio between the volume used by plants through evapotranspiration process and that reaching the irrigation plot. It indicates how efficiently the available water supply is used, based on different methods of evaluation (Michael, 1997). The design of the irrigation system, degree of land preparation, and the skill and care of the irrigator are the principal factors influencing irrigation efficiency. Efficiency in the use of water for irrigation consists of various components and takes into account water loss during storage, conveyance and application to irrigation plots. Identifying the various components and knowing what improvements can be made is essential to making the most effective use of this vital resource.

There are several publications describing the methods and procedures for evaluating the efficiency surface irrigation systems. The data analysis depends somewhat on the data collected and the information to be derived.

Among the factors used to judge the performance of an irrigation system or its management, the most common are efficiency and uniformity (FAO, 1989). These parameters have been subdivided and defined in a multitude of ways as well as named in various manners. There is not a single parameter, which is sufficient for defining irrigation performance and according to Lesley (2002) the measure of irrigation efficiency depends on the area of interest. Ultimately, the measure of performance is whether or not the system promoted production and profitability on the farm.

Kloezen and Garces-Restrepo (1998) reviewed different literature and summarize that process indicators help system managers to monitor the quality of daily and seasonal operational performance. Numerous studies focus on the definition of a number of process indicators. Common indicators defined in literature include:

- Conveyance, distribution, field and application, and project efficiencies;
- Reliability and dependability of water distribution;
- Equity or spatial uniformity of water distribution; and
- Adequacy and timeliness of irrigation delivery.

According to Molden *et al* (1998), much of the work to date in irrigation performance assessment has been focused on internal processes of irrigation systems. Many internal process indicators relate performance to management targets such as timing, duration, and flow rate of water, area irrigated and cropping patterns. A major purpose of this type of assessment is to assist irrigation managers to improve water delivery service to users. Targets are set relative to objectives of system management, and performance measures tell how well the system is performing relative to these targets.

According to James (1988), the performance of a farm irrigation system is determined by the efficiency with which water is diverted, conveyed, and applied, and by the adequacy and uniformity of application in each field on the farm. Mishra and Ahmed (1990) also said that irrigation efficiency indicates how efficiently the available water supply is being used, based on different methods of evaluation. The objective of these efficiency concepts is to show where improvements can be made, which will result in more efficient irrigation.

Irrigation efficiencies can be measured in many ways and also varies in time and management (Roger *et al*, 1997). Very "efficient" system by some definitions can be very poor performers by other definition. Lesley (2002) supported this idea and explained it as the public's perception of irrigation efficiency is focused mostly on water use, whereas farmer's perception relates more to production. For this reason, it is unrealistic to use one all encompassing definition. For instance, where water is very short, efficiency may be measured as crop yield per cubic metre of water used, or profit per millimetre of irrigation. It depends on what you want to know. Michael (1997) and Jurriens *et al* (2001) indicated that the primary performance indicators are: storage efficiency, application efficiency and distribution uniformity.

2.16 Application efficiency

After the water reaches the field supply channel, it is important to apply the water as efficiently as possible. A measure of how efficiently this is done is the application efficiency. One very common measure of on- farm irrigation efficiency is application efficiency. It asks how much of the water applied to the crop is actually used for crop growth or other beneficial uses? The definition of application efficiency, *Ea*, has been fairly well standardized as:

$$Ea = \frac{depth\ of\ water\ added\ to\ the\ root\ zone}{depth\ applied\ to\ the\ field}$$

According to Jurriens *et al* (2001), application efficiency is a common yardstick of relative irrigation losses and this definition is valid for all situations and all irrigation methods. Losses from the field occur as deep percolation and as field tail water or runoff to reduce the application efficiency. To compute E_a it is necessary to identify at least one of these losses as well as the amount of water stored in the root zone. This implies that the difference between the total amount of root zone storage capacity available at the time of irrigation and the actual water stored due to irrigation be known, i.e. the amount of under-irrigation in the soil profile must be determined as well as the losses (FAO, 1989).

According to Roger *et al* (1997), methods of determining application efficiency of a specific irrigation system is generally time consuming and often difficult because it may vary in time due to changing soil, crop and climatic condition.

Lesley (2002) explained and defined the situation of application efficiency with time and event specific and the equation could be used for a single irrigation event or more as a term reflecting seasonal performance. The difference in how it is used can be quite dramatic. For example, the first irrigation event using furrow irrigation can have a very low application efficiency if the length of run is long, furrows are freshly corrugated, stream size is wrong or for several other reasons. If water applications are too close together, or the amount of water applied is too high, the application efficiency will be lower than it should be. This will indicate low irrigation efficiency, showing that water is being wasted as a result of deep percolation. According to him, the purpose of application efficiency was to help estimate the gross irrigation requirement once the net irrigation need was determined and vice versa. Application efficiency does not show if the crop has been under-irrigated.

However, according to Roger *et al* (1997), it is possible to have high application efficiency i.e 50-90% can be used for general system type comparison. FAO (1989) reported that the attainable application efficiency according to the US (SCS) ranges from 55-70% whiles for ICID/ILRI this value is about 57%. Lesley (2002) suggested that it could be in the range of 50-80%. In general, according to Michael (1997) water application efficiency decrease as the amount of water applied during each irrigation increases.

2.17 Storage efficiency

Small irrigation may lead to high application efficiencies, yet the irrigation practice may be poor. The concept of water storage efficiency is useful in evaluating this problem. Jurriens *et al* (2001) express adequacy of irrigation turn in terms of storage efficiency and the purpose of an irrigation turn is to meet at least the required water depth over the entire length of the field. Conceptually, the adequacy of irrigation depends on how much water is stored within the crop root zone, losses percolating below the root zone, losses occurring as surface runoff or tail water, the uniformity of the applied water, and the remaining deficit or under-irrigation within the soil profile following irrigation.

The water storage efficiency refers to how completely the water needed prior to irrigation has been stored in the root zone during irrigation. The water requirement efficiency, E_r, which is also commonly referred to as the storage efficiency as defined by (Mishra and Ahmed, 1990 and FAO, 1989) as

$$E_r = \frac{volume\ of\ water\ added\ to\ the\ root\ zone\ storage}{potential\ soil\ moisture\ storage\ volume}$$

The requirement efficiency is an indicator of how well the irrigation meets its objective of refilling the root zone. The value of E_r is important when either the irrigations tend to leave major portions of the field under-irrigated or where under-irrigation is purposely practiced to use precipitation as it occurs and storage efficiency become important when water supplies are limited (FAO, 1989).

Water stored in the root zone is not 100% effective (FAO, 1992). Evaporation losses may remain fairly high due to the movement of soil water by capillary action towards the soil surface. Water lost from the root zone by deep percolation where groundwater is deep. Deep percolation can still persist after attaining field capacity. Depending on weather, type of soil and time span considered, effectiveness of stored soil water might be as high as 90% or as low as 40%.

2.18 Distribution Efficiency

When a field with a uniform slope, soil and crop density receives steady flow at its upper end, a waterfront will advance at a monotonically decreasing rate until it reaches the end of the field (FAO, 1989). Roger *et al* (1997) explained that water lost to percolation below the root zone due to non-uniform application or over-application of water as run-off from the field, all reduces irrigation efficiencies. To get a complete picture of an irrigation performance you need to have more indicators than just discussed above, because these are averages taken over the entire length of the field or furrows.

Although different cases might produce the same results for application and storage efficiencies, their distribution patterns could differ. One indicator used to represent the pattern of the infiltrated depths along the field length is the distribution uniformity (D_u), which is defined as the minimum infiltrated depth divided by the average infiltrated depth (Jurriens *et al*, 2001). This is given in the form:

$$D_u = \frac{minimum\ depth}{average\ depth}$$

Application efficiency is concerned with the distribution of water over the actual field. Jurriens *et al* (2001) proposed that distribution uniformity be defined as the average infiltrated depth in the low quarter of the field divided by the average infiltrated depth over the whole field. This term can be represented by the symbol, D_u. The same authors also suggest 'absolute distribution uniformity' D_u which is the minimum depth divided by the average depth. Thus, the evaluator can choose one that fits his/her perceptions but it should be clear as to which one is being used (FAO, 1989). The uniformity of application can be evaluated using the Christiansen Uniformity coefficient (Jensen, 1983; Michael, 1997; Jurriens *et al*, 2001). This is given as:

$$Cu = 100 \times \left(1.00 - \frac{\sum|d|}{n\bar{x}}\right), \quad d = x_1 - \bar{x}$$

Where:

Cu = Christiansen Uniformity Coefficient;

d =deviation of observation from the mean;

n = number of observations;

$\bar{x}$= Average depth infiltrated;

x_i= Depth infiltrated at observation point i.

