

# THE IMPACTS OF AGRICULTURAL SECTOR POLICIES ON THE DEMAND FOR WATER RESOURCES WITHIN THE VOLTA BASIN OF GHANA


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## **Dedication**

**I dedicate this accomplishment to the Most High God and to my beautiful daughter Elyon Nayorm Nornor- Quadzi for the joy, fulfillment and encouragement she's brought into my life.**





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## List of Acronyms and Abbreviations

ACP	Africa, Caribbean, Pacific
ADB	Agricultural Development Bank
CFA	Cooperation Financiere en Afrique Centrale
CGIAR	Consultative Group of International Agriculture Research Commodities and trade
DFID	Department for International Development
EPA	Environmental Protection Agency
FAO	Food and Agricultural Organization
FASDEP	Food and Agricultural Sector Development Strategy
GAMs	General Algebraic Modeling System
GDP	Gross Domestic Product
GIDA	Ghana Irrigation Development Authority
GLOWA	Global Change in the Hydrological Cycle
GLSS	Ghana Living Standard Survey
GNWP	Ghana National Water Policy
GPRS	Ghana Poverty Reduction Strategy
GSS	Ghana Statistical Service
GWC	Ghana Water Company
ICOUR	Irrigation Company of Upper region
ICWC	Interstate water Commission
IFPRI	International Food Policy Research Institute
IMF	International Monetary Fund
IMPACT	International Model for Policy Analysis of Agricultural
IPTRID	Poverty Reduction and Irrigated Agriculture
ISSER	Institute of Statistical Social and Economic Research
IWMI	International Water Management Institute
KMO	Kaiser-Meyer-Olkin
LP	Linear Programming
MCA	Millennium Challenge Account





MOFA	Ministry of Food and Agriculture
MOTAD	Mean of Total Absolute Deviations
MPC	Marginal Propensity to Consume
NAFTA	North American Free Trade Agreement
NCWD	Net Crop Water Demand
NGO	Non- Governmental Organizations
NLP	Non-Linear Programming
OECD	Organization for Economic Cooperation and Development
PCA	Principal Component Analysis
PMP	Positive Mathematical Programming
QPR	Quadratic Programming
SLM	Sustainable Land Management
SRID	Statistics, Research and Information Directorate
SSA	Sub-Saharan Africa
UN	United Nation
USA	United States of America
WRC	Water Resource Commission
WSM	Water Simulation Model

#### Units

Ha	Hectare
Kg	Kilogram
Km	Kilometer
Mt	Metric Tonnes
Cedi	Ghanaian Currency

#### Exchange rate

1USD = 1.45 GHS



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## Abstract

The agriculture sector in Ghana is the backbone of the rural economy. Agriculture employs about 60 percent of the population and contributes significantly to the GDP of the country. It is also a major foreign exchange earner. However, low productivity and inefficient resource use have resulted in a substantial threat to the livelihoods of the population that depend on this sector. The significant demand of water in the area for crop production renders farmers vulnerable to the recurrent decline in water supply as a result of drought.

This study contributes to the understanding of key limitations in the agricultural sector and offers prospective solutions to promote sustainable development of the sector. To achieve the above objective, 530 farm households were interviewed using the common sampling framework in the Volta basin area of Ghana from June 2007 to August 2008. A focus group discussion as well as interviews with institutions concerned with water and agriculture resources were also considered. Methodologically, a non-linear programming model named Multi-Analysis Tool for the Agricultural Sector (MATA) model was employed to achieve the stated objectives. The MATA model comprises of four different modules, the Consumption Module, the Macroeconomic Module, the Water Simulation Module (WSM), and the Production Module. These are all linked together in the final model. The WSM is the value added to the original MATA model as a result of recent climate change conditions affecting the agricultural sector in Ghana. Therefore, in order to consider the impact of water demand on the agricultural sector in Ghana, water supply variables were also considered and incorporated into the model as important constraint variables.

Our findings suggest that, water pricing as the only instrument for control of water use is not an operative instrument to significantly reduce agricultural water consumption. This is mainly because water consumption is not able to fall until water prices reach levels that negatively impact agricultural employment and farm income. Meaning that, agricultural employment and farm income would decrease before the demand for water reduces. The effect of this decrease on rural areas that are mainly dependent on irrigated agricultural practices will be disastrous. Furthermore, there will be a decrease in the availability of variety of crops offered for farming, as well as a reduction in the number of alternatives and significant technical and economic vulnerability of the agricultural sector. Finally, when water depletion/use decreases as a result of substitution of crops with higher demands for water, it is translated





into a major loss of employment both indirectly and directly in the sector of agriculture.

Even though price increases might not be an appropriate policy tool because of the high negative impact, we propose that a price approximately 2cedis/m<sup>3</sup> for water may be necessary to make farmers conscious of the scarceness of water resources, and to persuade them to adopt other water saving technologies without affecting the distribution of crops. Water pricing has helped other countries as revenues from the collection of the water prices could be administered by officials or water users associations for investment in water saving technologies and environment activities. Revenues that are not properly invested could be given to the Ghana Water Authority or the Volta Basin Authority.

It was also found that as farmers expect that prices of rice to increase in the future, more land could be allocated to the production of rice. Farm employment would also increase as most farmers would employ more agricultural labor with a reduction in off-farm labor.

Government's policies to encourage the production of a particular crop should take into consideration the farmer's price expectations. The outcome of the study also indicated that economic and ecological development could be achieved concurrently only under the existence of more flexible decision making at the farm level. It was also found that as government increases credit availability in cash to farmers most farmers instead of using the money to invest directly in agricultural activity use the money to increase the non-agricultural consumption, such as paying old debt, using the money to pay children school fees and investing in other nonfarm activities. The study, therefore recommends that government in a bid to increase farmers income and production, is encouraged not to give physical cash in terms of credit to farmers but could channel such money into agricultural input (like new improved seeds, fertilizers, machinery etc.) to farmers instead, so that such inputs would be given to them on credit basis payable with interest.



## KURZFASSUNG

Der landwirtschaftliche Sektor in Ghana ist das Rückgrad der ländlichen Ökonomie. Landwirtschaft beschäftigt über 60 Prozent der Bevölkerung und trägt weitgehend zum Bruttosozialprodukt des Landes bei. Es ist auch wichtigster Devisenbringer. Aber niedrige Produktivität und ineffiziente Ressourcennutzung haben eine erhebliche Bedrohung für die Lebensgrundlage der Bevölkerung, die von diesem Sektor abhängen geführt. Der hohe Wasserbedarf in der Region für Pflanzenproduktion macht Bauern verwundbar für den immer wieder vorhergesagten Rückgang der Wasserversorgung als Resultat von Dürre.

Diese Studie leistet einen Beitrag zum Verständnis der wichtigsten Einschränkungen und mögliche Lösungsansätze zur Förderung einer nachhaltigen Entwicklung im Agrarsektor. Um das genannte Ziel zu erreichen, wurden 530 Bauernwirtschaften im Gebiet des Volta Beckens in Ghana zwischen Juni 2007 und August 2008 nach dem üblichen Probensystem. Befragt. Eine Focus Gruppendiskussion als auch Interviews mit Institutionen, die Wasser und landwirtschaftliche Ressourcen betrafen wurden außerdem berücksichtigt. Methodisch, ein nicht lineares Programmiermodell genannt Mata wurde eingesetzt um die angegebenen Ziele zu erreichen. Das MATA Modell besteht aus vier Modulen, das Verbrauchsmodul, das makroökonomische Modul, das Wassermodule und das Produktionsmodul. Diese sind im finalen Modell alle miteinander verbunden.

Die Modellbefunde legen nahe, dass die Preisgestaltung des Wassers als einziges Instrument zur Steuerung des Wasserverbrauchs kein effektives Mittel ist zu einer beträchtlichen Reduzierung des Wasserverbrauchs in der Landwirtschaft. Dies liegt daran, dass der Verbrauch nicht fällt, bis die Preise ein Niveau erreichen, dass die landwirtschaftlichen Einkommen und Beschäftigung in der Landwirtschaft negativ beeinflusst. Wenn der Wasserpreis als politisches Mittel eingesetzt wird, wird eine Folge für die Landwirtschaft sein, dass das Einkommen der Bauern sinkt, bevor der Wasserbedarf bedeutend verringert wird. Die Auswirkung der Einkommensreduktion in den landwirtschaftlichen Gebieten, die von Bewässerung abhängig sind wird katastrophal sein. Zweitens werden weniger Kulturpflanzen für die Landwirtschaft zur Verfügung stehen mit der Folge einer kleineren Zahl von Alternativen und größerer technischer und wirtschaftlicher Verwundbarkeit des landwirtschaftlichen Sektors. Letztendlich, wenn der Wasserverbrauch sinkt als Folge des Austausches von Kulturpflanzen mit höherem Wasserverbrauch



(Reis, Mais) gibt es einen bedeutenden Verlust an Arbeitsplätzen, direkt und indirekt in der Verarbeitungsindustrie.

Selbst wenn Preiserhöhungen, wegen der hohen negativen Auswirkungen, keine geeignete Politik sind, empfehlen wir dass ein Preis (rund 2 cedi/m<sup>3</sup>) von Interesse sein könnte, um den Landwirten die Knappheit der Wasserressourcen bewusst zu machen und sie zu veranlassen, Wasser sparenden Technologien, ohne die Ernte zu beeinträchtigen, anzuwenden. Um die vollen Auswirkungen der Wasserpreisgestaltung zu erreichen, wie sie in anderen Ländern hilfreich war, die Einnahmen von der Erhebung des Wasserpreises sollten vom Staat verwaltet werden zur Investition in Umweltschutz und Wassereinsparung, während die Einnahmen, die nicht angemessen investiert wurden, der regionalen Wasserbehörde übertragen werden könnten.

Es wurde weiterhin festgestellt dass, als Landwirte erwarteten, dass die Preise für Reis in Zukunft steigen würden, mehr Land der Reisproduktion zugeteilt wurde und die Arbeitsplätze in der Landwirtschaft gestiegen sind, da die meisten Landwirte mehr Feldarbeiter einsetzen würden und da ist ein Rückgang auf dem nicht- landwirtschaftlichen Arbeitsmarkt. So wären für den Regierung die Erwartungen der Farmer ein Gebiet auf das man sich konzentrieren sollte, um für die Produktion einer bestimmten Kulturpflanze zu motivieren. Die Ergebnisse zeigten auch, dass ökonomische und ökologische Entwicklung gleichzeitig erreicht werden könnten nur durch flexiblere Entscheidungsfindung auf der Ebene der Landwirtschaftlichen Betriebe. Ferner wurde festgestellt, dass, als die Regierung die Verfügbarkeit von Barkrediten für die Farmer erhöhte, die meisten Farmer das Geld für nicht- landwirtschaftlichen Konsum ausgaben, wie alte Schulden bezahlen, Schulgeld für die Kinder oder nicht-landwirtschaftliche Aktivitäten, anstatt das Geld zu benutzen, direkt in Ihre landwirtschaftliche Arbeit zu investieren. Die Studie schlägt dafür vor, dass die Regierung in einem Angebot das Einkommen und die Produktivität der Landwirte zu erhöhen, ermutigt ist nicht Bargeld als Kredit and die Farmer zu geben sondern solches Geld stattdessen in landwirtschaftliche Produktionsmittel (wie neues verbessertes Saatgut, Düngemittel, Maschinen und so weiter.) umwandelt, so dass diese Produktionsmittel auf Kreditbasis zu ihnen gegeben würden, zahlbar mit Zinsen.



## **1.0 Introduction to the Study**

### **1.1 Background**

The agricultural sector is one of the most important sectors in the Ghanaian economy; exceeding industry and services in value (ISSER, 2003). Agriculture contributes extensively to economic growth and poverty reduction by contributing directly to food security, foreign exchange earnings, employment in the formal and informal sectors, and also serves as the major source of raw materials to the agro-based industry, and an important component of GDP. The agriculture sector has been the largest contributor to GDP, but its contribution to GDP has been declining slowly over the years, from 36 percent in 2005 through 35.4 percent in 2006, to 34.7 percent in 2007(MFEP, 2008 budget report). The major sub-sectors of the agricultural sector consist of staple crops, cocoa, livestock, forestry, logging and fisheries.

Agriculture is also the major source of livelihood within the Volta basin, within which agricultural practices follow the general patterns of agricultural land use throughout Ghana. The Volta basin includes some of the most important agricultural districts, noted for the production of grains (mostly maize) and tuber crops such as yam and cassava. In the lower Volta basin, comprising the Accra and parts of the Ho-Keta plains, livestock rearing also constitutes an important agricultural activity.

The most common type of land use in the basin area is rain-fed agriculture based on a bush fallow system, and is done mostly on a semi-commercialized basis. Irrigated agriculture in the Volta basin area would really be of an advantage to farmers. With a huge area available in the region for irrigation purposes, there are only two



main dams available for irrigation in the Northern part of the country that is Tono and Veia irrigation scheme and also one main dam in the Volta part of the country that is Kpando-Torkor irrigation scheme. Some of the small dams in Volta region are not in good working conditions as a result of the recession<sup>1</sup> of the Volta Lake coupled with poor access to the sites.

Despite the limited extent of irrigated agriculture, irrigation is the dominant source of consumptive demand for water resources. Within Ghana, water demand for irrigation in 2000 has been estimated as 565 million cubic meters per year (MCM), compared with 138 MCM for domestic use, and 26 MCM for livestock (Andah & Gichuki, 2003). Industrial demand is concentrated in the coastal area, largely outside of the Volta basin.

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<sup>1</sup> In the early 1980, there was a severe drought in Ghana and that led to the Volta Lake drying up so there was no water for farmers to use for agricultural production.



## 1.2 Statement of the Problem

Stretching over 154440 square miles, the Volta basin is part of the savanna zone in the West African. It is an international basin, with about 40% of basin area in Ghana, 40% in Burkina Faso and the remaining 20% in Mali, Cote d'Ivoire, Togo and Benin. The generation of electricity for use by the industries also competes with the agricultural sector for the water resources available. With a 3% Population growth rate in the country, the Volta basin area also experiences an increase in its population growth, leading to land use and land cover changes. The major problems affecting agricultural production in the basin, and elsewhere within Ghana, are those associated with the degradation<sup>2</sup> of agricultural farm lands due to the fact that lands has not been used properly and poor water use managements.

Productivity in agriculture is limited primarily by rainfall variability and unreliability, which cause moisture deficit where supplementary irrigation is not available. There is the potential for increasing conflict between agricultural production and environmental conservation driven by the accelerated demand for agricultural products and land. However, growth in the agricultural sector is critical to people in the rural areas as that is their main source of livelihood. The development of supplementary irrigation, in combination with the use of high yielding inputs, is central to the improvement of agricultural productivity. Water is no less critical to agricultural productivity than land, capital, and labor.

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<sup>2</sup>. As irrigated land is limited in supply, Farmers intensively cultivate those lands that are irrigated. It may lead to land degradation.





The magnitude of rainfall variations within the Volta basin, both seasonal and annual, is a very significant factor in determining the production of crops in the region and inadequate rainfall has large negative consequences. Therefore, in order to make use of the available lands in the basin, it has become necessary to improve on the infrastructure and related facilities associated with irrigation. Irrigation development can assist in meeting the domestic demand for food commodities, and also increasing crop production for the export market.

However, irrigation development will only succeed if it is economically cost effective. Most important, irrigation policy must be developed and evaluated within the context of competing demands for water resources, and possibilities of increasing economic water scarcity. Ghana is becoming gradually scarce of water as prospective water demand is exceeding available water resources<sup>3</sup>.

Ghana will soon be classified as a country with severe water stress if its population continues to grow at its current rate (3 percent) and water use efficiency is not increased effectively (Mualla and Salman, 2002). The severe drought that previously occurred within the period (1981-1983) provided a vivid picture of how scarce water resources can be in Ghana.

In Ghana not until lately, water demand management has received a lesser amount of attention as compared to the water supply development that has received much more attention from policy

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<sup>3</sup> Total Renewable water resources (TRWR) is estimated around 16 BCM per year. In other words, the per capita TRWR is less than the water scarcity index (1000m<sup>3</sup>/person/year).



makers. Water scarcity has become a social and economic concern for policy makers in Ghana in recent times.

Water as we all know is also a very vital part of agriculture production, without which agricultural production is impossible. Therefore, the sustainability and management of water resources in the country is also very crucial for economic growth and human existence. In Ghana, agricultural water demand is a dominant source of consumptive demand for water resources in the country (WRC, 2007). Therefore, a comprehensive water policy for Ghana's future must address agricultural water demand.

Coping with uncertainty caused by irrigation water supply gained attention as one of the main subjects needing to be addressed. Following the drought in 1983 and the projected future drought in the next ten years (Kasei, 2009) in Ghana, there is considerable need to increase agricultural water use. Conveyance losses associated to furrow/canal irrigation are so much. These major sources of water loss in irrigated agriculture have to be minimized for sustainable water resource management.

It is therefore of high importance for policy makers to identify policies that improve and expand the productivity of agriculture while ensuring that sufficient water and land resources are available for other vital uses and that is what this study sought to do. The key goal of this research is to empirically analyze the important issues and constraints facing this sector and propose some recommendations that would help manage water demand for efficient and effective water utilization to ensure sustainable increase agricultural production.