Distribution uniformity describes how evenly irrigation is applied to the crop. This needs to be measured in the field. FAO (1992) suggested that, distribution efficiency D_u of 65% as “sufficient” and D_u of 30% as “poor”.

2.19 Combined measures of efficiency

Application efficiency is the most important in terms of design and management since it reflects the overall beneficial use of irrigation water. Design and management strategy will be proposed in which the value of application efficiency is maximized subject to the value of requirement efficiency being maintained at 95-100%. This approach thereby eliminates storage efficiency from an active role in surface irrigation design or management and simultaneously maximizes application uniformity. If the analysis tends to maximize application efficiency, distribution uniformity is not qualitatively important and may be used primarily for illustrative purposes. Of course, some may prefer performance discussed in terms of uniformity or be primarily involved in systems where under irrigation is an objective or a problem. For these cases, uniformity is still available. The assumption of maximization of application efficiency in effect states that losses due to deep percolation or runoff are equally weighted (FAO, 1989).

A system with low distribution uniformity cannot have high application efficiency and still adequately water crops (Lesley, 2002). If the application efficiency is greater than the distribution uniformity, you can be pretty sure the crop has been under-watered. If the application efficiency is less than the distribution uniformity you can be pretty sure the crop was over-watered. This conclusion is also supported by Roger *et al* (1997) as it is possible to have high application efficiency but have the irrigation water so poorly distributed that crop stress exists in areas of the field.

2.20 Irrigation Scheduling

The purpose of irrigation scheduling is to determine the exact amount of water to apply to the field and timing of application. The amount of water applied is determined by using a criterion to determine irrigation need and a strategy to prescribe how much water to apply in any situation. Hence the importance of irrigation scheduling is that it enables the irrigator to apply the exact amount of water to achieve the goal. This increases irrigation efficiency. Proper scheduling is essential for the efficient use of water, energy and other production inputs, such as fertilizer. It allows irrigations to be coordinated with other farming activities including cultivation and chemical applications. Among the benefits of proper irrigation scheduling is: improved crop yield and/or quality, water and energy conservation, and lower production costs (James, 1988).

FAO (1989) explained that when surface irrigation methods are used, however, it is not very practical to vary the irrigation depth and frequency too much. In surface irrigation, variations in irrigation depth are only possible within limits. It is also very confusing for the farmers to change the schedule all the time. Therefore, it is often sufficient to estimate or roughly calculate the irrigation schedule and to fix the most suitable depth and interval: to keep the irrigation depth and the interval constant over the growing season. Important soil characteristics in irrigated agriculture include:

- water holding or storage capacity of the soil;
- permeability of the soil to flow of water and air;
- physical characteristics of the soil such as organic matter content, depth, texture and structure; and
- Soil's chemical properties such as the concentration of soluble salts, nutrients and trace elements (FAO, 1989).

Normally farmers will use their own experience and indicators (wilting characteristics, soil dryness) to determine when to irrigate (Smith and Munoz, 2002). According to them this has proved not very accurate and “scientific” advice to farmers on when to irrigate can lead to considerable water saving to a more rational planning of water distribution. Of several methods to determine *when to irrigate*, “Water indicator” and “Soil budget” are the two widely used techniques (James, 1988). The water budget technique is based on the equation:

$$= ET - P_e + RO_i + DP_i + L + D_{rz}(\theta_f - \theta_i)$$

Where:

I= Irrigation requirement; ET= evapotranspiration; Pe= effective precipitation (cm); ROi= runoff due to irrigation (cm); DPi= deep percolation due to irrigation (cm); Drz= depth of root zone (cm); Θ_f & Θ_i *= final and initial soil moisture contents.*

Water budget method is more commonly applied these days. The large amount of studies and research on crop water requirements has led to more accurate ETcrop estimation from weather data and has made the ETo based on water balance method the most convenient and reliable way to predict when to irrigate (Smith and Munoz, 2002).

Soil based irrigation scheduling involves determining the current water content of the soil, comparing it to a predetermined minimum water content and irrigating to maintain soil water contents above the minimum level. Soil indicators of when to irrigate also provide data for estimating the amount of water to apply per irrigation.

According to Mishra and Ahmed (1990), irrigation interval is calculated by the formula:

$$irrigation\ interval = \frac{AMD}{ETc}$$

Where: *AMD* = allowable soil moisture depletion, cm

ETc = daily water use, cm/day

Depth of irrigation application is the depth of water that can be stored within the root zone between field capacity and the allowable level the soil water can be depleted for a given crop, soil and climate. It is equal to the readily available soil water in the root zone (James, 1988). How much water to apply depends on the irrigator's strategy? A critical element is accurate measurement of the volume of water applied or the depth of application. A farmer cannot manage water to maximum efficiency without knowing how much water is applied. Also, uniform water distribution across the field is important to derive the maximum benefits from irrigation scheduling and management. Accurate water application prevents over- or under irrigation.

According to FAO (1989), the total available water (TAW), for plant use in the root zone is commonly defined as the range of soil moisture held at a negative apparent pressure of 0.1 to 0.33 bar (i.e soil moisture level called 'field capacity') and 15 bars (i.e 'permanent wilting point'). The TAW will vary from 25 cm/m for silt loams to as low as 6 cm/m for sandy soils.

The net quantity of water to be applied depends on magnitude of moisture deficit in the soil, leaching requirement and expectancy of rainfall. When no rainfall is likely to be received and soil is not saline, net quantity of water to be applied is equal to the moisture deficit in the soil, i.e. the quantity required to fill the root zone to field capacity. The moisture deficit (*d*) in the effective root zone is found out by determining the field capacity moisture contents and bulk densities of each layers of the soil (Mishra and Ahmed, 1990).

$$d = \sum_{i-1}^{n} \frac{(FC_i - PW_i)}{100} \times AS_i \times D_i$$

Where:

FCi = field capacity of the ith layer on oven dry weight basis

PWi = actual moisture contents of the ith layer on oven dry weight basis

Asi= apparent specific gravity of the ith layer

Di = depth of ith layer and, n=number of layers in the root zone

According to Jurriens *et al* (2001), the required depth (*d)* is not usually the same as the applied depth (*Da), which* is equal to the applied volume divided by the area. If the applied depth infiltrates the field area entirely, the applied depth equals the average infiltrated depth (*Dave).* Jurriens *et al* (2001) further discussed the average depth of water that is actually stored in the target root zone, Dreq as the storage depth (Ds). When the target zone is entirely filled, Ds will equal Dreq. If Ds < Dreq, then there is under-irrigation and if Ds > Dreq, then there is deep-percolation.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study Area, Location and Characteristics