### **1.3 Significance of the Study**

- This study contributes immensely to the ongoing debate about sustainable agricultural development in the Sub-Saharan region. It is also one of the few scientific studies to explore innovative policies that would reduce the inefficient water use in the agricultural sector of Ghana.
- The study also sought to make available to policy makers information about technological alternatives at farm level as well as to help in deciding in what way to promote a given kind of technology or policy.
- Furthermore, a dynamic and a nonlinear modeling technique provide insights into the potential policy environments for agricultural growth and development.
- Identification of policies and practices that ensure food security, income growth, price stability and other national and regional objectives, as well as water sector impacts are broader agricultural development goals tackled in this study.
- The study would help policy makers to decide on which policies are very efficient in water management and allocation, in the light of rampant water shortages and dropping water levels in Ghana.
- Finally, development partners and those in agricultural research would draw some insights from this study to help in their advisory and planning activities in the agricultural sector in Ghana.



#### **1.4 Organization of the Study**

The thesis consists of seven chapters. Chapter one comprises of a brief introduction and background to the research, Statement of the problem. Chapter two consists of the objective of the study, research questions and hypothesis. Conceptual framework, Significance of the study, study outline, a brief literature review. Chapter three is devoted to the overview and the role of agriculture in Ghana specifically reviewing various agricultural policies of the government, water demand conditions within the Volta basin and irrigation policies and other methods of irrigation in Ghana. Chapter four concentrates on the overview of the methodology including data collection and data processing methods, and the MATA model. Chapter five encompasses empirical overview of the methodology of the study, including calibration and validation of the model. Chapter six presents the results and policy implications based on the study. Chapter seven focuses on the estimates and discussions of the shadow prices of input constraints. Chapter eight is on the summary of the study, conclusions and policy recommendations, limitations of the study, and suggestions for further research.



## **2.0 Literature Review**

### **2.1 Introduction**

There have been a number of researches done in Ghana and other developing and developed countries on issues concerning the agricultural sector and the demand for water. In this chapter, we review a few of the research works on water and the agricultural sector to show what other researchers have done and what we know about water and agricultural sector, point out what has not been done and needs to be done so as to fill the gap in literature.

### **2.2 Theories on Water as a Natural Resource**

Water is the basis for all life, and life is based on water flows from the micro scale of a single plant to the global water cycle and that distinguishes this planet from others (C.J Perry and P.J.G.J, Hellegers 2004). Water as we all know is vital and needed in every aspect of life, water is therefore an imperative resource without which human existence and agricultural productivity is impossible. This makes water a common good to all.

The increase in population and urbanisation among others has led to the consequence of an increase in the demand for water as well as agricultural produce. This is supported by the theory of the tragedy of the commons. In the tragedy of the commons by Hardin 1968, the researcher drew attention to two human factors that drive environmental change; the first factor is the increasing demand for natural resources and the environmental services, stemming from growth in human population and per capita resource consumption. His second factor is the way in which humans organise themselves to extract resources from the environment and eject effluents into



it. He argues that if resources are not used sustainably, as population grows, there would be increase in the demand of natural resources, and with the earth's resources being a general common, there might be over exploitation and consequently scarcity for the future generations to use. This is so because free access and unrestricted demand for a finite resource ultimately structurally dooms the resource through over exploitation. This is for the reason that the benefits of over exploitation accrue to individuals or groups, each of whom is motivated to maximise uses of the resource to the point in which they become reliant on it. While the costs of the exploitation are distributed among all those to whom the resource is available (this may be a wider class of individuals than that which is exploiting it). This in turn causes demand for the resource to increase, which causes the problem to snowball to the point in which the resource is exhausted. Water can therefore be seen as a common good, it is a natural resource that is free for all and therefore if not managed well or not used in a sustainable way could lead to its exhaustion or scarcity. Therefore, if there are no policies put in place, people would want to exploit this resource for their own personal benefit without taking into consideration the future generation and other equally important users at large.

This can be related to a river basin panorama, where water serves a variety of human domestic needs, such as drinking, washing sanitation and cooking; lets drought-prone lands to develop into productive lands through irrigation; makes available habitat for plants, wildlife and fish; delivers water for industrial and urban uses; produces hydro-electricity; and supports lots of recreational and aesthetic practices.



Water can also be seen as an economic good. Water by and large as an economic good follows directly from Robbins' (1952) definition of economics as 'the science, which studies human behavior as a relationship between ends and scarce means which have alternative uses'. These requirements of an economic good is met by water: as it serves an array of ends (ranging from bathing, drinking and, through navigation, irrigation, recreation, waste dilution and disposal to environmental use), and consequently fulfills the conditions of 'alternative uses', and the widely observed competition between sectors (productive and environmental) confirms that water is frequently scarce. The International Conference on Water and the Environment (Dublin, 1992) highlighted that failure to be aware of the value of water has led to environmentally damaging uses of the water resource (ICWE, 1992). The recommendation of the outcome of the conferences confronts the problems inadequate financial support for repairs of dams and reservoirs as well as competition for scarce water.

In fact, water can also be said to be a social good to would benefit the society at large. Irrigation water use can also be a good means of reducing costs associated to food consumption for the poor. Irrigation in agriculture can also be of assistance in economic development for rural areas by providing jobs and supporting agro-based industries in highly populated areas, this issue does not only pertain to the developing countries (OECD, 2002).

Parts of Africa continent experience periodic drought due to water scarcity that affects agricultural production negatively. In order to keep water sustainable, water can also be imported to compensate for a dry climate in places where there is no water. When the need arises, African countries can also import water, first as a natural



resource and also in the form of food. In effect, easy access to water for domestic use as well as for development purposes underscores the central consideration that it ought to assume in policy making. Where water is in short supply and financial technological resources do not exist for water transfer, development faces considerable obstacles.

### **2.3 Empirical Literature on Water**

Reviews of empirical literature on water demand and the agricultural sector in Ghana revealed few studies in the area. Fewer studies concentrated on the demand for water for agricultural purposes within a basin, but rather most of the studies focused on household water demand. In terms of agricultural sector policies and productivity there are some few relevant works available.

Empirical review of literature suggests that there are more studies on water demand for residential (urban) uses than studies on rural water demand and agriculture water demand. Several studies using other functional approaches to evaluate elasticities of water demand in relation to price, income, and other variables. These studies made use of time series, linear programming models, and panel data, to estimate their demand for water.

As water insecurity can threaten the livelihood of households and economic sectors, especially irrigated agriculture and hydroelectric power generation, an empirical study done by Osei Asare Yaw (2005) investigates water security conditions and water demand behavior in the Ghanaian part of the Volta basin in West Africa. The study examined the extent of household water accessibility, identifies key factors that influence a household's choice for





improved water sources, and models household water demand in rural Ghana. He developed a common sampling framework method using principal component and cluster analysis to select observation units for household data collection. Water is often modeled as a homogeneous commodity (single good) but the study considered water as heterogeneous good disaggregating water into one for drinking and cooking and that for indoor purposes. Moreover, his modeling process applied a theoretical framework consistent with rational consumer behavior. The study uses a system of demand equations, applying a theoretically consistent demand model, the Linearised Almost Ideal Demand System (LAIDS) model that conforms to the fundamental consumer behavior to empirically model rural water demand in Ghana. In his study, he combines aspects of water quality and quantity in explaining rural household water demand behavior, an approach necessary for better understanding into their decision-making processes. This study attempted to place a value on rural water by estimating daily and hourly opportunity costs associated with the task of water collection using three different approaches, namely the national daily minimum wage approach, agricultural income approach, and the non-agricultural income of women approach. Some of the major findings from his work is that after disaggregating water into two heterogeneous goods, i.e., water for drinking and cooking (first good) and water for other indoor purposes (second good), the study finds complementary roles between the two goods in ensuring complete household water security. This means that irrespective of the usage purpose, water generally serves as an important resource that fulfils daily water needs for rural households. With income compensation to maintain targeted utility, water for drinking and cooking and water for indoor purposes become substitutes. This suggests that the two



goods are likely to serve as substitutes for affluent households whilst they may play complementary roles for poorer households.

Water for drinking and cooking and water for indoor purposes are normal goods and necessities. Without income compensation, households are more sensitive to changes in own-price of the two goods than with income compensation. Cross-price elasticities in both cases are less responsive to price. These imply that high water prices (high opportunity cost due to difficult water accessibility) has the potential of reducing desired quantities of daily water consumption for various household needs. Moreover, rural households in the Ghanaian Volta basin display different water demand behavior contingent on household size, income levels, type of good, and its price.

In another study by Karina Schoengold *et al*, (2005), using panel data and a natural experiment in rate reform, the study estimates the price elasticity of irrigation water demand and decomposes the total elasticity into its direct and indirect components. Their empirical strategy uses an instrumental variables analysis to account for the endogeneity of land allocation in the water demand equation. From the empirical analysis, the study finds that including the indirect effects of water price changes on output and technology choices, as well as the direct effect of improved water management leads to a significantly more elastic estimate of water demand than found in previous works.

In the international arena, awareness has lately moved to demand-based approach of determining the demand for water. In this case, the price of water is used as the key instrument to control the demand. Top-down and community-based methods have been



recommended by Parker and Skytta (2000) but without strong distinctions between these approaches.

## **2.4 River Basin Literature Review**

In terms of the river basin demand for water for agricultural use in Ghana, not much has been done in this respect. On the international front however, many studies have been conducted. With river basin demand for water, many researchers use mathematical programming and other software to model the demand for water in a river basin.

In terms of the river basin models, because the use and the value of river basin resources relies solely on the quantity and quality of water available in space and in time, and because many of its usage are physically connected through the basin hydrology, a more efficient way of managing water resources can be done by using a more comprehensive, basin-wide method. The main aim guiding a basin-wide method may include the fostering of an economic growth, maintenance of environmental quality, achieving of agricultural self-sufficiency, enhancement of foreign export trade, promoting regional development/autonomy, increase of employment, provision of resources for a growing population, improving quality of life, retention of national security, meeting of energy demands, and improvement of public health. Some of these objectives are compatible, whilst others are conflicting. A search of the literature discloses a wide range and number of published reports on river basin models used to support integrated water resources management. This study discusses a small number of studies representing basin-wide integrated modeling. The models



are selected to emphasize agricultural sector demand, regional planning, and multiple objective planning.

Nkegbe 2005 models household production and investment decisions in the Volta basin of Ghana. He uses cross sectional data over various districts. The study indicate that credit constraints, high cost of inputs, erratic rains and land degradation are the major limiting factors to agricultural production in the basin. The study also finds that the decision of what to produce, how much to produce and the financial cost of such decisions are the responsibility of the household head. The household farm production and investments model results show that labor use on farm, farm capital stock, and access to loan for production, cultivated area and gender of household head are significant determinants of production and investment decisions in the Volta basin.

More recently, several efforts are being made to connect economic optimization models directly with models of surface and groundwater hydrology, and often with other models of, for example, soil and water quality. One approach has been to construct a single model framework which contains both hydrologic and economic components. Many of these integrated models use GAMS as the programming language. Cai and Rose grant (2004) used an integrated GAMS model framework to evaluate the impacts of a range of policies on water use, allocation and agricultural output in the Maipo Basin, Chile. This study emphasized the choice of irrigation technology in response to various economic incentives, using the Dinar–Letey (1996) production function approach, which explicitly represents differing levels of irrigation efficiency related to the technology. Many other



studies have been conducted which utilize Cai, et al.'s integrated GAMS approach. These include Cai, et al.'s (2003a, b) studies of the Syr Darya Basin in Central Asia; Ringler and Cai's (2003) study of the Mekong Basin and Rodgers and Zaafrano's (2003) study of the Brantas Basin, Indonesia (Bharati, 2008). To illustrate, the Brantas study examined the impacts of a wide range of policies on water use and allocation, including volumetric pricing of irrigation water, water markets combined with a water rights framework, reduction in the level of government farm price support for paddy (rice), and investment in improving the efficiency of surface irrigation systems.

Another approach has been to link existing economic optimization and engineering hydrology and possibly other simulation models together using various software engineering methods, and running the linked models as ensembles. Important examples are Jenkins, et al.'s (2004) and Draper, et al. (2003) California water management studies. In these works, a network flow hydrologic optimization model (California Value Integrated Network, or CALVIN) was linked to the Statewide Agricultural Production Model (SWAP). SWAP is a mathematical programming model which is designed to maximize state-wide farm profit over a choice of water, land, technology and capital inputs. A similar study utilizing linked models, also in California, is Quinn, et al.'s (2004) work on climate change and water resources in the San Joaquin Basin. These authors linked a global climate model, HadCM2/PRM, to the PRISM rainfall-runoff model in a way to simulate inflows to the government water system assuming climate change. They then linked these models to the CALSIM water demand-allocation model, to the APSIDE salinity control and the DSM2-SJR surface water quality models. This allowed the



evaluation of impacts of climate change and government policy on water use, water quality and soil loss. Another study using linked models to examine the impacts of agricultural and other policies on water distribution and quality is the Integrated Water Resources Assessment and Management (IWRAM) project (Letcher, et al., 2002), in which the IHACRES rainfall-runoff model, a crop growth model (CACHCROP), linear programming economic model and a USLE-based soil erosion model, were combined to assess the impacts of climate, technological innovations, commodity prices, and government policies on agricultural output, land preservation and water supply within the Mae Chaem catchments, Thailand.

These, and other studies, demonstrate that by integrating economic, hydrologic and possibly other types of simulation models, it is possible to develop detailed and physically realistic analysis of the consequences of agricultural and other sectoral policies on water and land use. By developing such a suite of linked models, the planning and management of water resources at river basin scale can clearly be improved.

This study in a way to harmonize the demand of water and the agricultural sector rely on the Multi-Level Analysis Tool for the Agricultural sector (MATA) model. The original MATA model has been used in several important research publications, and has been applied in a country study of Indonesia from 1994-1997, to study the impact of liberalization of food crop trade in Indonesia, where the agricultural sector is characterized by a high diversity of biophysical and socio-economic conditions (Gérard et al, 1998). The MATA model has also been used in other countries such as in Benin on the impact of agricultural policy on food security, an agricultural modeling approach (Senahoun, J., et al, 2000), also in



Burkina Faso on the effect of exchange rate (CFA) devaluation on the agricultural sector (D. Deybe, 1998) in the paper “Can agricultural sector models be a tool for policy analysis? An application for the case of Burkina Faso”, also in India on the impact of different water tariffs reforms on rural livelihood and public resources in India a case of Haryana producers (Veronique Alary & Daniel Deybe, 2005) and finally Erwidodo, 1998 also used MATA model in his paper “the impact of trade liberalization on food production and farm income: A multi-level modeling approach”, to mention but a few.

The original MATA model has gained a lot of recognition in the modeling arena as one of the key programming models for assessment of performance in the agricultural sector. It was realized that climate change variables have been exempted from the original MATA model, as a change in the climate could have a considerable impact on water availability for both the agricultural and non-agricultural sectors in Ghana. The outcome of this study would therefore lead to the enhancement of the MATA model, which integrates the original MATA model with a water simulation module.

### ***Advantages of MATA***

- It differs from other basically accepted multi-market models by clearly taking into consideration the frame of time in order to regulate demand to supply in the agricultural sector
- The MATA model makes use of both multi-disciplinary and interdisciplinary approach for its policy analysis.



- The MATA model also produces signs of some possible trends that will in the future affect farmers' revenue, prices, land allocation, consumers' consumption and production.

### ***Limitations of MATA***

- It entails the use of an enormous array of data on producers and consumers in the agricultural sector.

## **2.5 Objectives and Research Questions**

The broad objective of this study is to identify and estimate the agricultural policies that have a positive impact on water demand as well as agricultural production, both in the short-term and long-term. Specific objectives include the following:

- To build an economic model to analyse production structures and the demand for water resources within the agricultural sector in the Volta basin area of Ghana.
- To assess the impact of water availability and agricultural sector policies on the overall pattern of agricultural production and demand for water resources in the agricultural sector of Ghana.
- To simulate the impact of alternative policies on income, employment and total wealth changes of agricultural producers





### **2.5.1 The Research Questions**

- How can farmers increase their agricultural production, income and reduce water demand under the current as well as various future socio-economic and ecological situations?
- What is the impact of agricultural sector policies on cropping activity in the basin area?
- What policies would reduce water use inefficiencies in the Volta basin and what are its impact on income, employment and total wealth changes?