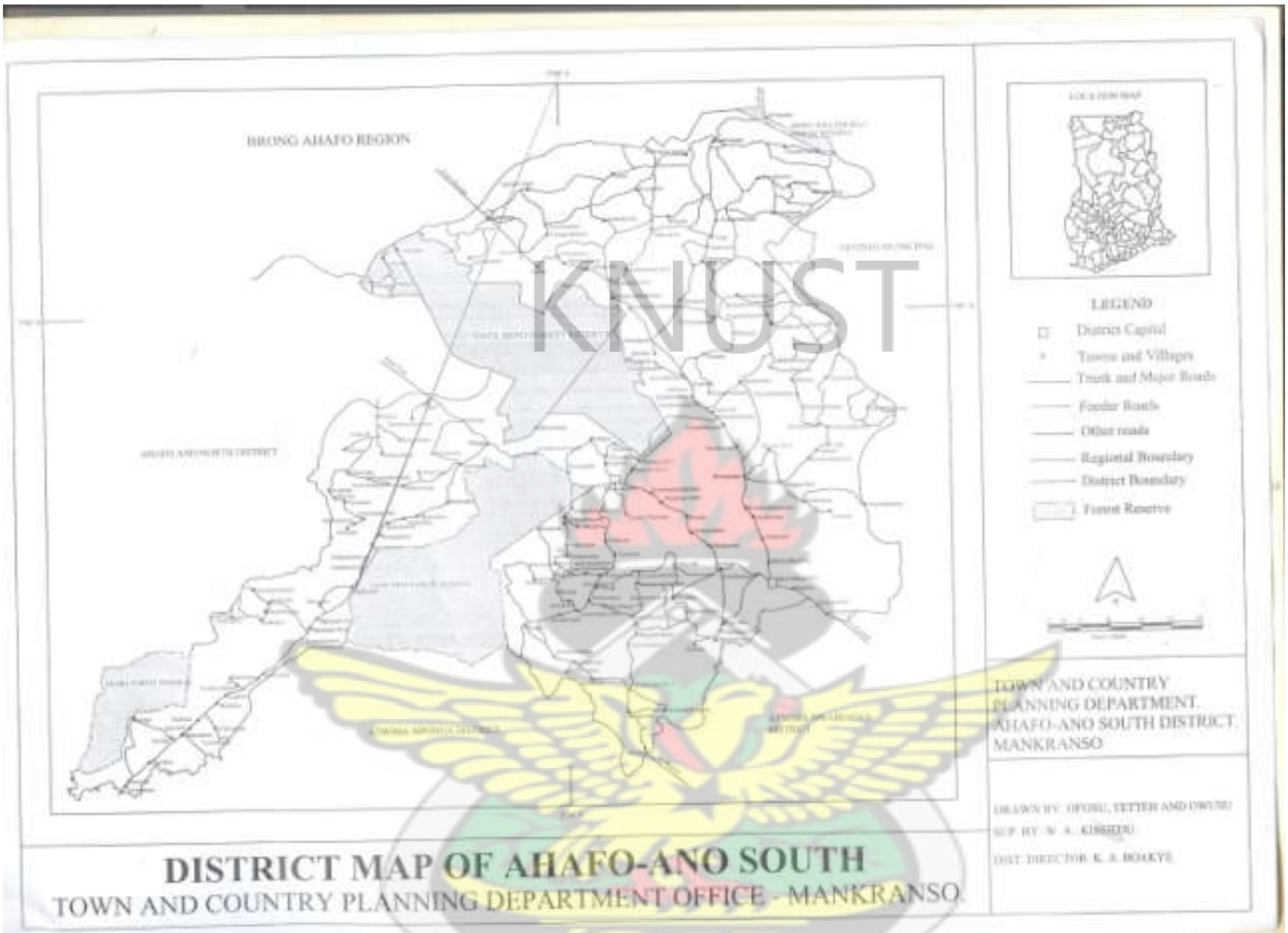

Figure 1: Plan of the Study Area

Ahafo-Ano South District was used for the study. There are 148 communities within the district. It is about 19 km away from Kumasi, the Ashanti Regional capital. Ahafo-Ano South District is in the North western part of the Ashanti Region on the Kumasi-Sunyani road. It is bordered to the North by Ahafo-Ano North, to the South by Atwima Nwabiagya District, to the East by Offinso South Municipality and to the West by Atwima Mponua District. The study area lies between latitudes 6° 40'' N and 6° 25''N and longitudes 1° 54'' E and 1° 60'' W. The district has a population of about 65,000 people. About 80% of the inhabitants depend solely on agriculture for their livelihood.

The communities of Mankranso, Adugyama, Potrikrom, Baniekrom and Dunyan Nkwanta were covered in the study. The rivers dammed and diverted for the various agricultural activities are Mankran and Dunyan. The sources of water used for small scale irrigation during the dry season farming include dams, streams and groundwater.

3.1.1 Description of communities under study

3.1.2 Mankranso

Figure 2: Cabbage production using drip irrigation at Mankranso

Mankranso is the Ahafo-Ano South District capital. The source of water used for small scale vegetable production is River Mankran and groundwater. Water from the river is diverted to the field for rice cultivation while others also pump water from the river to the field for dry season vegetable cultivation. Some farmers, especially the Chinese farmers in the area use drip irrigation (figure 2). Aside from being used for small scale irrigation for vegetable production during the dry season, it is also used for fish farming and as a main source of water for domestic purposes like washing, cleaning and bathing. The assemblyman of the area further explained that the river occasionally dries up due to vegetable farming along the river banks and the silting up due to erosion along the catchment area. Vegetable commonly grown in the area include*: Brassica Oleracea var capitata* (cabbage), *Cucumis sativa* (cucumber), *Citrullus vulgaris* (watermelon), *Lycopersicon esculentum* (tomato), *Hibiscus esculentus* (okro), *Capsicum frutescens* (hot pepper), *Capsicum annuum* (sweet pepper), *Phaseolus vulgaris* (French bean), *Lactuca sativa* (lettuce), *Daucus carota* (carrot); *Allium cepa* (onion) and different kinds of Chinese vegetables grown to feed foreign restaurants in Kumasi. Okro production during dry the season forms about 80% of all the vegetables grown in the area. Rice constitutes about 85% of field cultivation in the rainy season. Water is pumped from the river to the field for vegetable production. Buckets and watering cans are used during the initial growth stages to water vegetable crop production. The soil type downstream is clayey and upstream is clayey loam. The rate of water applications vary from one farmer to another depending on the capital resources of the farmer.

3.1.3 Climate

The land in the study area is under intense pressure due to the expansion of cultivated lands.

The Ahafo-Ano South District forms part of the semi decicious vegetation zone. The annual precipitation is about 1200mm of which 80% fall in the period from April to October. The driest months are November to February. The mean annual temperature of 25 ˚C. January is the hottest month with a mean maximum temperature of 24 ˚C and the coolest month is December with a mean minimum temperature of 20 ˚C. The average farm size for dry season crop production is 0.2 ha. Above 0.2 ha determine the inputs and wealth status of farmers

Weir over Dunyan River – Adugyama **A weir at Potrikrom**

A Weir at Dunyan Nkwanta

Figure 3 **Weirs at Ahafo-Ano South District**

3.1.4 Adugyama

Adugyama is about 5 Km from the district capital and is located in the North-eastern part of the district on the Kumasi-Sunyani road. It is bordered to the north by Potrikrom, to the South by Amakom, to the East by Biemso No I and II and to the West by Kunsu-Wioso. The community has a population of about 4,000 people. Dunyan River runs through the community. It has recently, weir constructed to retain more water for vegetable and rice production. This is being done by MoFA in collaboration with the African Development Bank (ADB). The kind of vegetables cultivated in the area includes cabbage, hot pepper, garden eggs, tomato, okra, carrot and lettuce. Rice is cultivated in the area. Pumping machines are used to lift water and apply to crops during the dry season. The soil type is sandy loam and that of lowland areas are clayey loams.

3.1.5 Potrikrom

This community is about 6km away from the district capital and 1km away from Adugyama. Prior to the establishment of the Potrikrom weir (dam) irrigation project, farmers in the community relied on rain for vegetable and arable crops particularly okra, rice and maize. The agricultural production was a little satisfactory due to the fact that the rainfall is heavy. In recent years farmers were able to farm vegetables in the period of October to April due to the frequent drying of the stream in the area. To solve the problem, the government of Ghana through MoFA and the African Development Bank is constructing a weir to retain more water for farmers in the area for dry season vegetable and arable crop production. Initially, the scheme was designed to cover a very large area but due to land litigation, the project has come to a halt. To settle the dispute, MoFA and other stakeholders have settled the dispute in order to expand the irrigable lands for the people in the area. The types of soil in the area are sandy loam and that of the low land area is clayey loam.

3.1.6 Dunyan Nkwanta

The community is about 6km from the district capital, Mankranso and it is located at the north-western part of the district. A dam (weir) was built two years ago. It provides a source of water for small scale irrigation. According to the extension staff, MoFA representative of the area, the weir was built to retain more water for the expansion of rice cultivation and to supply water for small scale irrigation. It also serves as a source of water for domestic uses. The rice farmers usually prepare their land in the early parts of February and March. The rice farmers divert water through canals to their farms, while vegetable farmers also use pumping machines to pump water to their fields to irrigate their crops. The main vegetables grown in the area are okra, garden eggs, tomatoes and hot pepper. The farmers irrigate their crops twice in a week. The soil types are sandy loam and clayey loam. Following the government's strategy to expand irrigated crop production, the government in collaboration with African Development Bank is expanding irrigable land to increase the land under irrigation and consequently the number of farmers working in the area. In response, local rice farmers have organized themselves to construct bunds for rice cultivation.