### **2.6 Hypotheses of the Study**

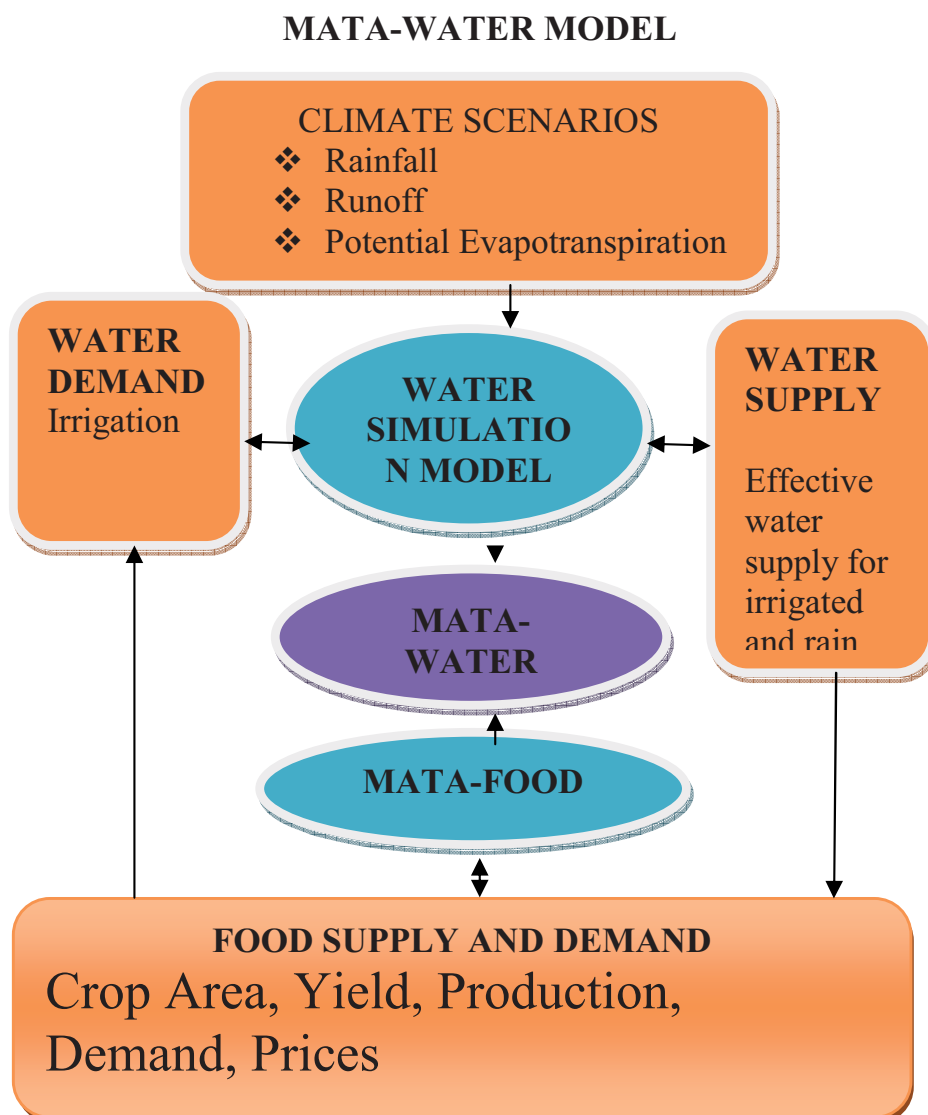
- Farmers are experiencing low agricultural production, high water demand resulting in lower income.
- Agricultural sector policies are not having significant impact on cropping activities in the Volta basin
- There are water use policies inefficiencies in the Volta basin leading to total wealth changes

### **2.7 Conceptual Framework**

The idea of the study is to find the impact of agricultural sector policies on water demand. These policies are mainly determined by the government and also induced by the microeconomic environment of the country. Agricultural sector policies do not only affect the agricultural sector when they are implemented but also affect the consumption, production, water, environment and

international trade sectors among other things. The study uses a partial equilibrium model that would consist of the production, consumption, and macroeconomic sector to enable the model to maximize the expected utility of wealth of the farmer given all its constraints. Policy simulations are also used to find out which policies are water efficient policies and which policies are not. Finally, recommendations are made on water management policies.

**Figure 2.1: Conceptual Framework**



Source: Rosegrant 2009 & own Compilation 2010



### **3.0 The Importance of Agriculture in the Economy of Ghana**

#### **3.1 The Role of Agriculture in Ghana**

Agriculture plays an important role in the socio-economic development of Ghana. Beyond its contribution to insuring food security, providing raw materials for local industry, generating foreign exchange earnings, providing employment and income for almost all of the population. It is also acknowledged to have other roles such as social stabilization, buffer during economic crisis; it also serves as a support to enable environmental sustainability, as well as cultural values that is related with farming.

Analyses of the Ghana Living Standards Surveys of 1991/92 and 1998/99 indicated higher growth rates in the economy were as a result of growth in agriculture propelled by forward linkage undertakings such as transportation and processing, and backward linkages such as the provision of services to the agricultural sector whilst spending of incomes earned from all these productive activities furthered the growth rate in the economy (GLSS, 1999).

A study by the Ghana Strategy Support Programme (GSSP) of the International Food Policy Research Institute (IFPRI) indicates that agricultural led growth is more effective in reducing poverty either at the regional or national levels, because of strong consumption and income linkages.

Agriculture can also assist the population through their social aspects, in that it helps in employment and therefore encourages the welfare of the farmers and the rural population as large. It also comes in handy to assist in unemployment situations.



At the macro level, following the crisis of the 1980s the recovery of the economy of Ghana, was based on the ability of the sector to increase its magnitude of the country's export, increasing the tax base, and domestic food security as well as to increase per capita income.

The development and maintenance of natural resources such as land, water, genetic biodiversity and forest can also be influenced by agriculture. Land degradation through poor agricultural practices reduces land productivity and limits poverty reduction. An effective agricultural policy would enhance the positive influences through carbon sequestration, contribution of tree cover for conservation and improved quality of soil, protection of watersheds, and enhancement of the beauty of natural landscapes (FASDEP, 2005).

In Ghana the cultural value of agriculture can be seen through the farming and fishing communities, which indicates that farming is quite vital because it provides food for the growing population and it is a dependable source of employment for the rural community. Hence a good agricultural sector policy would go a long way to better the livelihood of the population and increase their standard of living.

### **3.1.1 The Agricultural and Water Sector in Ghana**

Agricultural sector policies are established number of laws that is associated to domestic agriculture and imports of foreign agricultural products. Governments normally implement agricultural policies with the objective of achieving a specific



result in the domestic agricultural product market. Ghana like other African countries have various agricultural sector policies with the goal to achieve food security, increase in exports, increase in agricultural employment, increase in farmers income and provide enough raw materials to feed its growing industries by the year 2020 (this goals are part of its development goals in Ghana's Vision 2020).

Agriculture is the largest single contributor to the livelihoods of over 60% of the population in Ghana. Since about 67% of the Ghanaian population is rural (GSS, 1999), this makes the implementation of agriculture sector policies very vital to the growth and standard of living of the population in Ghana.

Over the years agricultural sector policies have been evolving as a result of political instability. Every political change in government comes with its own policies and strategies to achieve economic growth. Some of the policies that have evolved over the years from the twentieth century till now are: export promotion policies, import substitution policies, subsidy removal on inputs, tariffs, quotas, land expansion, credit allocation, irrigation investment, pricing policy, market liberalization, agricultural mechanization and modernization, agricultural research investment, rural infrastructure development and improvement in agricultural institutional capabilities. Agricultural sector policies like other policies could have positive or negative impacts on other sectors of the Ghanaian economy when implemented; this could be directly or indirectly.

Water is a vital resource to human existence and the agricultural sector. This makes water very important to the economic growth



of every economy. Water demand is usually defined as the volume of water requested by users to satisfy their needs over a period of time at a given price (DFID,2000).The most essential uses of water are for: drinking, washing, recreation, agricultural, power generation, waste dilution, mining, navigation and environmental(e.g. fishing and wildlife) purposes. Some of these water demands are seasonal and highly influenced by the weather; others are also influenced by other factors. As we are dealing mainly with agricultural policies, we would be looking at the second water use where water is withdrawn without any return flow. In this perspective, we would like to know which policies waste water and how water can be sustained and used in the future by future generations.

Ghana like any other country has its own policies that helps to sustain, prevent water wastage and manage its water resources over the years with the introduction of institutions like the Ghana Water Resources Commission, Ghana Water Company, Environmental Protection Agencies, Public Utilities Regulation Commission and Ghana irrigation development agency. All these institutions have been established to manage the Water Resources in the country and to help prevent pollution and other environmental and health problems associated with water. The government in its bit to sustain and provide available water in adequate quantities and in good quality over the years to come has also implemented some water policies in the national water policy (GWC, 2007).

The national water policy of Ghana is anticipated to make available a framework for the sustainable development of Ghana's water resources. It covers all water users and takes into account the a number of cross-sectoral problems related to the use of water and



the relations to other pertinent sectoral policies as those on agriculture, transport, and energy. Some of the water policy goals of Ghana are: improving access to safe water supply and sanitation to reduce the proportion of the population without access to basic water supply and sanitation by 50% and 75 % in the year 2015 and 2025 respectively. Second, the country's water policies are also geared towards promoting efficient and sustainable use of water to address food security and income generation for the population. Another policy goal is helping to halve the number of malnourished people by 2015 through investment in irrigated agriculture. Finally, the policies are also focusing on economic development as well as food self-sufficiency in Ghana.

Ghana's water vision for 2025 has the main objective to "promote an efficient and effective management system and environmentally sound development of all water resources in Ghana". According to GNWP 2007, some of the ways outlined to meet these goals are to increase the number of small scale irrigation, to encourage the involvement of district assemblies in the provision and maintenance of irrigation facilities. Also to encourage the building of big dams for irrigation purposes with the joint ownership of the private and public sector , also to enable an efficient use of fertilizer to reduce pollution of the water resources as well as to reduce inefficient use of water resources in the agricultural sector.

Some of the main challenges of decision makers in Ghana are how to balance the needs for water for agricultural purposes and for environmental source as well as that for hydropower and other users. Another major challenge they face is the constraints in developing the irrigation sector, due to high transaction cost of land and high cost of building the irrigation schemes or dams.



Hence, the opportunity costs of irrigation expansion are very high to the country. Irrigation expansion is associated with increased supply of water as it needs to guarantee a fixed supply of water to farmers, and also water supply in the further downstream in Lake Volta should be guaranteed for those living there too. This is another dilemma for policy makers to contend with.

Finally as a result of low irrigation practice and low rice production in the country, Ghana is presently importing rice, because it is not able to produce enough to meet its domestic demand. Price of rice has therefore been increasing at an increasing rate and the terms of trade have also not being favorably to Ghana. This has also led to the increase in prices of grains especially rice, forcing the government to remove all import duties on grains so as to reduce the price of rice for consumers to purchase.

For the country to decrease its balance of payment deficit as a result of increased use of the unavailable foreign exchange, Ghana may need to grow rice in the long run, so as to be able to supply and feed its growing population, and this requires higher irrigated area and increase demand for water resources. In the year 2010, Ghana has started increasing its domestic rice production and discouraging importation of rice by increasing the import duties on rice, thus making imported rice more expensive as compared to locally produced rice, turning the terms of trade in favor of Ghana.





### **3.2 Water Demand**

Water demand and its various components show significant spatial variation. Total water demand in Ghana in 2000 was estimated at about 38,979.59 million m<sup>3</sup> (FAO, 2003). Water demand can be broken down into four main categories of use: agricultural, domestic, industrial and environmental. However, environmental use is now the main issue of concern in many different countries.

Within the agricultural sector, water use can be divided into two components, rain fed and irrigated. Rain fed agricultural uses water supplies before they reach the river (i.e. consume part of the 56 percent of rainfall which does not contribute to runoff).

Irrigated agriculture covers 0.05 percent of total arable land in Ghana (MOFA, 2005) and provides about 30 percent of Ghana's total grain / agricultural output. The majority of the irrigated area is situated in the Upper East region of Ghana, this is also mainly because of their climatic conditions.

#### **3.2.1 Factors That Determine the Demand for Water in Ghana**

In trying to comprehend whether or not the current water and agricultural policies can increase agricultural production as well as provide surplus agricultural goods for Ghana to reach its goal of food security as a nation or whether these policies would rather force Ghana to rely more on the world food market there are a number of key variables which must be considered. In this section, some of these variables would be discussed.



Initially we would discuss four basic variables which directly or indirectly impact on the domestic, industrial and irrigation water demand in Ghana. These variables would be considered together as consumptions factors.

### 3.2.2 Consumption Factors

Under this, segment the four most important variables to be discussed are; population growth, urbanization, income growth and the economic structure of the country Ghana.

**Population growth:** A primary driver of change in Ghana's direct and indirect water demand is growth in the population. Ghana's population has been increasing over the years from 15,190,000 in 1990 to 23, 382,848 in 2008. The population growth rate also increased from 1.87 percent in 2000 to 1.928 percent in 2008(see Table 3.1). Based on the current water demand by the population at 38,979.59 million m<sup>3</sup> in 2000(FAO of the UN, 2008) an increase in population would imply an increase in the demand for water and food. This increase in the demand for water would affect positively both agriculture demand for water to increase food production and that for domestic water demand as well.

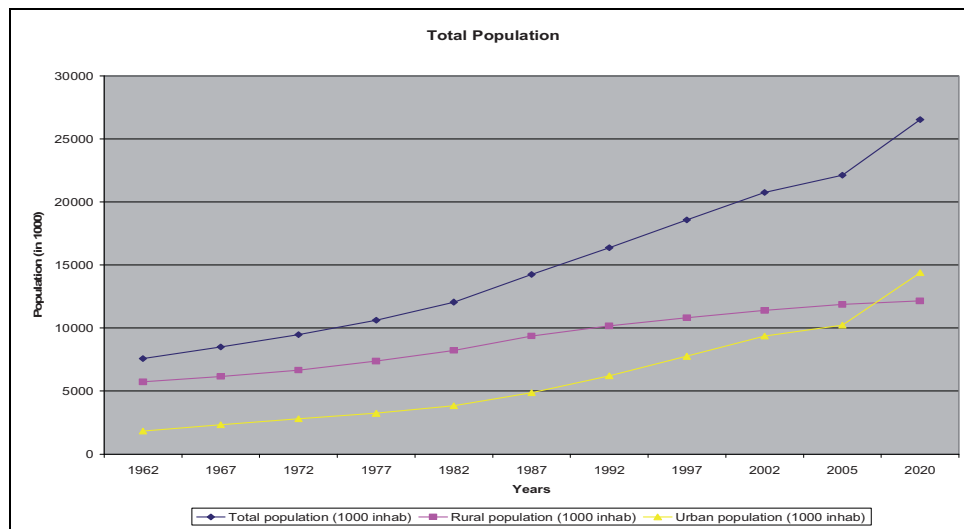
**Table 3.1: Data on Population Growth Rate**

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008
Pop Growth Rate	1.9	1.8	1.7	1.5	1.4	1.3	2.07	1.97	1.9

**Source: FAOSTAT, 2008**



**Figure 3.1: Graph on Population Growth rate**



**Source: FAO of the UN, 2008**

### 3.2.3 Urbanization

From the diagram above while population will be the primary factor driving the overall water demand, urbanization of the population will also be the secondary factor and as well very important. From the diagram above, urbanization of the population has been increasing over the years; this is as a result of growing cities and life styles of the growing population. Ghana's urban population is also expected to continue expanding perhaps doubling from the present levels by 2025. Urban domestic water use is twice as high as rural and so a shift in population, coupled with increasing per capital use in both the urban and rural sectors (Quan and Zhang 2000), could increase domestic water demand by more than 50 percent over the next 25 years. This would also indirectly affect the availability of water for agriculture water use as the domestic water and agricultural water use are competing for the same available resource, water.



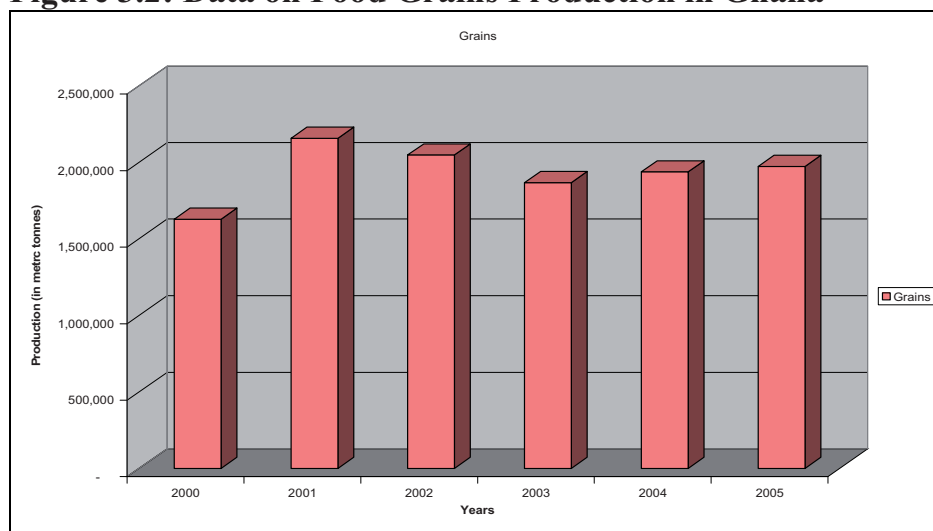
### **3.2.4 Income Growth**

Income growth influences agricultural water demand in two important ways. First expanding income provides a means for increasing food expenditures. Second, income growth is associated with changing dietary composition, in particular a shift away from direct grains consumption and toward meat or higher grains like rice.

Ghana's per capita food consumption increased dramatically after economic reforms, and per capita economic growth, began in the late 1990's. At the same time dietary composition shifted away from low grains and towards rice, meat and other products. The increased food production to meet rising consumption levels obviously increases agricultural water use. Also important, the shift towards meat actually increases the rate at which additional water must be used to meet a given level of demand, due to the caloric cost of converting grains to meat (grains to meat conversion ratios are between 2 and 7 to 1 depending on animal type and production process).

In Ghana, between 2000 and 2005, food grain production increased considerable from 1,626,651 metric tons in 2000 to 1,973,162 metric tons in 2005 (MOFA, 2005) as a result of high demand for grains by the growing population. A key question for Ghana's agricultural water future will be not only how much income will continue to grow , but how the correlation of income growth with both increased food demand in general and increased meat demand in particular will change as Ghana reaches even higher consumption levels.

**Figure 3.2: Data on Food Grains Production in Ghana**



**Source : MOFA 2005**

### 3.2.5 Economic Structure

Part of the increase in Ghana's per capita income stems from the rapid shift in Ghana's economic base from agriculture to industry. Industry (including the service sector) now makes up 60 percent of the sectoral contribution to GDP of the country in 2005 with a growth rate of 7.7 percent (ISSER, 2006). Along with industrial growth has come an increase in industrial water demand. Since the early 1990's, industrial water demand has grown at an annual rate of 5 percent. If the same pattern holds, industrial water use will increase fourfold by 2025. Thus, an increase in industrial demand for water would indirectly affect the demand of water for agricultural production. As has been the case with domestic use, however, industrial water use tends to have low depletion rates. As such, much of the water used in industrial output can be recycled for other uses if appropriate technologies are applied.

Another major factor that determines the demand for water in the agricultural sector would be those factors that pertain to agricultural production such as: cropping intensity and activity, crop yield, cropping patterns and irrigation efficiency or water use



scheme. Agriculture sector is by far the highest water user at present. Irrigation contributes immensely to the production of grains as well as vegetables during the dry season. Contribution to growth of crop yield and cropping intensity is very significance. Agriculture water demand in the future depends on the extent of yield growth both in irrigation and rain fed, and increase in cropping intensity as well as cropping patterns.

Cropping intensity: arable crop land has been increasing from 3,850,000 hectares in 1999 to 4,185,000 hectares in 2003 (FAO, 2001). Net irrigation area or area equipped for irrigation has also increased considerably. The increase in irrigation is the major contributor to cropping intensity increase. Dalal, Ram C, 2003 estimated that increase in irrigation has contributed to about 50 to 100 percent increase of the overall cropping intensity in Ghana over the last two decades. Cropping intensity also accounts for infertility in cropping area over a period in the irrigation area, as a result this can lead to increase demand for water and fertilizer use.

Crop yield: the exact association of the growth of irrigation with the growth of crop productivity in Ghana is not clear for example, while irrigated area increased by 27 percent over the last two decades, the grains yields increased by over 70 percent. Though several inputs other than irrigation have contributed to the growth in crop yield, many argue that the contribution from other inputs such as high yielding varieties would not have been realized without irrigation.

The contributions of irrigation to the growth of irrigation intensity and yield were very important factors for projecting future food demand. Rain fed agricultural would also determine future demand



for irrigation water because if there is enough rainfall in the various seasons there would be a reduction in the demand for irrigation water and thus a reduction in the water demand for agricultural water for crop production during the dry season.

Changes in cropping patterns would also go a long way to reduce the amount of water used for agricultural production.

### **3.3 Ghana's Agriculture Sector Policies and Water Demand**

In this section, we look at the various agriculture policies and their influence on water demand in Ghana. We focus on some major agricultural sector policies such as; the pricing policy, the input subsidy policy, the credit allocation policy, the land expansion policy, research investment policy, taste and preferences of consumers, agricultural mechanization and modernization policy, land policy, and irrigation investment policy in Ghana and how these can affect demand for water and the profit/income of farmers.

#### **3.3.1 Pricing Policy**

Pricing policy in Ghana has evolved over the years. In the early 1960's, output prices were controlled by the various governments in order to control inflation and to make agricultural food products affordable to the poor mostly to the detriment of the producers which are the farmers. Up until 1983 when the economy went into depression allowing the introduction of the Economic Recovery Programme (ERP) that led to market liberalization the countries prices were fixed by policy makers. In recent times as a result of the market, liberalization policy the invisible hand (the demand



and supply activities) is allowed to determine the prices of commodities in the country.

After the ERP, market liberalization has been the pricing policy for a while, but government still intervenes in terms of some export crops like cocoa and fixes prices for such commodities. Market liberalization has been the policy in terms of agricultural output pricing for subsequent government till now. This policy has both negative and positive effects on the producers specifically farmers.

The existing market structure of low agricultural output prices in Ghana, international oil shocks, fluctuating international prices, existence of middle men, poor road infrastructure, and exchange rates fluctuations, output prices as well as farmers' income and standard of living are usually left in the balance. This makes pricing policy very vital as a policy instrument especially as it affects farmers' production decisions. For instance, in 1960 when government increased prices of cocoa as a result of its export promotion policies, most small scale farmers quickly changed their production from traditional food crops to the production of cocoa thus increasing the production of cocoa and making Ghana a leading producer of cocoa (Wayo Seini, 2003). Another example is that of cassava starch plant, government in the year 2006 announced a ready market for cassava starch plant, a factory was put in place to buy the product of all farmers that produced this cassava starch plant which enabled the export of Ghana manufacture. This actually increased the price of cassava, as a result, most of the farmers immediately switched to the production of cassava.





Pricing policy has therefore been very important in the growth the Ghanaian economy. If the price of a commodity increases and farmers make more profit in producing it, farmers immediately move to the production of this commodity, thus if the commodity is a crop that uses more water, consequently the demand for water would increase as price increases for the crop or commodity.

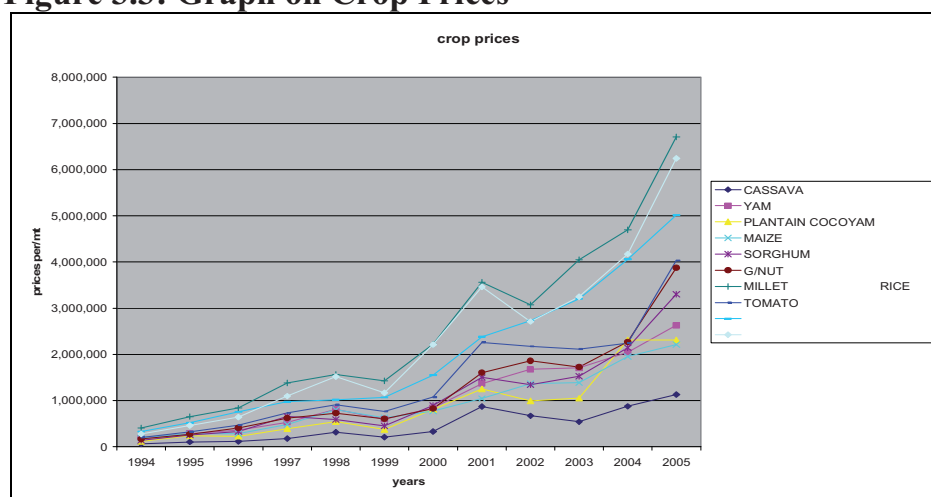
Markets are also one important factor that influences price fluctuations in Ghana. There are very few organized markets in the country, thus markets for some food crops do not really exist making it difficult for farmers to gain profit because they are offered extremely low prices for their products. A study by Saa Dittoh, (1998) raised concerns on the prices offered for tomatoes in Ghana and stated that as a result of its low prices, farmers are forced to increase acreage of land used in production of tomatoes in order to make profit. Farmers in a bid to make profit increases their irrigated production unsustainable and also their water use, if prices of the commodities are continually allowed to be determined by the interplay of demand and supply, output prices would continue to be low and fluctuating. There is therefore the need for strategies that aim at ensuring stable prices. Table 3.2 gives an idea of the prices of various agricultural commodities produced in Ghana and the fluctuating prices over the years till now.

**Table 3.2: Nominal Weighted Average Rural Wholesale Price (¢) Per Mt.**

CROPS	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Cassava	63,098	105,940	112,219	177,099	314,827	210,824	329,670	868132	670198	540,216	873,899	1,127,907
Yam	196,858	288,262	360,640	531,552	811,065	595,705	840,000	1368000	1675588	1,708,172	2,048,831	2,626,736
Plantain	118,419	236,971	226,806	391,536	541,933	372,627	812,500	1250000	993750	1,050,000	2,313,887	2,309,230
Cocoyam	190,331	280,713	286,921	480,204	800,093	631,313	769,230	1043956	1366429	1,386,143	1,952,231	2,209,549
Maize	141,766	251457	330632	657,115	592,091	451,872	895,000	1500000	1341310	1,529,400	2,145,344	3,304,720
Sorghum	166,530	273,744	408,997	622,898	728,790	604,175	825,660	1605505	1862156	1,725,587	2,270,037	3,875,725
G/Nut	409,172	652,589	839,005	1,380,930	1,568,538	1,429,326	2,219,490	3560976	3074244	4,048,293	4,695,562	6,706,915
Millet	201,167	323,557	467,492	733,016	910,781	764,879	1,075,200	2258065	2173280	2,117,011	2,245,223	4,031,022
Rice	330,159	516,007	754,748	974,871	1,016,067	1,067,993	1,550,000	2380000	2729710	3,203,020	4,057,391	5,013,630
Tomato	276,407	461,061	642,662	1,097,489	1,521,176	1,169,256	2,211,450	3461538	2710038	3,250,058	4,173,902	6,244,731

Source: SRID, MOFA

**Figure 3.3: Graph on Crop Prices**



Source: SRID, MOFA 2005

From Figure 3.3, it is realized that prices of crops have been fluctuating over time and have mostly increased in recent times. For instance cassava in 1994 costs 63,098 thousand per/Mt but has increased to 1127907 million per/Mt representing about a 100 percent increase in price over a space of about 10 years.

### 3.3.2 Subsidies on Inputs Policy

Agricultural inputs are the major source of cost to production. Some of the major inputs are fertilizer, chemicals, seeds, water and

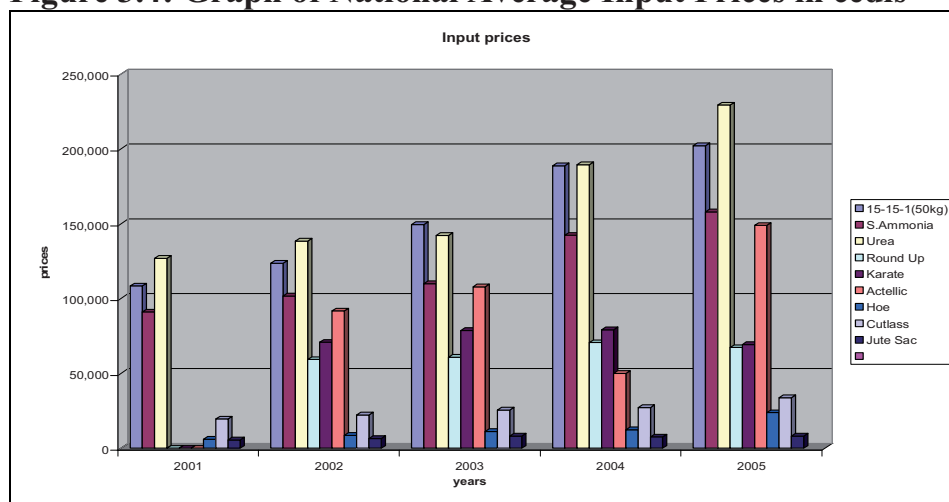
machinery. In Table 3.3 is a list of agricultural inputs used in Ghana. Before 1983 agricultural production was highly subsidized especially inputs. Government subsidized mainly fertilizer, an important cost component in agricultural production. Fertilizer cost is mainly the major input cost to farmers apart from machinery. After the Structural Adjustment Programme, input subsidies were eliminated. Farmers now buy their inputs at the market price. In Ghana, fertilizer uses have been on the low considerably after the elimination of subsidies in 1990's. For an example, 45000 tonnes of fertilizer were traded into Ghana in 1990 for agricultural production, but in 1994, the figure had fallen to less than 12000 tonnes. This fall is as a result of high fertilizer price making it difficult for agricultural producers to use (FAO, 2003).

**Table 3.3: National Average Input Prices in Cedis (Nominal Prices)**

Input	2001	2002	2003	2004	2005	Change % 2002-03	Change % 2003-04	Change % 2004-05
15-15-15	108,400	123,580	149,480	188,650	202,190	21	26.2	7.2
S. Ammoni a	90,940	101,650	109,860	142,220	158,010	8.1	29.5	11.1
Urea	126,860	138,440	142,200	189,440	229,360	2.7	33.2	21.1
Round Up	-	59,250	60,740	70,600	67,300	2.5	16.2	-4.7
Karate	-	70,780	78,770	79,100	69,240	11.3	0.4	-12.5
Actellic	-	91,670	107,880	50,000	148,840	17.7	39	-0.8
Hoe	5,890	8,540	11,180	12,380	23,800	30.9	10.7	92.2
Cutlass	19,490	22,200	25,550	27,120	33,710	15.1	6.1	24.3
Jute Sac	5,600	6,390	8,040	7,540	8,170	25.8	-6.2	8.4

**Source: SRID MOFA, 2005**

**Figure 3.4: Graph of National Average Input Prices in cedis**



**Source:SRID MOFA 2005**

Table 3.3 indicates that input prices have been increasing considerable over the years especially the prices of fertilizers. An example to look at is that of 15-15-15, from 108,400 cedis in 1994 to about 202,190 in 2008, a very sharp increase and warrant government to do something about it. This is very important for the agricultural sector because most developed countries provide subsidies on input for their farmers, The USA for instance, gives a significant amount of financial support to their farmers by means of home administration. The European Union has similar support programmes also for their farmers as well. So is the French, they are even prepared to go to “war” if their farm subsidies becoming an issue for concern to the E.U. In the U.K, they make sure that their farmers are provided for through the agricultural mortgage corporation and for the Scottish they engage agricultural securities that are in charge of administering subsidies on inputs for the agricultural sector. This has really led to the sustenance of the agricultural sector in the developed countries and lessons should be learned from this experience.



### **3.3.3 Credit Policy**

Credits in Ghana are usually given by the banks. Access to bank credit is very difficult, especially to agricultural workers. This is so because the banks acknowledge agricultural activities as a very risky venture to invest in and usually the loans given to agricultural workers have ended in bad debt to the banks. It is more often than not believed that farmers are not able to control what happens to output especially in the rainy seasons. The Nkrumah's Government acknowledging this fact established two categories of banks in 1965; these banks were the agricultural development bank (ADB) and the rural banks. ADB's main purpose was aimed especially for the development of food and agriculture in Ghana. Profitability was not a key requirement for ADB. The bank is excluded from income tax and is also exempted from the application of any of the provisions of the company codes 1963 (act 178). The rural banks were to be privately owned and funded. It was therefore intended that they support and provide short and medium term financing for rural businesses and cottage industries and even for short term expenses for individual needs of the farmers and small businesses. This goal has now been realized and the rural banks are a success story in the country today.

The Agricultural Development Bank lost its focus as the years passed by, its percentage of credit given to farmers have declined over the years. Other commercial banks have also declined to give credit to agriculture workers making it very difficult to access credit from the formal sector. A greater percentage of small scale farmers are unable get the assistance from the banks for their farming activities or by means of agricultural credit. Also the lending rates of the banks are quite high as 40 percent per year which is too high for these farmers and occasional when credits are



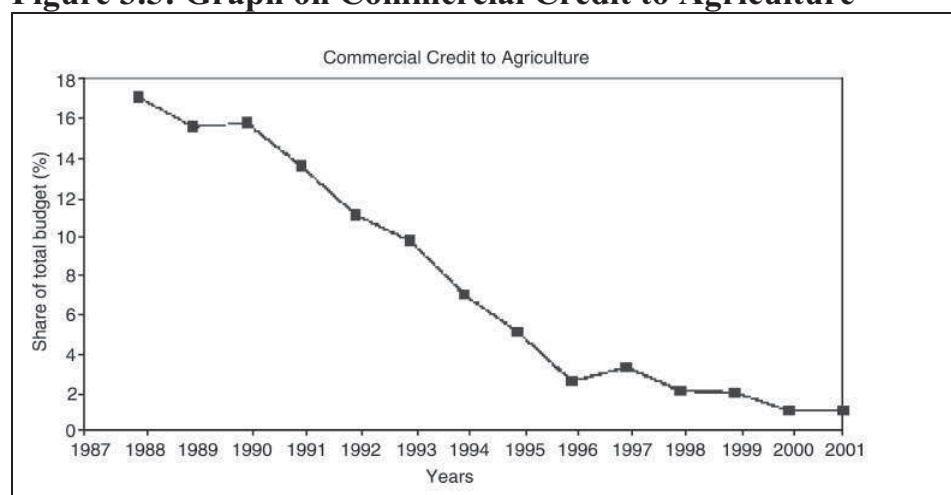
offered it is usually given to them at the wrong time of the season, when they would not be able to invest them into production, thus making the money not viable to them at that period of time and making it difficult for them to repay. However, there are certain amounts of informal credits in rural areas by which traders within the community lend farmers some inputs for which they are to pay back after they harvest their grains. In addition, other forms of informal credit exist as well, an example is when families do not have enough food supply, they could go and borrow some food items mainly grains from other farmers and later repay after their harvest usually with a 50 percent interest rate. There are also some support from NGO's who have introduced other forms of credit schemes for small scale farmer to assist them with new hybrid improved crops as well giving them fertilizer on credit. Meanwhile, these arrangements have not been able to cover a large or greater portion of the farming population.