Baniekrom

The community is about 2km from Dunyan Nkwanta and it is located at the North western part of the district on the Mankranso-Tepa road. Most of the farmers in the area are into inland valley rice cultivation. The people depend on rainfall when the streams in the area overflow their banks. The farmers, whose farms are along the stream, divert water to their fields which have been bunded to keep water for rice production. The vegetable farmers in the area use pumping machines to pump water to irrigate their crops. The main vegetables grown in the area are okra, tomato, cabbage and hot pepper. The farmers irrigate their crops twice every week till harvesting. It takes a farmer about 6 hours to be able to irrigate 0.2 ha farm land based on the water application technology. The soil types are sandy loam and clayey loam at the inland valley.

3.2 Methodology

The data for this study was collected in three stages. During the first stage of data collection, qualitative data were collected through observation and in depth informal and guided interviews with flexible open-ended questions supporting the participatory rural appraisal (PRA) research methods (Grbich,1999). Structured questionnaire of twenty (20) was drafted on the basis of the collected qualitative data and pre-pilot tested at Adugyama and Baniekrom in order to improve the question wording, structure and content before the sample survey. Irrigation potential sites in the Ahafo-Ano South District were surveyed to assess some of the general challenges facing small-scale irrigation development in the areas and potential opportunities that can enhance irrigation activities in the same areas. During the field survey, the interview schedule were administered to the farmers, officials and other opinions leaders/stakeholders on issues regarding the potential and challenges of small-scale irrigation to come out with possible solutions of improving water utilization in the district for small-scale irrigation farming. Five (5) communities were selected from 20 identifiable small-scale sites for structured interview schedule administered to the small-scale irrigation farmers in the study area. The interview schedule was randomly administered to small-scale irrigation farmers sighted during the field survey to the various sites in the study area. Formal interviews of MoFA officials and other relevant agencies responsible for irrigation development in the state were carried out. Five identifiable groups each were randomly selected for the interview from all the five study communities.

The walk-through inspections used to obtain data on the functional operational conditions of the various water application methods in the study areas was also done.

3.2.1 Data Collection

Primary field data collection started with a reconnaissance survey of various sites and discussions with relevant government agencies (MoFA) and non-governmental organization (JIRCAS). Primary data collection was from key informant interviews, semi-structured interviews, focus group discussions, direct field observations and structured questionnaire. The structured questionnaires was designed to cover water application, land size, source of water, personal data e.g. (age, sex, educational status) source of funds, problem facing farmers, type of crop cultivated, inputs acquisition, labour requirement, farm management practices, local food security and marketing of produce.

Focus group discussion was conducted in with farmers and selected elders in various communities and MoFA officials in the field. Qualitative observations were made on land preparation methods, soil conditions of irrigable lands, water applications and techniques, fertilizer application method, and farm management practices.

Additional data were collected through:

- Frequent field visits were made to observe and investigate the method of water applications and practices related to water management techniques carried out by the farmers.
- Moisture contents of the soils of the selected irrigation fields before and after irrigations were determined by taking soil samples at different depths of the soil profile.

Secondary data was obtained from reports on socio-economic impact of small scale irrigation done by the Japan International Research for Agricultural Science (JIRCAS), MoFA operations, *''SAWAH''* system of rice production, and other studies were collected from the internet and libraries

3.2.2 Statistical Analysis

The qualitative and quantitative data collected from primary and secondary sources were analyzed using quantitative methods and descriptive statistics (frequency and percentages). The Statistical Package for Social Sciences (SPSS) software was used to analyse quantitative data. Data collected from focus group, group discussions, observations and key informant interviews were assessed qualitatively. The outcomes of the statistical analysis were presented using charts, cross-tabulation

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Introduction

Results gathered from the study using the various data collection tools are presented and discussed in this chapter.

4.2 Demographic Characteristics of Respondents

4.2.1 Ages of Distribution respondents

Table 1 presents the age distribution of respondents in the five study communities. The age group that had the highest percentage of respondents was 41-50 years representing 44% of the total. The age group 31-40 years formed 30% of the respondents. The age group 51-60 formed 18% of the respondents. The least percentage recorded was 8% representing the age group 20-30 in all the five communities selected for the study.

Table 1: Age distribution of the respondents in five study communities

COMMUNITY	Age (y)				**Total (%)**
	20 – 30	31 – 40	41 – 50	51 – 60	
Mankranso	1	5	13	5	**24**
Adugyama	0	6	8	6	**20**
Potrikrom	1	12	7	3	**23**
Baniekrom	3	5	9	3	**20**
Dunyan Nkwanta	3	2	7	1	**13**
Total	**8**	**30**	**44**	**18**	**100**

Source: Field Survey, 2011

4.2.2 Educational Background of Respondents

From Table 2, it can be seen that 55% of the respondents had elementary/JSS education and could speak, write and read Basic English. 23% of the respondents had primary education or no formal education. 17% of the respondents were found to have had SSS/O level education with 5% having tertiary education. Thus most respondent (78%) farmers have a high level of education being the JHS or Middle school. Thus introduction of new technology must be done very carefully.

Table 2: Educational background of respondents

Educational level	Nº of respondents	Total (%)
No or formal Primary Level	23	23.0
Middle/JHS	55	55.0
SHS/O Level	17	17.0
Tertiary	5	5.0
TOTAL	**100**	**100.0**

Source: Field Survey, 2011.

4.2.3 Gender Distribution of Respondents

Table 3: Gender Distribution of Respondents

Community	Gender		Total Number
	Male	Female	
Mankraso	23	1	24
Adugyama	17	3	20
Potrikrom	16	7	23
Baniekrom	17	3	20
Dunyan-Kwanta	10	3	13
TOTAL	83	17	100

Source: Field Survey, 2011.

Among the farmers interviewed, 83% were males whereas 17% were females. This information is represented in Table 3. This support studies that indicates majority of farmers especially irrigation farmers are males.

4.3 Land Acquisition, Preparation and crops grown

4.3.1 Land Ownership

From all the farmers interviewed, 74% indicated that they did not own their plots of land while 23% indicated that they had their plots of land for farming through rent or share cropping. Few farmers owned their plot of land for irrigation representing 3% as shown in Table 4.

Table 4: systems of Land Ownership

Land Ownership	Farmers	Total (%)
No or Rented Land	74	74
Own Land	23	23
Share Cropping	3	3

Source: Field Survey, 2011

4.3.2 Tillage Practices of Farmers

Table 5 presents the proportion of the respondents who practice various tillage types.

Table 5: Tillage Practices of Farmers

Tillage Practice	Number Of Farmers	Farmers (%)
Tractor (small size)	40	40
Manual	60	60
Draught animals	0	0
Total	100	100

Source: Field Survey, 2011.

As presented 60% of the respondents use manual tillage in their cultivation of farm lands. 40% of the respondents use hand operated small tractor for land preparation. None of the farmers use draught animals to till their lands this is because most of the farmers cannot afford the use of small size tractor.

4.3.3 Crops Grown by Farmers

Almost all the farmers interviewed, were either rice or okra farmers. Few of the respondents were found to grow other crops such as cabbage, tomatoes, pepper, lettuce and egg plant. The rice farmers use the perennial water flow through water diversion system into the bunds or rain fed cultivation.