In an attempt to increase credit to farmers, the government of the United States of America and the government of Ghana had signed the millennium challenge compact on August 1, 2007 which made possible a transfer of \$547 million to Ghana from the Millennium Challenge Account (MCA) of the United States of America. The fund is established to support the process of transforming agricultural through increased commercialization to promote economic growth and reduce poverty. Part of this money is set aside to be given to farmers as credit and this scheme is known as the Agricultural Credit Programme (ACP), this money would be used as a revolving credit facility which will be held and controlled by the Bank of Ghana.



In a nutshell, credits from commercial banks to agricultural workers have been declining over the years as a result of increasing interest rates and poor access. It is believed that if farmers have enough financial resources they would produce quality products and their production would also increase thus giving them more profit, at least up to the point when marginal revenue is equal to marginal cost. Figure 3.5 shows the magnitude of decline of credits from commercial banks to agricultural workers and gives a vivid picture of the decline.

**Figure 3.5: Graph on Commercial Credit to Agriculture**



Source: MOFA, 2005

**Table 3.4: Change in Commercial Credit to the Agricultural Sector in Ghana**

Year	Commercial Banks	Secondary Banks
1991	13.6	13.0
1992	11.1	8.7
1993	9.6	7.5
1994	6.6	9.3
1995	5.2	12.7
1996	2.4	17.3
1997	3.2	20.2
1998	2.2	22.2
1999	1.6	23.2
2000	1.0	11.0
2001	10.4	23.2
2002	2.1	10.8
2003	0.7	0.1
2004	1.9	13.9

Source: SRID, MOFA 2005





From Figure 3.5 it is realized that credit allocation to the agricultural sector has rapidly reduced over the years and is almost getting into zero and probably negatives.

Most banks, however, are of the opinion that if farmers are insured it is easier for them to get access to loans, since they could use their insurance as collateral to issue the loan (excerpts from the focus group discussions with bank officials).

As a policy that might affect water demand, if farmers get enough credits and are able to afford all their input especially fertilizer they would, more output would be produce from using a small piece of land and limited amount of water, than expanding the land acreage and using more water.

#### **3.3.4 Land Policy**

Land policy is one of the major issues under consideration recently in Ghana. Unlike in other countries where land is owned by the government , for instance , in China( Land Administration Law of the people of China, Ninth National People's Congress, August 29,1988) and a greater part of the Asian countries, in Ghana lands are owned by families, chiefs, tendana's and private individuals. This makes it very difficult for commercial farming, because in order to be able to get a large piece of land at the same place for any commercial farming, you have to meet a large number of people, including chiefs to get the land, and it is highly impossible therefore creating a high transaction cost for large commercial farming. In order for agricultural production to increase considerably, land expansion would have to be considered, there are a number of available pieces of land that has not been cultivated. If large scale farming is made easy, it would increase output, reduce prices, create economies of scale, demand more



water, increase income, employment and foreign exchange earning of the country and consequently increase economic growth, and reduce poverty.

Ghana has 23,823,000 hectares of land of which agricultural land covers about 1,497,000 hectares that is about 62.9 percent (FAO,2000).There are about 1,561,000 uncultivated hectares of land that can be cultivated if access to land is made more favorable. The government in 2007 had put in place some policies to help in that direction and even though its implementation is inevitable, it is considered as a step in the right direction. The new policy on land comprises of a more complete set of proposals that are for improving the land tenure system in the country through ensuring security of tenure and protection of land rights, and ensuring planned land use. The new policy strategies are towards the establishment of land banks to improve access, administering title registration to assure tenure security and development and implementation of land use plans at the district, regional and national levels. There are also the establishments of customary land secretariats to enable the facilitation of traditional land administration. In Ghana land tenure security is a constraint to agricultural investment making the use of modern equipment and mechanization almost impossible (MOFA, 2007). The implementation of land policy in Ghana would increase agricultural output and thereby indirectly increase the demand for water.

### **3.3.5 Macroeconomic Policies**

The growth rate of the agricultural sector is dependent highly on the macroeconomic environment of the country. Policies such as the inflation rates, lending rates, trade (exchange rate, quotas and



tariffs); fiscal and monetary (interest rates) policies are very essential to the investment ability in the agricultural sector.

For instance high lending rates affect farmers' ability to go for credits from the banks, and besides with their low productivity they would not be able to compete with the commercial sector for funds. Also, in terms of exchange rate, it is a key macro price in the economy and its level directly affect trade balance, e.g. the depreciation of the cedi to the U.S.A dollar exchange rate from 49.8% in 2000 to 2.2 percent in 2004, resulted in the volumes of nontraditional exports increasing sharply from US\$ 71.7 million in 1993 to US\$ 705.4 in 2004(MOFA, 2005). At the same time, this also affected the rice, poultry product and tomato paste market. Making the importation of these commodity viable than producing them locally, hence having a very serious effect on the rice and poultry production in Ghana. Other macroeconomic instabilities such as international oil shocks, inflation, interest rate, discount rate, as well as high cost of energy and poor infrastructure facilities also have serious consequences on the agricultural sector. This should also be a policy area that its effect on profits, water, and output in the agricultural sector should be investigated.

### **3.4 Irrigation Policies**

#### **3.4.1 Overview of Irrigation Policy**

Irrigation is said to be the artificial usage of water for the cultivation of crops, usually irrigation becomes the main source of water provision to the crops from the cultivation stage to the harvesting stage. In most countries, irrigation practices are mainly used in dry season or in areas of rainfall shortfalls. Irrigation is therefore one of the major means of increasing output growth in agricultural.



Countries that have specialized in irrigation farming or have invested to a large extent in irrigation have increased their output tremendously and economic growth over time. Examples of such countries are China, Israel, India, Malaysia etc, these countries as a result of irrigation has increased their agricultural growth so much so that they have become very powerful forces in the international market. China for instance has experienced enormous agricultural growth over the past few years as a result of its investment into small ground water wells which every farmer can access and even build by himself. China's food production has increased from 48 percent in 1990 to 71 percent in 2007 what is more this has also affected its economic growth from 3.8 in 1990 to 11.9 in 2007( China statistical year book, 2007). An irrigation policy therefore encourages investment into irrigation infrastructure to promote production and economic growth.

Ghana unlike the Asian countries started irrigation development relatively late in the 1960's. The country started with the investment into large scale irrigation scheme like the building of the Tano and the Veia irrigation schemes in the upper east region. The high cost of building the dam and maintenance coupled with their low performance records indicate failure in regards to their anticipated benefit (Alam, 1991; Kortenhorst et al.1989; Adams, 1992) this discouraged the government from further irrigation development in large scale irrigation facilities, the government instead started to promote with the help of other non-governmental agencies small scale irrigation instead (Turner, 1994). Farmers on the other hand took a long time to appreciate and to accept the irrigation technology and practice it. This was so because there were no training into irrigation technology use and how beneficial



it could be for them as farmers, not until recently Ghanaian farmers have not been very eager to use irrigation as a means of farming since they were all mainly rain fed farmers.

### 3.4.2 The Extent of Irrigation in Ghana

Irrigation in Ghana is not so much wide spread like in other countries where irrigation is a basic necessity. In Ghana, irrigation is a luxury or privilege to farmers. Farmers that have access to irrigation facilities in their area are seen to be far better off in terms standard of living than farmers who are not.

**Table 3.5: Land Use (Specific to Agriculture)**

	Hectares	%
Total Land Area (T.L.A.) (2005)	23,853,900	100.0
Agric. Land Area (A.L.A.) (2005)	13,628,179	57.1
Area under cultivation (2005)	7,194,900	30.2
Total area under irrigation (2005)	11,000	0.05
Area under inland waters(2005)	1,100,000	4.6
Others (forest reserves, savannah woodland, etc) (2005)	9,125,721	38.3

**Sources: Survey Dep't, MOFA, Accra**

\* 2000 Population Census Estimates from the Ghana Statistical Service, Accra.

Note: Percentages will not add up to 100, because area under cultivation is part of Agric. land area, while area under irrigation is part of area under cultivation.

From Table 3.5 the total area under cultivation is about 13,628,179 hectares whilst total area under irrigation is just 11000 hectares that is about just 0.05% of total land area. This indicates that irrigation development is very essentially slow for a country that is looking at agriculture as an engine of growth. Government

therefore in its vision 2020 and GPRS 2 and MCA have policies for the development of small scale irrigation facilities and have envisaged a projected 100,000 hectares by the year 2020 (GNWRP, 2007). From research, it is proven that most of the irrigation facilities are located in the three upper regions leaving the rest of regions with very little irrigation facilities.

### 3.4.3 Small Scale Irrigation in Ghana

Irrigation in Ghana is very much on the low scale firstly because of high cost of constructing irrigation facilities in Africa as a whole and in Ghana in particular. Constructing irrigation in Ghana does not require finances alone but other contributing factors such as macro policies and institutions, socio-economic political factors as well as project level parameters not forgetting transaction cost of land. All these factors put together make constructing irrigation facilities in Ghana more difficult than in Asian countries.

**Table 3.6: Average cost of World Bank funded irrigation projects, 1960-93**

	No. of projects	Unit cost(US\$/ha)	No. of projects	Adjusted units cost(US\$/ha)
East & south Asia	112	2,831	107	4694
East Asia	56	4291	56	7379
South Asia	56	1370	51	1746
India	30	1421	27	1596
Europe	17	4743	17	4759
Middle east	9	5062	7	4663
Africa	30	12925	30	20833
North Africa	12	4911	12	5226



Sub-Saharan Africa	18	18269	18	31238
Latin America & Caribbean	20	3923	20	10283

**Source: A. Inocencio (IWMI, 2003), Pan Africa Conference, Addis Ababa**

Table 3.6 above gives a fair overview of how expensive it is to construct an irrigation facility in Ghana which is in the Sub-Saharan Africa area. Comparatively, one can see that it is very easy to construct irrigation facilities in the Asian countries than in the African countries. Irrigation development in Ghana is very poor. As discussed earlier, the land tenure system in the country also makes it very difficult for government or any organization to get land to construct a large or small scale irrigation facility without accumulating a high cost of payment of compensation to all families, chiefs and individuals whose land would be encroached on in the process of construction. Another major reason why irrigation is expensive in Ghana is as a result of corruption and inadequate social infrastructure these factors automatically increases the cost of construction.

Another major reason why irrigation in Ghana is underdeveloped is as a result of lack of market for locally produced goods. This really makes it impossible for farmers to use existing irrigation facilities to their fullest capacity. Most of the existing irrigation schemes are underutilized, making the government and other contributing agencies very reluctant to develop more irrigation facilities until recently that government is making a conscious



effort to use the development of irrigation infrastructure as an engine of modernization in the agricultural sector of the country. Finally, the incomes of farmers are very low so it makes it very impossible for farmers to construct irrigation facilities on their own.

Pump irrigation however, is the only irrigation method that is increasing tremendously in Ghana. This is so because farmers just need to buy a pump and pipes for its connection, as it really increases irrigation in some areas but it is also a disadvantaged because it only favors farmers who are very close to a river or stream. If farmers are not near any water resource then they might not be able to put that into use.

#### **3.4.4 Irrigation Pricing**

Cost of irrigation in Ghana is not too expensive as farmers do not pay for irrigation water but pay a fee towards the maintenance of the irrigation facility. The fee each farmer pays actually depends on the type of crop it grows in the season; the amount is usually between US\$1 and US\$2 for a plot of land. This amount is collected by ICOUR which is an established institution in charge of the large scale dams, but for the small scale schemes, fees are paid to water user associations at these dams. The fees are usually deposited at the banks and are used for any maintenance and repairs when the need arises.

#### **3.4.5 The Importance of Irrigation to Agriculture**

Irrigation farming to a country is very vital. In Ghana irrigation farming, in recent times has become one of the most beneficial farming activities in the country. Rain fed farming is losing its value, as the rains arrive very late or very early, and farmers are unable to make good use of them. And even when the rains come,





at times, they flood and destroy all crops leaving farmers with no harvest as in the case of November 2007. Hence, rain fed farming is no more reliable as a result of global warming or climate change. Farmers are therefore, relying mainly on irrigation farming for their livelihood, bearing in mind that irrigation water can be controlled and not cause flooding.

Irrigation farming is very beneficial to the poor small scale farmers. This is because; it promotes higher production, reduces the risk associated with poor yields, and provides full term agricultural employment. Irrigation also facilitates small scale farmers to make use of other ways of cropping pattern and to move from the production of low-value crops to more profitable crop production. When food production increases, more food is released in the system for the rural people as well as making food also affordable for the growing population.

In as much as Irrigation water has a positive ability in increasing production it is therefore seen as a significant socioeconomic “good”, it can also become a socioeconomic “bad” to the society as it can also lead to issues of land degradation, salinity, water borne diseases(malaria, schistosomiasis), the destruction of the ecosystem and also reducing water available for other uses given that irrigation demands more water than other users.

### **3.5 Water Supply**

Water availability in Ghana is usually from surface water and a small amount from groundwater aquifers and rainfall. There are three main surface water sources; these are from the three river systems such as the Volta river system, Southwestern river system, and the Coastal river system. The Volta river system comprises of

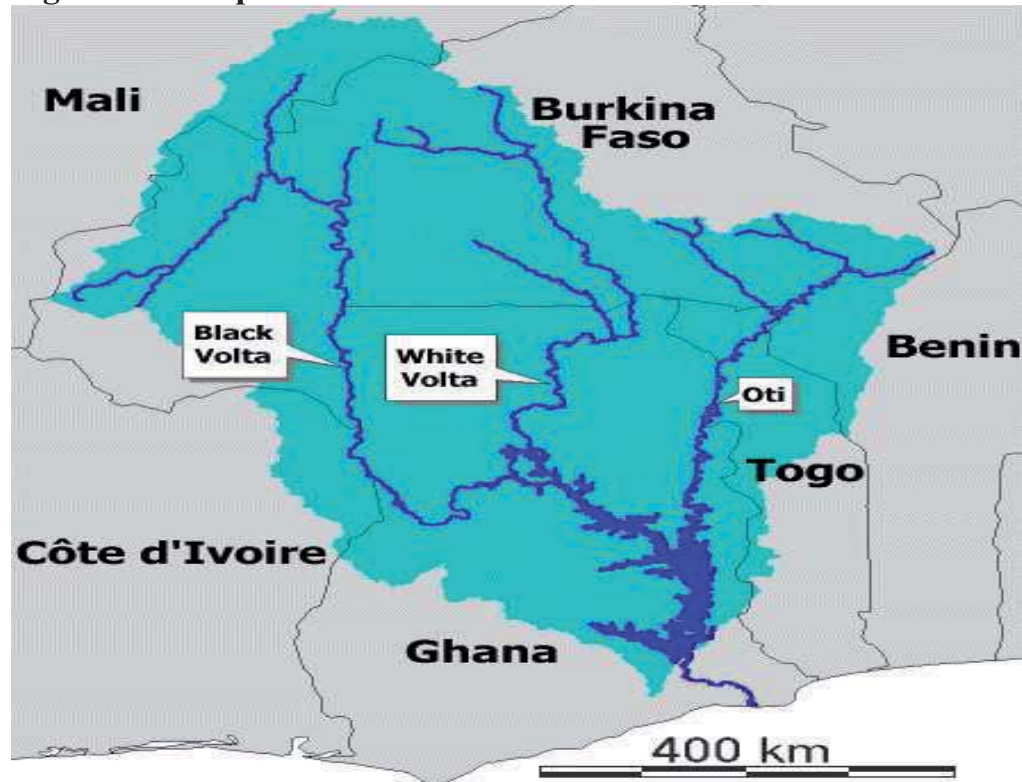


the red, black, white, and Oti, rivers and covers 70 percent of the country area. The southwestern river system comprises the Bia, Tano, Ankobra and Pra rivers and covers 22 percent of the country area. And the coastal river system comprises the Ochi-Nakwa, Ochi Amissah, and Ayensu, Densu and the Tordzie rivers, covering 8 percent (240,000km). There is also a fresh water surface known as Lake Bosumtwi (GNWRP, 2007).

The total annual runoff from all rivers is 56.4 billion m<sup>3</sup> of which 41.6 billion m<sup>3</sup> is accounted for by the Volta River. The mean annual runoff from Ghana alone is 38.7 billion m<sup>3</sup> which is 68.6% of the total annual runoff. The Volta, South-western and Coastal system contribute 64.7, 29.2 and 6.1% respectively of the annual runoff from Ghana. (FAO, 2000)

Table 3.7 gives a summary of surface water availability within and beyond the country. Table 3.7 shows that, 50.2 % of the combined catchments areas of the river basins in Ghana lie outside the boundaries of Ghana. The country however receives 69.7 % of waters generated by these catchments. Appendix 1 gives you a more detailed supply and demand of water in the various dams and reservoirs in the country.