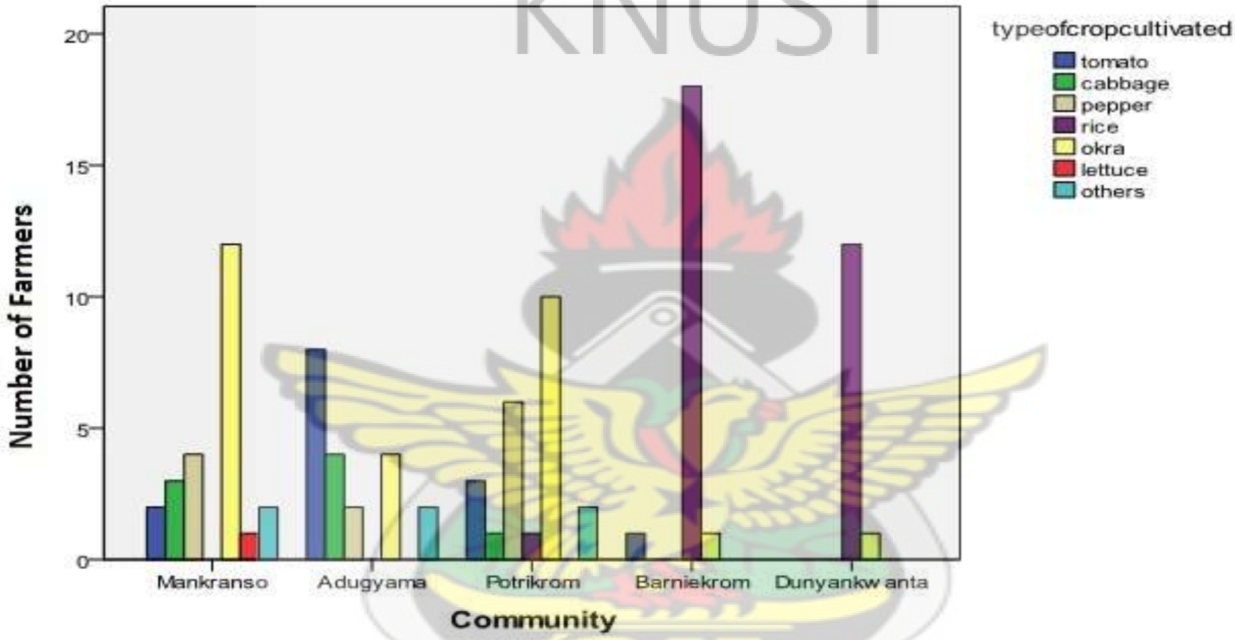

Figure 4: **Crops grown by farmers**

4.3.4 Seeds Source

Based on the responses from farmers interviewed, seeds for cultivation are mostly produced by the farmers themselves. About 60% of the respondents indicated that seeds especially for rice and okro are usually produced by the farmers. Twenty nine percent of the respondents purchase seed from the market. Seven percent of the respondents also collect seeds from friends who are into the business for so many years. Four percent indicated that they were obtained seeds from MoFA in the Ahafo-Ano South District.

Table 6: Seeds source for cultivation

Source Of Seeds For Cultivation	Number Of Respondents	Percentage
Own produce	60	60
Purchased	29	29
Friends	7	7
MoFA	4	4
TOTAL	**100**	**100**

Source: Field Survey, 2011.

4.4 Irrigation

4.4.1 Methods of Water Application

From figure 5, it was revealed that 63% of the respondents use simple motorized diesel pumps for water application. 31% of the respondents also divert water into the field especially rice fields for irrigation. 4% use watering cans to apply water to crops especially for cabbage and onion farmers. 2% of the respondents use buckets and cups to apply water to crops mostly when the crops are a few days old.

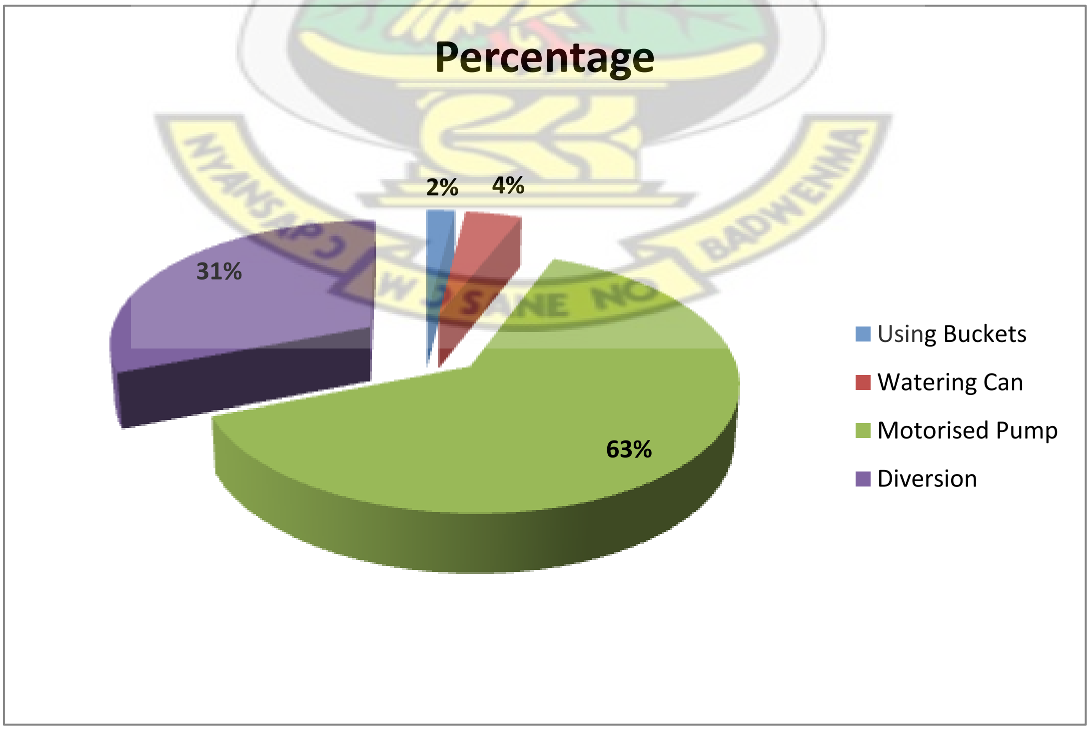

Figure 5: method of Water application

4.4.2 Source of Water for Irrigation in the District

The sources of water for irrigation as shown in Table 7 were varied**.** The main source of water for irrigation by farmer is stream/river representing 90%, eight percent of the respondents depend on well/borehole for irrigation and 2% of the respondents use reservoirs for irrigation. The reason account to high usage of the stream/river is the fact that, the two main rivers passes through all the communities. It is accessible, available and easy to use by farmers.

Table 7: Sources of water for irrigation

Community	Source of water			Total
	Stream / river	Well / borehole	reservoir	
Makranso	17	7	0	24
Adugyama	17	1	2	20
Potrikrom	23	0	0	23
Barniekrom	20	0	0	20
Dunyan Nkwanta	13	0	0	13
Total	90	8	2	100

Source: Field Survey, 2011

4.5 Marketing of Produce

Table 8: The average price of commodities during the rainy and dry seasons

Crop Type	Rainy Season Amount/Crate /Basket/Bag (Gh₵)	Dry Season Amount/Crate /Basket/Bag (Gh₵)
Tomato	10.00	50 per crate
Okro	1.00	20 per black bucket/bowl
Garden egg	5.00	50 per bag
Cabbage	10.00	80 per bag (large sack)

The horticultural crops are perishable and have short shelf-life. So marketing is a central idea in their production process. Farmers decisions and responses are governed by market and related institutions (FAO, 1989). The price of these crops fluctuate from year to year, day to day, from season to season, and from market to market (Table 8). Therefore, profitability of horticultural crops depend on marketing skills and getting good market information rather than expertise (FAO, 1989). The great variation of prices makes it potentially very profitable but also very risky. Ahafo-Ano South district is found near the main highway from Kumasi to Sunyani and is easily accessible to traders from Kumasi.

Figure 6: A plastic bucket used to measure and sell okra fruits

DISCUSSIONS

4.6 Overview of Irrigation at Ahafo-Ano South District

Irrigation development in the Ahafo – Ano South District as in many other districts, has served many goals and objectives. The justification put forward for irrigation development stems from a mixture of technical, socio-economic and political reasons. From the technical point, irrigation allows the stabilization of crop production during the rainy season through supplementary irrigation during dry-spells, as well as dry season cultivation which would be impossible without irrigation. Socio-economically, it has been established as a mechanism to fight rural poverty to ensure food sufficiency to uplift the rural population through development of agribusiness which would rely on the produce from irrigated farms.

Small–scale irrigation in the Ahafo-Ano South District covers a range of technologies to control water from floods, pumping or stream - flow.

Land is the major productive component in the Ahafo Ano South District. Farm lands appear to be very important scarce factor in production. In the study area, owned land, shared cropping and rented land were the main to land for cultivation. The average land holding size for farming is 0.2ha. Renting of farm land is a common practice in the study area. Sharing of farm produce is also highly practised especially those into rice cultivation along river banks. In the Ahafo-Ano South District, land is owned by individuals, clan or family and the chiefs are custodian of family lands. Sale of land for agriculture is not common, but land rental and sharing through agreement between users for one or two cropping seasons is common in the study area. The rental value of the land depends on the quality of the land and access to irrigation and demand for the same piece of land. Landowners who have farm plots close to irrigation water thus have higher incomes from rented land or share cropping. Land owners who have farm lands with access to irrigation water will have higher returns especially during the dry season. The value under the in-land valleys for rice production after two years of JIRCAS and MoFA training, skills development has increased.