**Figure 3.6: Map of the Volta Basin**



The Volta River basin; shared by Ghana Ivory Coast, Upper Volta, Togo, Benin and Mali

**Table 3.7: Area of Volta Basin in the Different Countries**

River Basin	Area(Km <sup>2</sup> )				Mean Annual Runoff(x10 <sup>6</sup> m <sup>3</sup> )			
	Within Ghana	Outside Ghana	Total	%Within Ghana	Within Ghana	Outside Ghana	total	%within Ghana
Black	35107	113908	149015	23.6	4401	3272	7673	57.4
White	45804	58948	104752	43.7	6073	3492	9565	63.5
Oti	16213	56565	72778	22.3	2498	8717	11215	22.3
Lower	59414	3237	62651	94.8	9114		9842	92.6

**Source: Water Resources Availability in Volta basin (Adaptation, 2005)**



**Table 3.8: Urban and Rural Population Distribution**

Year	Population	Rural (%)	Urban (%)
1970	8,559,313	71.1	28.9
1984	12,296,081	68.0	32.0
2000	18,912,079	56.2	43.8

**Source: Ghana Statistical Service, 2002**

### **3.6 Water Demand and Supply Situation in Ghana**

Water resources contribute immensely to the development of economic growth and poverty reduction in Ghana. Water demand for industries has been increasing rapidly as well as that of hydropower generation, agriculture, mining, recreation, domestic and environmental development. As a result of these demands, water supplies would be overused with its high consequent effect of pollution and environmental degradation. The situation would be worst as urbanization increases and the population continues to grow, standard of living rises, mining becomes widespread, and human activities are diversified. Rainfall in the country has also decrease over the years, with longer dry seasons and more tributaries with most rivers and lakes drying up quickly, thus decreasing the availability of ground and surface water for the increasing population.

If total available water in 2007 was 39.4 billion m<sup>3</sup> per annum and irrigation projection for 2020 is 400,000 million m<sup>3</sup>, and hydropower projected is 378,430 million m<sup>3</sup>, domestic and industry projected 273,000 million m<sup>3</sup> with the population increasing at 3 percent per annum, coupled with adverse climate change, available water supply would decline in the long run and might not be able to sustain the growing demand, thus leading to

water scarcity in the future years to come. A vulnerability analysis for the water sector was performed by care international; this was based on projected demand for domestic, industrial and irrigation water in 2020 and 2050 based on assumed socio-economic indicators and climatic scenarios. Three river basins were chosen for the analysis; the Pra, the Ayensu and the White Volta. These were chosen to represent the three major hydro climatic zones in the country. (Hydro climatic zones are the Volta basin system, the southwestern basin system and the coastal basin system).

**Table 3.9: Annual Urban and Industrial Water Supply and Demand in 10<sup>6</sup>m<sup>3</sup>**

BASIN SYSTEM	2000			2020			WATER AVAILABILITY
	DEMAND	SUPPLY	WATER BALANCE	DEMAND	SUPPLY	WATER BALANCE	
VOLTA	63.3	107.75	44.47	121.42	107.75	-13.67	24,175
SOUTH-WEST	92.15	57.31	-34.84	175.85	57.32	-118.53	13,125
COASTAL	164.78	70.21	-95.27	318.77	70.21	-248.56	2,110
TOTAL	320.71	235.27	-85.64	616.04	235.28	-380.76	39,410

**Source: Ministry Of Works and Housing 1998**

Based on the projections of temperature and rainfall, the reductions in flow and in groundwater recharge in three basins were estimated. Table 3.10 shows the three studied basins. It is assumed that these results can be extrapolated to other basins with the same climatic zones. (Daze, 2007).



**Table 3.10: Projected Water Demand**

Basin	Projected reduction in flow (%)		Projected Reduction in Recharge (%)	
	2020	2050	2020	2050
<b>Pra</b>	17	33	17	29
<b>Ayensu</b>	20	37	5	36
<b>White Volta</b>	16	37	22	40

**Source: DAZE, 2007**

It was concluded that the water sector is only marginally vulnerable, despite significant reductions in flow and recharge. However, it notes that the country will face water management problems in the future, and acknowledges that the demand estimates used are conservative and do not take into account the potential increases for food security, export, and the energy sector as it is particularly vulnerable due to its high reliance on hydropower.( Daze, 2007). In this case, what happens to the excess demand of water in the country?

Falken *et al* (2000) noted that water scarcity could have a tremendous effect on economic growth and development of a country and therefore policies should be put in place to avoid any country from getting into that situation.



## **4.0 Methodology and Theoretical Background**

### **4.1 Types of Models**

This methodology seeks to model the impact of agriculture and water policy on defined agricultural systems in the Volta basin area. This would help us analyze with more realism the irrigation farming system in the Volta basin. In this study the irrigation farming systems is defined as a set of farms that have the same productive specialization. This would start with mapping of irrigational system in the basin, labeling of the various zones and exploring this irrigational farming system in line with water policies in place.

A mathematical programming model is used in this study. The methodology tries to reveal the point of view of the farmers as a part of an irrigation or farming unit. Mathematical programming models in recent times have taken the center stage of agricultural sector modeling. These models are mainly used to find an optimal solution at the farm level. There are different types of mathematical programming models such as the linear programming (LP) problem, Non-linear and quadratic programming problem. The linear programming model is a programming model that comes out with an optimum solution to a problem. In LP model, the objective function, the constraints depends linearly on selected variables. The LP model helps in various ways to analyze issues on resource allocation in various fields of study such as in business and economics. The model also helps in forecasting the way that businesses react to external shocks. Furthermore the LP model helps by minimizing or totally taking care of aggregation problems normally associated with other



models. The LP model is the most used mathematical programming model for problems in agriculture (Hardaker et al 2004).

A nonlinear programming (NLP) problem is a way that equations are written in an inequality and equality form, these equations are known as constraints and are usually associated with an objective function that has to either be maximized or minimized with at least one existing nonlinear constraints.

The LP model has numerous merits and demerits. One merit of the linear programming model is the fact that it requires less data input. Since the factors of production, land labor and capital are scarce, the LP model assists in their optimal allocation.

As a demerit, the LP model, the certainty assumption may not be representative of what is happening on the ground when the objective or constraints functions are linear in nature. Policy decisions are naturally not linear, in that in decision making some win and others lose. Policy making and the respective results in real life are just not linear. For the agricultural sector which is mostly affected by farmers decisions, government decision, land tenure problem and environmental factors among others, there is the need for the methodology to accurately capture all the relevant variables and model them as precisely as possible which the LP model may fail to achieve.

Another programming model worth mentioning is the one that assumes a quadratic form, where the function or equations are modeled nonlinearly.

The methodology considered in this study takes into account the importance of price expectation and risk in agricultural decision





making, and is dynamic and recursive in nature. This methodology is known as the MATA model.

#### **4.2 Why the Need to Use the MATA Model**

The Multi-Level Analysis Tool for the Agricultural sector (MATA; Gérard et al, 1994) focuses on modeling agricultural sector outcomes and captures policy changes driving these outcomes. The MATA model is programmed in GAMS modeling language. The MATA model assumes a non-linear function, and seeks to model selected variables with the help of CONOPT3 serving as a solver.

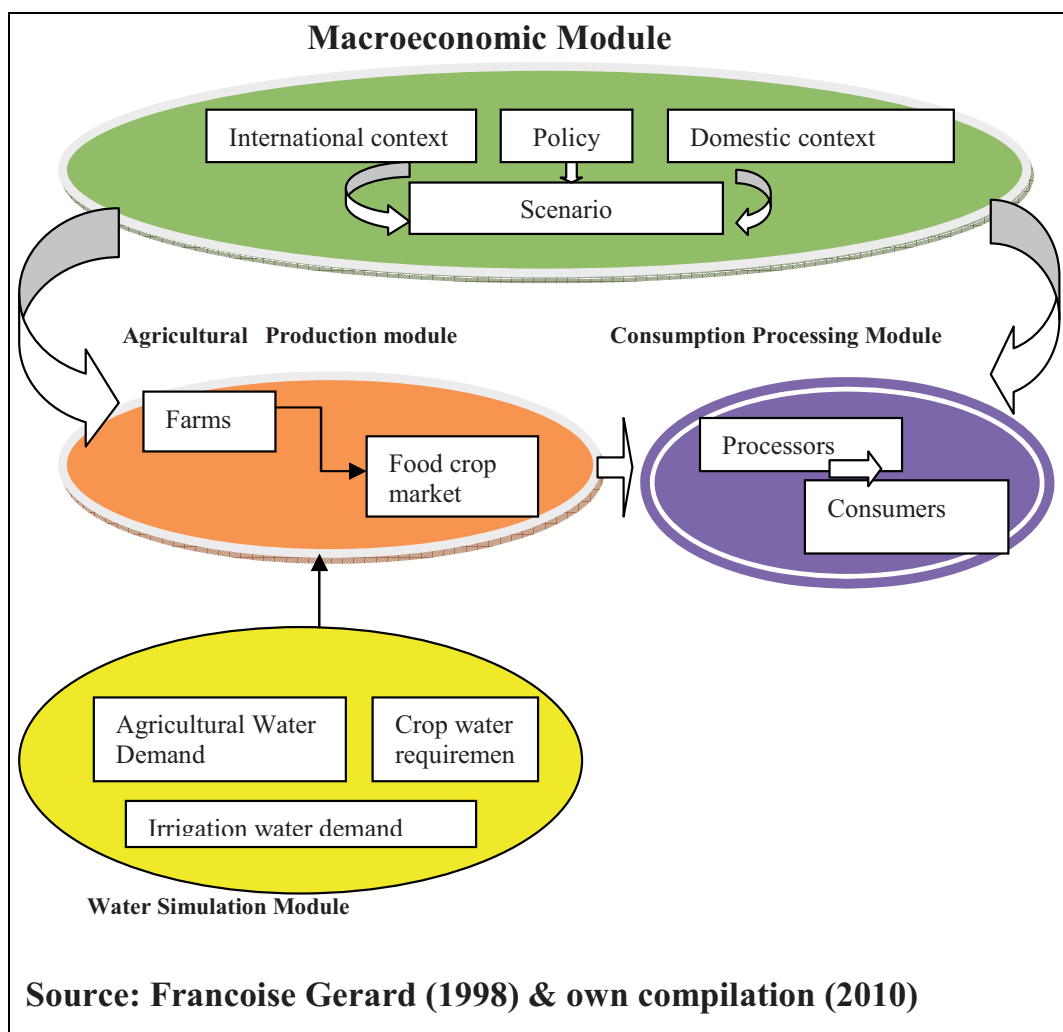
According to Gérard et al, 1997, the ability of the MATA model to capture both micro and macro simulation model within a multi-level framework provides relevant insight into the practical challenges associated with the agricultural studies. This multi-level model comes to do what other models fail to do by incorporating risk that comes from agricultural production, making provision also for time for adjustment and fluctuations in agriculture markets. Price expectations are also incorporated into the model bearing in mind that the model is recursive and dynamic in nature. The model further more takes into consideration an important factor such as market imperfections for credit, capital, land and labor. These are the distinctive features that make the MATA model different from any other modeling approach (Gérard et al, 1997).

Furthermore, the MATA model simulates the impact of policy either at a regional level or at the national level. The regional level structure, stress that a smaller scope is described first, then the adjustments required to integrate several zones and the aggregation process are presented and finally the simulation on the whole

sector is described. The simulations can focus on the production only or on the whole sector.

The results from the MATA model are made more realistic with the incorporation of market imperfections. In order to be able to run this model a large scope of data is necessary for the programming of the MATA model. To assemble all these data needed for the model together, is highly resource demand and to analyze it in a consistent framework, taking into consideration relationships within the agricultural sector is also very complex, but this is what is proposed in MATA methodology.

**Figure 4.1: The MATA Methodology**





The original MATA model as shown in Figure 4.1 is made of three individual components namely: the macro-economic model that captures the broad policy positions that impact on the decisions of both farmers and consumers, the production component which centers on farming activities whilst the model of commodity chain which focuses on processing firms and consumer decision making. These modules virtually describe the flow of food from the farm gate to the consumers. The MATA model used in this study has been improved by the addition of a fourth module which is known as the water module. The water module describes the demand for water by the agricultural sector in the country as well as water supply in the country. The four modules are then inter- linked (connected together under the MATA programming model).

MATA methodological technique clearly encompasses agricultural sector wide variables sometimes referred to as macroeconomic factors, variables on changes in food prices normally associated with the consumer behavior, the commodity chain which tracks the processing stages, the respective geographical areas and distribution of products from the farm gate to the final consumer whilst the production aspects of the methodology details the amount of food production and the respective value associated with specific food policies. Tackling the agricultural performance in a broader context (or sector wide) and then narrowing it down to the farmer specific decisions (micro context), the methodology accounts for different levels of performance evaluation. This is however made possible by the advances in computer modeling techniques with the ability to accommodate huge data sets that would have been virtually impossible to model a few decades back (Gerard et al, 1997).



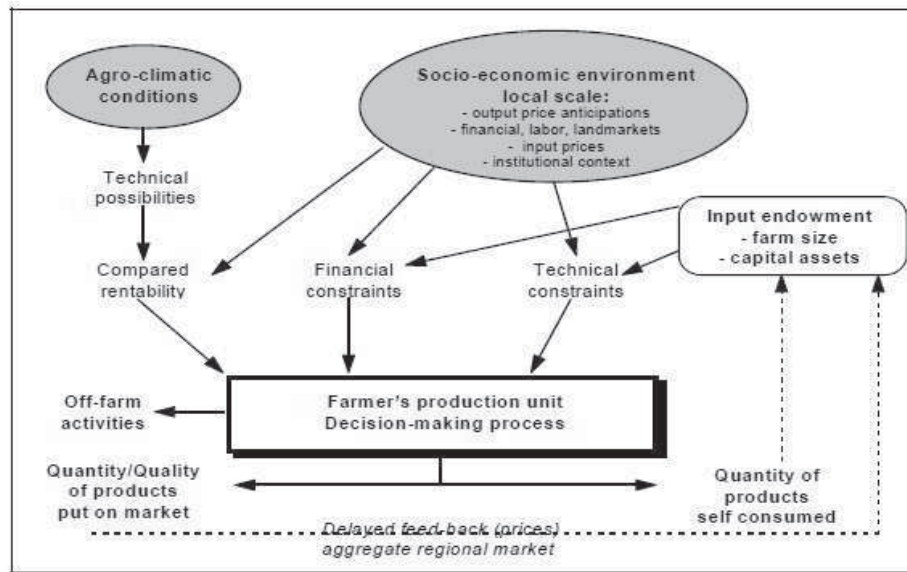
#### **4.2.1 The Agricultural Production Module**

In economics, the function that indicates the output of a firm, farm, or the whole economy for all combinations of input is a production function. In the agricultural sector, the agricultural production system is characterized by a set of farming systems, determined by a typology. This is very important as it makes it feasible to identify the spatial differences, high diversity of agro-climatic and socio-economic environments in which agricultural activity functions. The structure of the agriculture production module begins first with a zonation<sup>4</sup> of the study area to determine homogeneous areas in terms of agro-climatic and socio-economic environment or view point. The second step is to classify in each zone, the farms according to their factor endowment such as land, labor, equipment liquidity, and saving. Then each farm is represented through the formalization of the decision process of the farmer by a non –linear programming model (Gérard et al, 1998). Figure 4.2 represents a break-down for one farm type.

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<sup>4</sup> Zoning is a determination of zones with similar characteristics on agricultural potentiality and socio-economic context. It is usually done to take into account the diversity of agricultural production conditions in terms of activities and techniques (crop management, yield average and variability, risk of pest and diseases) possible impact on environment and markets conditions.

**Figure 4.2: Description of the Production Module**



**Source: Françoise Gerard, 1998**

Prospects and limitations are established by agro-climatic and socio-economic condition for each type of farming system. Then an objective function is also determined with the inclusion of calculations that distinguishes between agricultural and non-agricultural labor also for estimating the allocation of land between crops and techniques for each farm type. Also as a result of the recursive nature of the model the results of each year determines the beginning point of the next year and this is done in the model by updating farm endowment in factors and liquidity (Gérard et al, 1998).

Producing Agricultural product is naturally a risk oriented venture. Agricultural farmers are confronted with an array of variables such as the price and yield of crops, as a result of the risky nature of this venture, the income of producer is mostly not stable. Such risk factors like disaster such that agricultural produce may be destroyed as a result of natural hazards such as flood, fire, pests, or drought.



The nature and impact of agricultural risk that pertains in the agricultural sector differ in nature with the farming system, climatic conditions, policy, political and institutional setting in the region or country. Nevertheless, agricultural risks could be said to be everywhere in the world, but its severity is mainly seen mostly in the developing countries such as Ghana, as a result of their subsistence nature of farming. Several empirical studies have proved that farmers normally behave in risk-averse manner (e.g., Binswanger 1980 and Dillion and Scandizzo 1978). This is so because farmers would like better to have a stable income than to have income that is associated with risk. Therefore ignoring risk-aversion behavior in farm planning models often, leads to results that are unacceptable to the farmer, or that bear little relation to the decision he actually makes. To resolve this problem several techniques for incorporating risk-averse behavior in mathematical programming models have been developed in recent years (Hazel and Norton, 1986).

For this study, a Neumann-Morgenstern expected utility function is used, the reason for this is to integrate risk into the model structure unambiguously through a combination of income and risk aversion coefficient (De Frahan et al.2007). The effect of the risk usually implies price expectations which are also captured in the model formulation. In the production module application (Erwidodo and Gérard et al, 1998), it is assumed that each farmer chooses from a set of activities and techniques that maximizes the expected utility of wealth under simultaneous constraints. Wealth is defined as the total value of assets at the end of the year. In order to consider the farmers risk attitude, the mean variance analysis (Markowitz, 1959) is used.