4.6.1 Crop Grown using Small-Scale Irrigation

Crops grown without irrigation (rain fed) in the study area are maize, rice, cassava, cocoyam, plantain, tomato, egg plant, okra, groundnut, cabbage, lettuce, onion, cowpea, bean, carrot and pepper. Majority of the farmers in the study area will either grow one or multiple of the crops during the rainy season. In addition to rain fed cultivation, irrigation farmers produce cash crops for the second season within a year in dry periods using irrigation water. The main field crops grown using small scale irrigation in the study area are rice and maize and the dominant vegetables are okra, pepper, tomato, cabbage, lettuce, egg plant and beans. The major cropping season is from April to September. In this period both irrigating and non irrigating farmers produce rainfed crops. The minor cropping season is practiced in when there is less rain from October to December. The dry season is January to April. In this cropping season, only irrigating farmers can cultivate using water from streams, underground wells and rivers. Access to irrigation has been regarded as a powerful tool that provides a greater opportunity for multiple cropping, higher cropping intensity and crop diversification. Farmers who have access to small scale irrigation can cultivate twice a year. Thus irrigation increases the intensity of cropping. For arable crop cultivation using small scale irrigation, rice was the dominant. It is grown by 10% of irrigating sample farmers. Maize and other crops were grown by 6% of the respondents. Vegetables were the commonly produced crops with small scale irrigation systems. The most frequently grown crop was okra by 78% of irrigating farmers. About 16% of the respondents grew either tomato, cabbage, pepper, garden eggs or more than one of these vegetable crops.

Agricultural production resources in the study area include land, labour force, motorized diesel pumps, hand operated motorized tractor, agricultural extension personnel, water resources, markets, and NGOs. The presence of these production resources has several benefits including increase wealth of farmers; improve food security and nutritional value of diet.

There are different reasons why okra is grown by most farmers. The major reason for producing okra are seed availability, resistance to diseases, higher income, easier to cultivate, high demand, good production, locally available, low water demand and ease to harvest.

4.6.2 Use of inputs

The main inputs used in the study area are chemical fertilizers, poultry manure, improved seeds, weedicides/herbicides and pesticides. A farmer who uses one or more of these inputs increases his or her income significantly.

4.6.3 Opportunities, Food Security and Field Training

Farmers using irrigation the technologies are doing well - the motor pump users, but the water diversion scheme users are relatively much better off. Women, who do most of the field work, are gaining greater earning power. The income gained from small scale farms using motor diesel pumps in Ahafo-Ano South District is very impressive. The average income per head of okra farmers during the rainfall and dry season farmers using motorised pumps to cultivate okra is good. Price of commodities increases during dry seasons. For instance in Table 9, the average price of okra during the rainy season increases from ₵ 1– ₵ 20 during dry season per the *black plastic* bucket and a crate of tomato also from ₵ 10 – ₵ 50.

In addition to, the higher income of pump and dam technology are attracting a younger generation back into the farms.

4.6.4 Key Lessons or Opportunities for Water Management

The District has substantial water resource potential. What is constraining production is access to appropriate water management technologies, infrastructural and institutional support services (including roads, financial institutions and market) and enabling environment for effective private sector involvement. The lesson with water management systems vary from one community to the other while huge opportunities exist for water management on sustainable basis. Some of these lessons and opportunities are highlighted as:

- Several NGOs have assessed the water potential in the study area of operation to be huge. If it is exploited efficiently, it would contribute significantly towards poverty reduction and solving the country's food insecurity problems, especially if irrigation of food crops and vegetables along with high value crops are emphasized.
- All the communities covered in the survey indicated willingness to participate in any form of good water management technologies or interventions that will improve their current livelihoods. This reflects the willingness of local level participation and cooperation. This willingness will improve water management interventions in the area.

4.6.5 Constraints to Small-Scale Irrigation

Most farmers perceive financing, marketing, pump breakdowns and knowledge on irrigation management as the key constraints to their farming.

1. Financing: Equipment cost especially motorized equipment requires a substantial cash outlay. Most of the farmers do not have collateral to safeguard loans either from the agricultural bank, rural banks or commercial banks. NGOs have recently provided rice farmers who are in groups with agricultural inputs and technological assistance.
2. Marketing: Crops are sold in many ways i.e. directly by farmers to consumers in local markets, through middlemen and through district school/feeding secretariat. Market information is lacking so farmers who transport their produce to distant towns may find the market flooded with the produce. The middlemen and women who take advantage of what has been a market pool to amass wealth by taking advantage of the market failure. They pay or buy the commodities at low prices and sell them at much higher prices. Clearly, farmers need some protection, probably in the form of better market information.
3. Pump breakdowns are also a major problem: Farmers are not trained to maintain their pumps and generally do not carry spare parts.
4. Knowledge and capacity for technology development and application are also inadequate. In addition to, government policies and financing has favoured the dealers of motorized pumps who

import the equipment from abroad. These dealers also face severe problems or are handicapped by strict borrowing conditions, heavy import duties and taxes and restrictive import licenses.

4.6.6 Government's Role

Government currently does have a critical role to play in creating an enabling environment for technology development and uptake for small-scale irrigation.

- Government should develop policies and regulations for irrigation equipment manufacture, importation, promotion and servicing. Lower priced inputs and joint manufacturing approach should be encouraged.
- Government can assist agricultural and engineering departments and faculties to strengthen their programmes on irrigation through research and innovation grants.
- Government should develop mechanisms to facilitate access to credit or loans for small-scale irrigation farmers.
- Government can also play a direct role in extension service training and provision of other technical support services like training on small-dams construction, scheme design and the production of manuals for design and management of micro-dams and water diversion structures.

The crops that by far dominate the agricultural landscape of the Ahafo –Ano South District are rain fed rice, maize and Okro in the wet season.

Physiographically, the landscape of the Ahafo-Ano South District consists of hilly areas, undulating land, non-flood plains, flood plains and river levees. Greater attention should be given to the role of women in agriculture particularly in view of the increasing feminization of the region's rural population and increasing accounts that farm labour in rural districts is getting dramatically old.

4.6.7 Availability of labour

On many small farms, the farmers and their families provide the labour force operating the irrigation system and no direct cash payment is made for outside help. In this case, the cost of labour may not be included in the operating cost calculations. However, in some cases the farmer and some members of family may have employment elsewhere and have to hire labour for irrigation. In this case, the cost of the labour would need to be included. This can be a significant cost and may have an influence on the values and choice of system, particularly as some systems are more labour intensive than others.

4.6.8 Farmers In-Service Training

Most of the farmers have very little knowledge of modern farming practices as seen in Table 2. Therefore is a knowledge gap. In 2010, the Mankranso MoFA and JIRCAS set up field school for rice production. The schools were led and managed by JIRCAS and extension agents who shared new research findings and technologies as they were incorporated them into farming activities. Members learned improved farming practices provided by facilitators (extension agents). The regular supervision and evaluation of the field school as reviewed by MoFA-Mankranso showed increases in the productivity at all the project sites. Rice farmers employing improved rice production techniques have increased their yields significantly. At Potrikrom, the farmers produce high quality rice which they sold to the School Feeding Programme (Government) making a significant contribution to district/national development.

The farmer field school approach was first developed in south-east Asia in the late 1980s for pest management. Unlike traditional approaches which rely on extension workers providing top - down advice, field schools enabled group farmers to find solutions for themselves. That means farmers will develop solutions to their problems. They are more inclined to put into practice what they have learned themselves rather than if they are handed ready-made, but possibly inappropriate solutions. The field schools enable the farmers to understand what their needs are and articulate them into their farm business. Even though most of the farmers did not go to high school, yet a good number of them are conducting or constructing their own bunds to get higher yield, earn income and to reduce poverty.

Through field school experimental learning and participatory group approaches, farmers have made decisions, solved problems and acquired new skills and techniques. Those who applied what they learned are reaping the benefits of higher yields. As the farmers share their knowledge with their neighbours, productivity and profits are growing.