The mean-variance rule presumes that the preferences of a farmer among various possible outcomes are based on expected income  $E[Y]$  and its associated variance  $V[Y]$ . This decision rule results from the expected utility theory if the decision maker has a quadratic utility function for income  $U(Y)$ . However, quadratic functions are characterized by increasing absolute risk aversion violating an important element of risk aversion theory which states that absolute risk aversion declines as income level goes up. Regrettably, a quadratic utility function is characterized by increasing absolute risk aversion, as well as having a maximum value beyond which the marginal utility of income actually declines. It has therefore been rejected untenable by most theorists (e.g. Pratt, 1964). Despite this, the quadratic utility function can still provide an excellent second-order approximation to more desirable functions (Levy and Markowitz, 1979).

An alternative derivation of the E, V (mean-variance) decision rule follows the utility function of the exponential form  $U(Y) = 1 - e^{-\alpha Y}$  and income  $Y$  which is normally distributed (Freund 1956). In this case.

$$E[U(Y)] = E[Y] - \frac{1}{2} \beta V[Y] \quad (4.1)$$

Where  $\beta$  is a risk –aversion parameter, it might be expected that since farm income is often an aggregate of many independent sources of revenue and cost risk, then by the central limit theorem, it should be approximately normally distributed.



#### **4.2.2 Risk in the Constraints**

To this point, we have assumed that all the  $x$ , and  $y$ , coefficients of a farm model are deterministic. This is not always a plausible assumption. Yield risks that affect gross margin or wealth are also likely to affect activity labor and machinery requirement. Fluctuations in input costs affect the capital requirement of the farm activities as well as wealth of the farmer. Autonomously of gross margin or wealth risks, a farmer may also face risks in resource supplies as well seasonal labor, off-farm labor, water for irrigation, and forage supplies for livestock feed are examples of risks that may confront the farmers.

Risk in the constraint set can considerably affect the viability of a crop budget in any given period of time. Consequently, in seeking to find better farm plans in relation to a farmer's income objectives, the analyst must be sure that the plan will be feasible at an acceptable risk level.

The MATA model is able to make use of different objective functions. Although most agriculture sector models use profit maximization as their objective function, in this study we would maximize wealth, which is used as a proxy to represent the total value of the farm, for the reason that the model is dynamic in nature with a static optimization. Nevertheless, another study was used as a test case (for the case of Java lowlands in Indonesia) and expected profit was the objective (still taking risk into account), leading to the same results (Meaning the objective function with either expected profit or wealth does not make much difference in results, Gerarad, 1998).





### 4.2.3 The Consumption Module

The consumption module<sup>5</sup> represents consumer behavior as well as processing and marketing of agricultural products (Gérard and Versapuech 1977).

Consumption, in the agricultural production module is divided into three items:

- Self-consumption of agricultural products to meet minimum calorie and protein needs
- Minimum consumption in cash to cover minimal needs at the household level in terms of food, clothes, school expenditure and others
- Consumption as a share of profit (Marginal Propensity to Consume)

In economics, the only mathematical function used to determine how much a consumer spends on items is known as the consumption function. The function is used to determine the amount of total consumption in an entire economy. It consists of autonomous consumption that is not influenced by current income and induced consumption that is influenced by the economy's income level.

The consumption function is shown as the linear function;

$$C = C_x + C_y * Y^d \quad (4.1)$$

---

<sup>5</sup> In this study, demand systems are not used as in the original MATA model that considered urban consumption through the consumer utility function. This is because, the study concentrates mainly on the production side and not consumption as well.



Where

- $C$  = total consumption,
- $C_x$  = autonomous consumption ( $C_x > 0$ ),
- $C_y$  = is the marginal propensity to consume (i.e. the induced consumption) ( $0 < C_y < 1$ ) and
- $Y^d$  = disposable income (income after taxes and transfer payment, or  $W - T$ ).

Autonomous consumption characterizes consumption when income is zero. In estimation, this is usually assumed to be positive. The marginal propensity to consume (MPC), on the other hand computes the rate at which consumption is changing when income is changing.

#### **4.2.4 The Macro Economic Module (Context Module)**

In this module, the general macro-economic and institutional context is portrayed. Some of its parameters can be modified to simulate alternative conditions, such as input prices, credit conditions or urban household revenue as well as interest rates (Deybe, 1998). The module considers key macroeconomic goals, such as price stability and rates of economic growth as well as narrower micro economic targets for production and consumption. The macroeconomic module describes the environment in which farmers; processors and consumers decisions come to pass (Gérard et al, 1997).

The module captures trends on macro-economic variables such as population and income growth, evolution of employment opportunities in the non-agricultural sector, interest rate, and relative prices. The scenarios are defined in this module in combination with policy measures affecting variables and can be

done directly using the policy simulation file. The impact of policy on employment in the agricultural sector for example is calculated in this module by adding up the results of the agricultural production and consumption modules (Gérard et al, 1997).

#### 4.2.5 Water Demand Module

Water demand is assessed as crop water requirement based on hydrologic and agronomic characteristics. Net crop water demand (XNCWD) in a year is calculated based on an empirical crop water requirement function (Doorenbos and Pruitt 1979): This method was used also by Rosegrant et al 2008, in the IMPACT-WATER model by IFPRI (International Food Policy Research Institute).

$$XNCWD = \sum_{cp} \sum_{ct} kc^{cp,ct} * ET_0^{ct} * XA^{cp} = \sum_{cp} \sum_{ct} ETM^{ct,cp} * XA^{cp} \quad (4.2)$$

In which cp is the index of crops, ct is the index of crop growth in stages,  $ET_0$  is the reference evapo-transpiration (L), kc is the crop coefficient, and A is the crop area.

Part or all crop water demand can be satisfied by effective rainfall (PE), which is the rainfall infiltrated into the Zone and available for crop use. Effective rainfall for crop growth can be increased through rainfall harvesting technology (Rosegrant, 2008). Then net irrigation water demand (XNIRWD), with consideration of effective rainfall use and salt leaching requirement is

$$XNIRWD = \sum_{cp} \sum_{st} (kc^{cp,st} * ET_0^{st} - PE^{cp,st}) * AI^{cp} * (1 + LR) \quad (4.3)$$

Where AI is the irrigated area, LR is the salt leaching factor, which is characterized by soil salinity and irrigation water salinity.



Total irrigation water demand represented in water depletion (XIRWD) is calculated as

$$XIRWD = XNIRWD / XBE \quad (4.4)$$

In which BE is defined as basin efficiency. The concept of basin efficiency was discussed and various definitions were provided by Molden, Sakthivadivel, and Habib (2001). The basin efficiency used in this study measures the ratio of beneficial water depletion (Crop evapo-transpiration and salt leaching) to the total irrigation water depletion at the river basin scale. Basin efficiency in the base year (2005) is calculated as the ratio of the net irrigation water demand (XNIRWD) to total irrigation water depletion estimated from secondary data records. Basin efficiency in future years is assumed to increase at a prescribed rate in a basin, depending on water infrastructure investment and water management improvement in the basin (Rosegrant et al, 2008).

The projection of irrigation water depends on the changes of irrigated area and cropping patterns, water use efficiency, and rainfall harvest technology. Global climate change can also affect future irrigation water demand through temperature and precipitation change, but was not considered in the original modeling framework (Rosegrant, 2008).

#### **4.2.6 Connecting Production and the Water Component**

One of the renowned ways of connecting the water component into the production function is through the crop yield function. This method was used by Rosegrant et al 2008, in the IMPACT-WATER model by IFPRI (International Food Policy Research

Institute). Policy analyses based on scenarios analyzed with IMPACT –WATER were published in an IFPRI book titled *World Water and Food to 2025: Dealing with scarcity* (Rose grant, Cai and Cline, 2002). Another paper that used results from IMPACT-WATER to make policy evaluations is a study prepared for North American Commission for Environmental Cooperation titled *Modeling Water Availability and Food security: A North American Application of the IMPACT-WATER Model* (Rose grant, Runge and Cai), which looked at implications of NAFTA on water use and agricultural production in North America. IMPACT –WATER is also currently used for a World Bank report on the role of agriculture to achieve the millennium Development Goals and a small effort by the US EPA on the role of greenhouse gas mitigation for rice in China. This study therefore employs the water simulation model of the IMPACT-WATER model for its water model analysis<sup>6</sup>.

### **4.3 Water Supply**

Water supply is acquired from the dam, rainfall, and surface water (runoff) from the basin. With the assumption that environmental and ecological flow requirements are fixed constraint in water supply, we focus on the determination of off-stream<sup>7</sup> water supply. In the model, water supply is calculated from three different sources, such as irrigation (dams), effective rainfall and runoffs or discharge. Two steps are employed to determine off-stream water supply by sectors. The first is to determine the total water supply characterized as depletion/consumption (WDP) in each month of a

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<sup>6</sup> Not all the components of the WSM were adopted, only the part that suited the MATA model was adopted.

<sup>7</sup> Off-stream use of water is water withdrawn or diverted from surface water for public water supply such as irrigation, industry, livestock and hydropower generation



year; and the second is to allocate irrigation water supply to diverse crops in the basin.

In order to assess the total amount of water available (surface water) for off-stream uses in a basin, hydrologic processes, such as precipitation, evapotranspiration, and runoff are taken into account to determine total renewable water (TRW). Additionally, anthropogenic impacts are combined to define the fraction of the total renewable water that can be used. These anthropogenic impacts can be classified<sup>8</sup> as follows: (1) water demands; (2) flow regulation through storage, flow diversion, and groundwater pumping; (3) water pollution and other water losses (sinks); and (4) water allocation policies, such as committed flows for environmental purposes, or water transfers from agricultural to municipal and industrial uses. In a nutshell, water supply is calculated based on both hydrologic processes and anthropogenic impacts through the model.

In estimation, it is stated that water availability in the downstream basin depends on the rainfall drainage in the basin and the inflow from the upstream basin(s). Then surface water balance at the basin scale can be represented as:

$$ST^t - ST^{t-1} = ROFF^t + INF^t + OS^t - XSWDP^t - RL^t - EL^t \quad (4.5)$$

in which  $t$  is the modeling time interval;  $ST$  is the change of basin reservoir storage;  $INF$  is the inflow from other basin(s);  $OS$  represents other sources entering water supply system, such as water desalinized;  $RL$  is the total release, including the committed in stream flow and spill in flooding periods;  $EL$  is the evaporation

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<sup>8</sup> In this study, only the water demands impacts are considered.



loss mainly from surface water,( Rosegrant, 2008); and  $XSWDP^t$  is the total water depletion from surface water sources which is equal to water withdrawal minus return flow. It is determined from this water balance equation, with an upper bound constrained by maximum surface water allowed for withdrawal ( $XSMAWW$ ) as:

$$\sum_t XSWDP^t / DC \leq XSMAWW \quad (4.6)$$

It is also assumed in the equations, that flow release ( $RL$ ) must be equal or greater than the committed in stream flow; monthly reservoir evaporation is calculated based on reservoir surface area, and climate characteristics.<sup>9</sup>

Where  $DC$  is the water depletion coefficient, The value of the water depletion coefficient in the context of the river basin mainly depends on the relative fraction of agricultural and nonagricultural water use (that is, larger agricultural water use corresponds to a higher value of water depletion coefficient), as well as water conveyance/distribution/recycling systems and pollution discharge and treatment facilities.

The estimation of the  $XSMAWW$  in the base year (2005) is based on the actual annual water withdrawal in 2005 (WRI 2007). Therefore water supply represented as depletion for agricultural sectors is calculated as:

$$WDP^t = \sum_t (IRWD^t, XSWDP^t + XPE^t) \quad (4.7)$$

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<sup>9</sup> Data and some calculations for all the variables needed were collected from a hydrologic GLOWA Volta student and also from other secondary data sources.



From the equation above  $IRWD^t$  represents irrigation water calculated from the water available in the dams,  $XSWDP^t$  water available from surface water and  $XPE^t$ , water available from effective rainfall. Finally, total water available for crop evapotranspiration ( $NIW$ ) is calculated by introducing the basin efficiency ( $BE^{10}$ ) for irrigation systems and discounting the salinity leaching requirements, as

$$TNIW^t = BE * WDP^t / (1 + LR) \quad (4.8)$$

For the second step, this is to allocate irrigation water supply to diverse crops in the basin. Here total water available can further be allocated to crops according to crop irrigation water demand, yield response to water stress ( $ky$ ), and average crop price ( $PC$ ) for each of the major crops considered in the basin, including rice, maize, and other crops.

The allocation fraction ( $ALLO$ ) is defined as:

$$\pi^{i,t} = \frac{ALLO^{i,t}}{\sum_{cp} ALLO^{i,t}} \text{ and,} \quad (4.9)$$

$$ALLO^i = AI^i * ky^i * [1 - PE^{i,t} / ETM^{i,t}] * PC^i$$

In which,  $ETM^{cp,t} = ET_o^{cp,t} * kc^{cp,t}$  is the maximum crop evapotranspiration;  $\pi$  is a scaled number in the range of (0, 1) and the sum of  $\pi$  over all crops is set to equal 1. The effective water supply allocated to each crop is then calculated by

$$NIW^{i,t} = TNIW^t * \pi^{i,t} \quad (4.10)$$

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<sup>10</sup> Basin efficiency for the Volta basin used is 0.55 (Claudia Ringler & Rosegrant, 2005)





Thus, irrigation water is allocated based on profitability of the crop, sensitivity to water stress, and irrigation water demand (total demand minus effective rainfall) of the crop. Higher priority is given to the crops with higher profitability, which are more drought sensitive, and/or that require more irrigation water (Rosegrant, 2002).

#### 4.3.1 Effective Rainfall

Effective rainfall ( $XPE$ ) depends on total rainfall ( $PT$ ), previous soil moisture content ( $SM0$ ), maximum crop evapotranspiration ( $ETM$ ), and soil characteristics (hydraulic conductivity  $K$ , moisture content at field capacity  $Zs$ , and others).  $XPE$  is calculated by an SCS method (USDA, SCS 1967), given  $PT$ ,  $ETM$ , and effective soil water storage:

$$XPE^{cp,st} = f * (1.253PT^{st^{0.824}} - 2.935) * 10^{(0.001ETM^{cp,st})} \quad (4.11)$$

In which  $f$  is the correction factor that depends on the depth of irrigation, that is,

$f = 1.0$  if depth of irrigation per application,  $DI$ , is 75mm,

$f = 0.133 + 0.201 * \ln(Da)$  if  $DI < 75$ mm per application, and

$f = 0.946 + 0.00073 * Da$  if  $DI > 75$ mm per application.

Depth of irrigation application is 75mm to 100mm for irrigated land, and 150mm to 200mm for rain fed land. If the above results in  $XPE$  greater than  $ETm$  or  $PT$ ,  $XPE$  equals the minimum of  $ETm$  or  $PT$ . When  $PT < 12.5$ mm,  $XPE = PT$ . (Rosegrant, 2002)

Moreover, the effective rainfall for crop growth can be increased through rainfall harvesting technology. Rainfall harvesting is the



capture, diversion, and storage of rainwater for plant irrigation and other uses, and can be an effective water conservation tool, especially in arid and semi-arid regions. Water harvesting can provide farmers with improved water availability, increased soil fertility, and higher crop production in some local and regional ecosystems, and can also provide broader environmental benefits through reduced soil erosion. Advanced tillage practices can also increase the share of rainfall that goes to infiltration and evapotranspiration. Contour plowing, which is typically a soil-preserving technique, should also act to detain and infiltrate a higher share of the precipitation. Precision leveling can also lead to greater relative infiltration, and therefore a higher percentage of effective rainfall. A coefficient ( $\lambda$ ,  $\lambda > 1$ ) is used to reflect the addition of effective rainfall from rainfall harvesting at various levels, (Rosegrant, 2002).

$$XPE^{*cp, st} = \lambda * XPE^{cp, st} \quad (4.12)$$

#### 4.4 The Structure of the MATA Model

##### *The Procedure of the MATA Production Function Module*

The structure of the programming model categorizes sets, parameters and the scalars. The sets are the lists of agro-ecological regions, farming systems, activities, productions, types of lands, types of irrigation, types of off-farm labor, equipment, type of inputs for crops, and seasons. Parameters are defined as dependents on sets an example the land available is not the same for each farm type, meaning that land available is dependent on the sets that contain farm types (exags). Scalars are typically not dependent on



sets and have no dimension; an example of a scalar is interest rates for credits.

The data collection is done by aggregation into Zones for each farm type. Equations signifying various farm constraints and opportunities at the farm and regional level are also categorized and estimated. Initial value for core endogenous variables are also determined, included also are macroeconomic data and trends through the context module, scenarios are further displayed through a combination of different policy scenarios. All these are looped through a dynamic sequence where each year is solved in a chronological way, first initial parameters are updated to previous year results by the update file and results are stored (by storput file) and displayed in a suitable format for policy analysis.

#### **4.4.1 Data Acquisition**

This section of the study gives a brief knowledge of how the sampling was done and how data was acquired and, type of data collected and how typology was done. Ghana is located in West Africa and consists of ten different regions.

**Table 4.1: Ten administrative regions in Ghana and their Capital Towns**

REGION	CAPITAL TOWN
Ashanti	Kumasi
Brong Ahafo	Sunyani
Central	Cape Coast
Eastern	Koforidua
Greater Accra	Accra
Northern Region	Tamale
Upper East Region	Bolgatanga



Upper West	Wa
Volta	Ho
Western	Sekondi-Takoradi

Source: FAO, 1996.