Figure 7: Farmers field training by extension agent

Source: MoFA Ahafo-Ano South

4.6.9 Training and Extension Services for Small Scale Irrigation

Extension is the mechanism by which information and technologies are delivered to farmers (Moris, 1991). A more comprehensive definition of extension service is given by the world bank as a process that help farmers to become aware of improved technologies and adopt them in order to improve their efficiency, income and welfare [Purcell and Anderson (1997) in Gebremedihn and Pedon (2006). In the Ahafo-Ano South District, most of the farmers cannot read and interpret information in printed form. Thus, there is the need to disseminate agricultural information to these numerous farmers by extension agents. The farmers in the study area were previously practising irrigation without much knowledge on agronomy, proper water application techniques and crop protection. For example, the rice farmers in all the five selected communities were not bunding their rice farms for efficient use of water application and control systems. The vegetable farmers were not using the right quantity and method of fertilizer application, but with the farmers' field school modular by the extension agents, they are now convinced that with the requisite knowledge and skills they will boost or increase outputs.

Figure 8: Land demarcation for bunding by extension agents

Source: MoFA Mankranso (extension agents and farmers)

4.6.10 Household Food Security and Livelihood

The development of small-scale irrigation schemes in the study areas has increased cropping intensity and income from crop production. According to the survey results and discussions with farmers, their incomes have increased as compared to the situation before the implementation of the irrigation schemes. Before the construction of the dams, farmers depend on rain for production of food crops. The farmers indicated that the income from the sale of crops produced during the rainy season were not enough for household expenses. As a result they faced food, seeds and lacked capital to purchase farm inputs. The implementation of small-scale irrigation schemes has helped the farmers to diversify crop production and income resources. Majority of the farmers currently are into dry season irrigation than before due to constructed dams (weirs). From the focus group discussion, the farmers indicated that income from the produce has increased tremendously since the farmers can now diversify their crop farming operation. The major issue of concern among rural farmers is to be able produce all year round for income and to secure food all year round for consumption. For instance rice farmers in Potrikrom indicated that they are able to produce enough for household consumption with the surplus sold to the School Feeding Programme Secretariat in the Ahafo-Ano South District since the implementation of the irrigation schemes.

4.6.11 Livelihood of the Farmers

Farmers feel that their livelihoods have improved substantially since the use of pumping machine. "We have all benefited a lot from the use of pumping machines, we now have enough food and cash to take us through, many of us have building materials to start building, we have money to pay our children's school fees" they said. We are also able to buy household items and fertilizers and other chemicals for our farming activities, we have plans to expand our farms to obtain more money for our families. Opanin Charles a 55-year old, father of eight, has built a house from his okra farm just in two years. The okra farmers intend to buy additional pumping machines and farm inputs to expand their farms. Sometimes traders go to the farmers at the farm gate, and sometimes they negotiate on phone or even travel to the buyers' locations for the okra fruits. They also diversify their activities to provide them with more opportunities to increase their incomes and safeguard themselves against market and weather fluctuations as shown in figure 7 and 8.

Figure 9: Solanum melongena.

Figure 10:Abelmoscum esculentus.

Source: Field Survey

4.6.12 Motorised Pumps and water diversion schemes

For many farmers across the study area getting water to their crops was a big challenge. Farmers who have access to irrigation have substantially higher incomes and better food security than their neighbours who rely on rainfall. In particular, vegetable cultivation in the dry season is very profitable. But this needs a reliable method of drawing water from an available water source, be it a river, stream, groundwater, dam or a reservoir. Pumps are the obvious choice. Smallholder irrigation farmers have existed for more than two decades in the district. Some years ago, they were using the bucket method of water application. But it was tedious to transport the water. There was a considerable scope for expanding their water use when more labourers are employed. But now that motorised pumps are more easily accessible to buy or to rent, the use of bucket is falling out of favour. The smallholder individual irrigation sectors are buying made in China and India motorised pumps for dry season vegetable production as shown in figure 10. This has reduced the dependency on rain fed agriculture and the scope for further growth and poverty reduction is substantial.

Figure 11: Low horse power diesel pump

Source: Field Survey

4.6.13 The Low Horse Power (Hp) Diesel Pump for Small-Scale Irrigation

The low horse power (HP), diesel pumps are very popular among farmers in the Ahafo-Ano South District especially those who are into okra, pepper, tomato, cabbage, garden eggs and lettuce cultivation.

The pumps are sold between 500-¢1000. The use of small pump sets is becoming increasingly popular in the District. The biggest obstacles for the farmers are high cost and low quality of pump set. Apart from investment cost, the fuel cost is increasingly going higher.

4.6.14 Calibrating the Water Pump

The objective of calibrating the pumps is to determine or adjust the volume of water to apply to a given area of land. The factors which influence calibration are:

- Walking Speed: increasing the speed at which the water applicator moves over the field results in low volume of water being applied per area. Conversely, a lower speed results in the application of high/greater volume of water per area.
- Pump Pressure: increasing the pump pressure results in a greater volume of water being applied per area. Lower pressure results in less volume applied.
- Nozzle Size: The use of nozzle tips with large openings results in a greater volume of water being applied. Smaller nozzle size openings will deliver a lower volume of water and will reduce the surface flow and will enhance a high rate of water delivery but the pattern or distribution of water as well as droplet size will vary.
- Pipe/Hose Size: The size of the pipes affects the pressure and volume of water delivery on the field. Large diameter PVC pipes used to convey water from the source gives a large volume of water to the field or area irrigated. Water applicator should move very fast so as not to waste water and encourage surface flow, which may also wash away soil nutrients.

4.6.15 Diversion systems

Diversion systems are probably the most common form of irrigation system for rice cultivation in the Ahafo-Ano South District. Diversion system often utilizes natural river flow, however, regulation of water through a permanent structure (bunds) on the field is also common practice to increase and improve water use efficiency on the field. Diversion systems have been sustained over a period and are able to deliver water regularly throughout the cropping season. A key characteristic of diversion systems in the Ahafo-Ano South District is the adequacy of water supply during rainy season and the ability to regulate a dry season crop in addition to providing supplementary irrigation during the dry season.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

It can be inferred from the information gathered from the study at the Ahafo-Ano South District that the area is endowed with agricultural potential that can help to improve food security and safety. The area records a number of areas which are potentially reliable for inland valley rice production and lands which are also suitable for the production of vegetables. As identified in the study, there are many factors that hinder the development agricultural development in the district. These include inadequate funds, water shortages and modern skills and knowledge of efficient water application methods, lack of spare parts for pumps, high cost of fuel for pumps lack of market transparency and perceived high cost of inputs are the main factors affecting farming activities in the District. Ahafo-Ano South District, which is in the forest belt, is vulnerable during the dry season.

Access to irrigation increases the opportunity for crop intensity and diversification, which increase cropping income. Irrigation is becoming a practice to increase total annual income for many household in the study area. In addition to their normal rainfed cultivation, irrigating households cultivate vegetable crops using small-scale irrigation. The main irrigated vegetables were okra, tomatoes, egg plant and the main arable crops grown were rice and maize. Irrigated crops were selected based on good production potentials, good yield and ease of cultivation.

The use of small diesel pumps for water delivery and application during the dry season vegetable production is far better than the use of watering cans and bucket and cup form of water application. Rice farmers divert water from stream/rivers directly to their field as they need. Most of the rice farmers used diversion ditches to irrigate their land. Irrigation of diversion of stream flow is better than pump system for its low operation and maintenance cost, but the pump system can be used to lift water to the uplands with ease.

The two main rivers, Mankran and Dunyan in the study area are potentially viable and reliable when properly dammed to capture and stored water during the rainy seasons and used to supply water during the dry season.

5.2 Suggestions for Improving Small-Scale Irrigation in Ahafo-Ano South District

- Farmers should form groups or cooperatives to enable them channel their needs to benevolent organisations for needed assistance.
- Inputs for farmers should be made available and on time especially fertilizers, seeds, tools and machines at affordable prices to enable farmers produce efficiently and maximally.
- The government should construct more weirs in the area to bring more people on board or the youth to take agriculture so as to solve the unemployment canker in the area and Ghana as a whole.
- The Ministry of Food and Agriculture (MoFA) should encourage farmers to use organic manure especially poultry manure, since it is common and has high plant nutrients and can improve the structure and fertility of the soil.
- Farmers should go through regular in-service training and equip themselves with modern ways of water and land use management in both irrigated and non-irrigated lands to improve food security.
- The top-down approach of solving problems should give way to the bottom-up approach which embrace the involvement of the local people in tackling the problem of water and land use management.

- The judicious use of water and land resources should be encouraged in the Ahafo-Ano South District.
- There should be an organisational support and supervision, advisory and extension officers for the rural farmers.
- There should be an improvement and expansion of existing small-scale irrigation schemes in the streams and rivers in the District.

5.3 RECOMENDATIONS

Based on this study, the following recommendations may contribute to a sustainable development of smallholder irrigation schemes.

The search for solutions to the District's poverty and food insecurity require efforts to reverse negative trends that have hitherto limited the impact of well meaning intervention. In doing this, the recognition of the heterogeneity of the rural society of Ahafo–Ano south District of Ashanti which consists of groups of poor people with different level assets and endowment is necessary. With this recognition, a possible approach recommended is to:

1) Provide selected technologies based on experiences elsewhere to overcome natural phenomenon such as dry spells and drought.
2) Enhance productivity through proper land use and water management, which may require strategic and applied research.
3) Invest in rural water development as multiple water use systems to reduce poverty and improve livelihood through provision water of for agriculture.
4) Consider the infusion of small scale irrigation development in the state's poverty reduction programme.

5) Government, the private sector and other stakeholders must view irrigation development as a potential goldmine and consider an irrigation master plan assessing the needs of water for irrigation of agricultural crops under climatic changes and prepare long term projection for the required water resources to be used in agriculture.

6) Farmers should find ways to better match their production plan with market demands. They should adopt seed multiplication programmes to reduce seed costs and improve access to high quality seeds. They should also increase the capacities of water application in order to meet crop water and consumer demand at the peak required.

7) In as much as irrigation system in the Ahafo- Ano South District serve other water uses other than agriculture, it is recommended that research and policy analysis be done to determine the best use of water resources.

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Appendix 1

CONFIDENTIALITY

Any information provided on this document is for research purpose only and shall by no means be made to reflect your identity. Your identity shall not be made known to anybody, institution or organization.

Tick where appropriate or provide brief and precise answers where appropriate.

Questionnaire to farmers at irrigation sites

PROFILE OF RESPONDENT

1. Name of farmer ………………………………………………………………………………………………
2. Gender Male ☐ Female ☐
3. Age (i) 20 – 30 ☐ (ii) 31 – 40 ☐ (iii) 41 – 50 ☐ (iv) 51 – 60 ☐
4. Name of Community ……………………………………………………………………………………………
5. Educational status ☐ (i) No education/Primary ☐ (ii) Middle school/J.H.S. ☐

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

LAND ACQUISITION

6. Do you own the plot of land for your irrigation farming? Yes ☐ No ☐
7. If no, what is your plot ownership agreement?

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

   (d) Sharecropping (i) *Abunu* ☐ (ii) *Abusa* ☐

☐

8. If yes, how did you acquire it (a) gift ☐ (b)purchase ☐ (c) inheritance

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

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

11. (i) Did you encounter any problem in acquiring your plot of land?

    Yes ☐ No ☐

    (ii) If yes, what were the problems? (a) High cost of lan☐ (b) Land litigatio☐

    (c) Others (state)……………………………

CROP CULTIVATION

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

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

    (a) Tomato ☐ (b) Cabbage ☐c) Pepper ☐(d) Rice ☐ (e) Okra ☐f) Lettuce ☐

    (g) Others (state) …………………………………..

14. (a) Do you have any problems with regards to your crop cultivation? Yes ☐ No ☐

    (b) If yes, indicate (i) inadequate labour ☐ (ii) high cost of labour ☐

    (iii) Unsuitable weather condition ☐ (iv) inadequate water supply ☐

    (v) Problem of viable seed ☐(vi) inadequate credit facility ☐

    (vii) Others (state) ………………………………………………………

15. How do you acquire seeds? (a) produce it myself ☐ (b) purchased from market ☐

    (c) supplied by friends ☐ (d) supplied by MoFA ☐

    (e) supplied by NGO ☐ (f) others (state) ………………

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

17. (a) Which of the following fertilizers do you apply to your plots?

    (i) Organic manure ☐ (ii) Inorganic fertilizers ☐ (iii) None ☐

    (b) If organic manure how many kilograms do you apply to your crops? ………………………

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

19. How do you get fertilizer? (i) Purchased ☐ (ii) Open market dealers ☐

    (iii) Supplied by MoFA ☐ (iv) Supplied by friends ☐

☐

(v) Supplied by NGO

20. What type of fertilizer do you use in your irrigation farm?

Type of fertilizer	**Quantity (bags)**
NPK	
Urea	
Sulphate of Ammonia	
Single-super phosphate	
Potash	

IRRIGATION

21. What is your source of water? (i) Stream ☐ (ii) Well ☐ (iii) Reservior ☐ (iv) River ☐ (v) Borehole ☐

22. How do you apply water to your crops? (i) Uses Bucket ☐ (ii) Watering can ☐ (iii) Pumping machine ☐ (iv) Diversion of water to the field ☐

23. How many people assist you to irrigate your farm? State……………………………………..

24. How many years have you been into this method of irrigation? ……………………….

25. Why have you chosen the method of water application indicated in (19)? State why!

(a) It saves time ☐ (b) It is cost effective ☐ (c) It saves labour ☐ (d) Others (state)…………………………

26. (i) Do you experience water shortage? Yes ☐ No ☐

(ii) If yes, which month(s) of the year? ………………………

27. How many cans or buckets do you apply to your farm in a day? ……………………………….

28. (i) Do you get regular and enough water supplies to your crops? Yes ☐ No ☐

(ii) If yes, at what interval du=o you water your crops? ……………………….

29. How long does it take you to irrigate your plot in a day? …………………………….

30. What do you think are the problems confronting the water delivery in your farm?

(a) High cost of fuel ☐ (b) inadequate labour ☐ (c) long drought ☐

(d) long distance from water ☐ (e) stress on water source ☐ (f) others (state)………………

31. What do you think can be done to minimize water losses on your farm?

(a) Improve knowledge of water application ☐

(b) Knowledge of crop water requirement ☐

(c) Effective use of water ☐

32. How long in a day do you pump water to your crops? (state) ……………………………….

MANAGEMENT

33. Do you take vegetable or arable crop as a full time or part – time?

(a) Full time ☐ (b) Part- time ☐

34. (i) Do you face any problems with labour acquisition? Yes ☐ No ☐

(ii) If yes, how do you solve the problem? (a) Provision of incentive ☐

(b)Provision of tools and equipment ☐ (c) provision of good salaries and wages ☐

35. Which agro-chemicals do you use? ……………………………….

36. What management practices do you take to ensure high yield of your crops?

(a) Fertilizer application ☐ (b) Weed control ☐ (c) disease and pest control ☐

(d) Regular water application ☐

FINANCING AND MARKETING

37. How did you source funds to start farming? (i) Personal/family ☐ (ii) Money lenders ☐

(iii) Financial Institutions ☐ (iv) NGO's ☐

(v) MoFA ☐

38. Where do you sell your produce? (i) Local market ☐ (ii) Farm gate ☐

(iii) District capital market ☐

(iv) Regional capital market ☐

39. Do you have specific buyers or market? Yes ☐ No ☐

40. Does your produce meet the demands of the market? Yes ☐ No ☐

41. If no, how would you improve the situation?

(a) Increase farm size ☐

(b) Have access to credit ☐

(c) Improve farm management practices ☐

(d) Improve water delivery ☐

(e) Improve the quantity and quality of labour ☐

42. (a) Do you make profit from the sales of your produce? Yes ☐ No ☐

(b) If no, what will be the reason(s)? (a) Low yield ☐ (b) Seasonality of produce ☐

(c) Large family size (consumption) ☐ (d) Poor disease and pest control ☐

(e) Large number of farmer producing the same commodity ☐ (f) others (state)………

Appendix 2

Checklist for Focus Group Discussion

1. When were the various weir constructed and what informed the construction of those weirs?
2. Why did you choose those area or sites?
3. How do you evaluate the prevailing land tenure system in the area as to the sustainability and productivity of the irrigation agricultural practice of small holder irrigators? –issues of tenure security and of equity in land subdivision among small holder farmers.