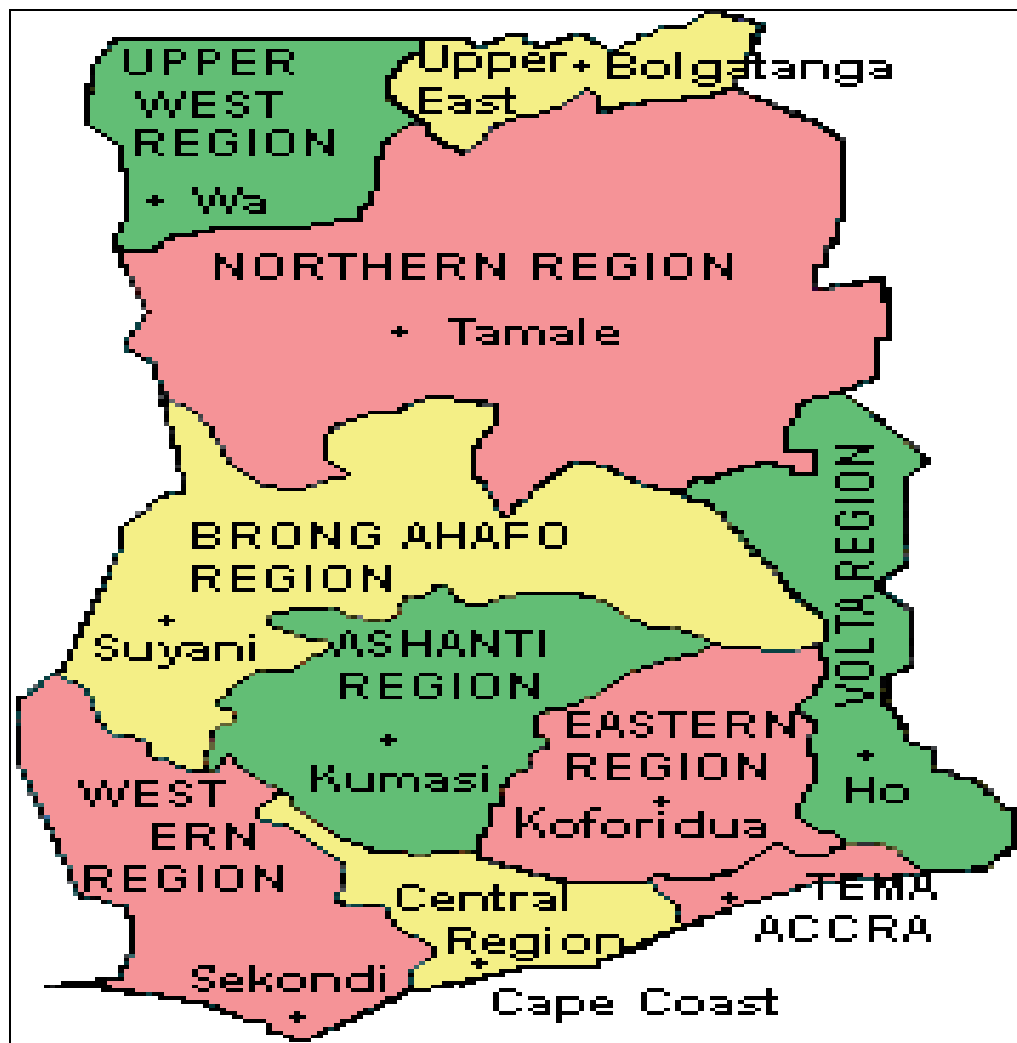
The populations in the various regions are as follows:

**Table 4.2: The population associated to the various regions and their growth rates**

REGION	POPULATION	GROWTH RATE	RURAL	RURAL
	('000)	(%)	('000)	(%)
<b>Ashanti</b>	3 613	3.4	1 685	46.6
<b>Brong Ahafo</b>	1 815	2.5	1 137	62.6
<b>Central</b>	1 594	2.1	995	62.5
<b>Eastern</b>	2 107	1.4	1 379	65.4
<b>Greater Accra</b>	2 906	4.4	359	12.3
<b>Northern</b>	1 821	2.8	1 337	73
<b>Upper East</b>	577	1.7	476	82.6
<b>Upper West</b>	921	1.1	776	84.3
<b>Volta</b>	1 635	1.9	1 194	73
<b>Western</b>	1 925	3.2	1 226	63.7
<b>Total/Average</b>	18 914	2.6	10 564	55.9

Source: FAO, 1996

**Figure 4.3: Map of Ghana**



Source: Ghana Web, 1999

#### **4.5 Agro Ecological Regions in Ghana**

As described earlier with the production module of the MATA model, the first step is to identify homogeneous zones from both agro-climatic and socio-economic view point. This we did by dividing the Volta basin area according to the agro ecological zones in the country Ghana. The country is divided into six agro-ecological zones on the basis of their climate. The natural vegetation is determined by the different climatic conditions and influenced by different soil types. These agro-ecological zones from north to south are: Sudan Savannah Zone, Guinea Savannah



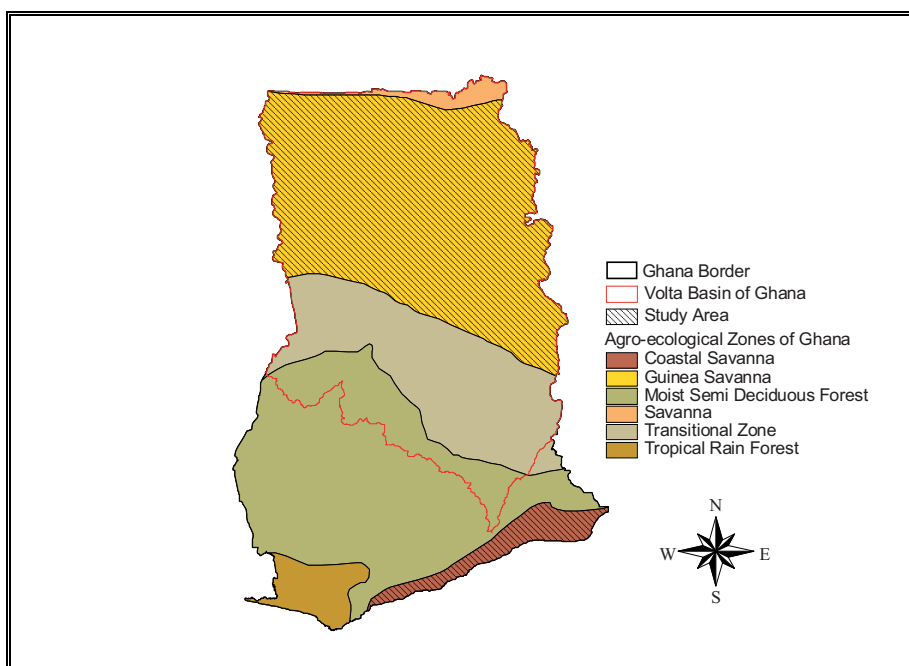
Zone, Transition Zone, Semi-deciduous Forest zone, Rain Forest Zone and the Coastal Savannah Zone.

**Table 4.3: Climates of the agro-ecological zones**

<b>Agro-ecological zone</b>	<b>Area (km<sup>2</sup>)</b>	<b>Mean annual rainfall (mm)</b>	<b>Range (mm)</b>	<b>Major rainy season</b>	<b>Minor rainy season</b>
<b>Rain Forest</b>	9 500	2 200	800-2800	March-July	Sept.-Nov.
<b>Deciduous Forest</b>	66 000	1 500	1200-1600	March-July	Sept.-Nov.
<b>Transitional Zone</b>	8 400	1 300	1100-1400	March-July	Sept.-Oct.
<b>Coastal Savannah</b>	4 500	800	600-1200	March-July	Sept.-Oct.
<b>Guinea Savannah</b>	147 900	1 000	800-1200	May-Sept.	
<b>Sudan Savannah</b>	2 200	1 000		May-Sept.	

Source: Adapted from data from the Meteorological Department, Legon, Accra, Ghana

**Figure 4.4: Agro-ecological Zones in Ghana**



Source: Arc GIS, 2010(using existing coordinates from, IWMI)

**Figure 4.5: The Volta Basin and Agro-ecological Zones in Ghana**

The map below shows the Volta basin superimposed on the agro-ecological zones

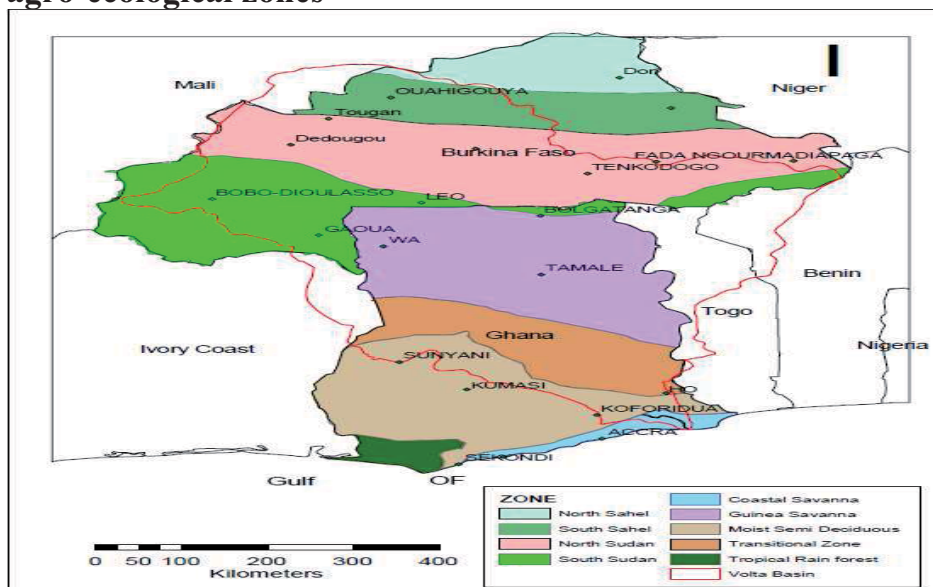


Figure 24: Map showing the agro-ecological zones of Ghana and Burkina Faso

Source: GLOWA Volta Project, 1999



#### 4.5.1 Zoning of Basin Area

For the reason of this study the agro-ecological zones that would be used for the comparative analysis is the guinea savannah (ZONE 5) and Moist Semi Deciduous Forest (ZONE 2). These two agro-ecological zones are chosen because the guinea savannah is the largest agro-ecological zone and is at the northern part of the country with only one rainy season, whilst the Semi Deciduous Forest is at the southern part of the country with two rainy seasons. As well as differences in their vegetation, population, climatic conditions and soil texture this would make it interesting to analyze and compare results of the two major agro-ecological zones.

**Table 4.4: Agro-ecological zones in Ghana**

Agro– ecological Zone	ZONES
Rain Forest	ZONE 1
Deciduous Forest	ZONE 2
Transitional Zone	ZONE 3
Coastal Savannah	ZONE 4
Guinea Savannah	ZONE 5
Sudan Savannah	ZONE 6

**Source: Own compilation, 2010**

#### 4.5.2 Farm Typology

As a result of the production function to be used in the MATA model, one needs to make sure that farm types are put together in a homogeneous group. Most farms households are heterogeneous but





in order to analyze the farming systems for policy analysis, it is required that the farms are made into homogeneous groups. It is very necessary to do a typology of the farming systems in order to determine the main characteristics of the production systems in each zone found out earlier (guinea savannah, zone 5) and the Moist Semi Deciduous Forest (ZONE 2). Theoretically, this is to find out farmers with the same production factors, the same practices and get similar productions. In order that this is done, a statistical approach that is the principal component analysis as well as qualitative analysis is used to derive the three farm types in each zone.

Farm typologies are necessary when one expects farm structure to alter the supply response and income distribution. The rational of these typologies were first formalized by Day 1963 and discussed in details in Hazel and Norton 1986. Within each basin area, farm types were distinguished using the principal component analysis factor loadings (PCA).

The common sampling framework was used for the study sampling, the typology was drawn from the principal component analysis done below and validated through intensive survey of a representative number of farmers in each group and in all regions within the Volta basin.

#### **4.5.3 Principal Component Analysis**

Principal component analysis (PCA) is determined by a mathematical technique that is able to make a number of correlated variables to transform into a smaller number of uncorrelated variables that is known as principal components. The first principal component accounts for as much of the variability in the data as



possible, and each succeeding component accounts for as much of the remaining variability as possible (Shaw, 2003).

**Table 4.5: Farm Structural Endowment Variables Used To Characterize Farming Systems**  
*(Descriptive statistics of the Variables used in the factor analysis)*

<b>Variables</b>	<b>Mean</b>
Household head number	209.40
Amount of equipment( cedes)	123733.36
Area of plot used in irrigation(ha)	3.12
Quantity of water used a day(m3)	1.72
Assets owned	1.80
Amount of cattle in value(cedes)	18280.00
Cost of labor(cedes)	1001783.20
Amount of poultry owned(cedes)	366903.20
Amount – Fertilizer & weeding (cedes)	563680.00
Number of livestock	8.08
cost of inputs used(cedes)	2.80
Amount of fees of irrigated land(cedes)	4686400.00
agricultural labor employed	3.32
Area (rain fed land)(ha)	3.32
Lack of credit facilities	1.50
Number of observations	512

**Source: Own calculation, 2009\*\*\*some missing data**

**Table 4.6: KMO and Bartlett's Test**

<b>KMO and Bartlett's Test</b>		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.602
Bartlett's Test of Sphericity	Approx. Chi-Square	197.619
	Df	91
	Sig.	.000

**Source: Own Calculation, 2009**

The Kaiser-Meyer-Olkin<sup>11</sup> (Table 4.6) measure and the Bartlett's test are highly significant and this means the sample is suitable for principal component analysis (Hair et al 1998). The rotated component matrix (Table 4.7) is the main outcome of the principal component showing the factor loadings of the classification variables.

**Table 4.7: Rotated Component Matrix**

<b>Rotated Component Matrix<sup>a</sup></b>					
	Component				
Variables	1	2	3	4	5
Household number	-.050	.897	-.132	.020	.187
Amount of equipment	-.157	.856	.224	-.021	-.155
Area of plot used in irrigation	.877	-.155	-.017	.236	-.136
Quantity of water used a day	.207	-.499	.486	-.099	-.002

<sup>11</sup> Kaiser-Meyer-Olkin (KMO) is a statistic that measures the adequacy of a variable to be included in factor analysis based on correlation and partial correlation. There is a KMO statistic for each individual variable, and their sum is the KMO overall statistic. KMO varies from 0 to 1.0 and KMO overall should be 0.60 or higher to proceed with factor analysis. If it is not so, the lowest individual KMO statistics values will be adopted, until KMO indicates some improvement.



Assets owned	-.435	.007	.307	.256	.236
Amount of cattle in value	-.026	.007	.066	-.150	-.920
Cost of labor	.925	-.103	.301	-.002	.000
Amount of poultry owned	.880	-.062	-.033	.272	.035
Amount – Fertilizer & weeding	.896	-.123	.151	-.158	.072
Number of livestock	-.408	.162	-.153	-.455	.415
cost of inputs	.107	.107	-.132	.860	.194
Amount of fees of irrigated land	.749	-.071	.133	.522	-.077
Agricultural labor employed	.027	.111	.809	-.188	.035
Area in rain fed land	-.193	.092	-.656	-.247	.289
Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.					

**Source: Own Calculation, 2009**

**Table 4.8: Reported Eigen Values From Data Set**

Component	Initial Eigen values			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	5.545	36.966	36.966	5.545	36.966	36.966
2	2.839	18.929	55.895	2.839	18.929	55.895
3	2.344	15.626	71.521	2.344	15.626	71.521
4	1.362	9.078	80.599	1.362	9.078	80.599
5	1.117	7.446	88.046	1.117	7.446	88.046
<b>TOTAL</b>	13.3			13.3		

**Source: Own Calculations**

Table 4.8 shows the factor loadings of each variable on each of the factors. The sum of squared factor loadings Eigen values indicate the relative importance of each factor in accounting for the variance associated with the set of variables being analyzed. The first factor with the value of 5.545 is more important than the second with the value of 2.839 in explaining the variation of the fifteen variables. The total of the Eigen values which is 13.3 represents the total amount of variance extracted by the five factors. The percentage is the total variance explained by the five variables which is about 88 percent. Based on the results of the PCA, Cluster analysis was further used to classify these variables into three major clusters (k-means) such as large scale farm types, Medium scale farm types and Small scale farm types. This classification is in terms of the area of the farm, assets of the farmers, the number of labor employed, and number of livestock of the farm.

## **4.6 Farm Types**

### ***Cluster Analysis (CA)***

Clustering is the classification of objects into groups (called clusters) so that objects from the same cluster are more similar to each other than objects from different clusters. Often similarity is



according to a distance measure. Clustering is a common technique for statistical data analysis. Each cluster thus describes, in terms of the data collected, the class to which its members belong; and this description may be abstracted through use from the particular to the general class or type.

Large scale farm types are farms types with a much higher farm area, whose assets are the most in terms of value, which employed a higher number of labor and has the most livestock compared to the medium and small scale farm types.

Medium scale farm types as compared to the small scale had more farm area than the small scale but lesser than the large scale in terms also of assets, labor employed and livestock.

Small scale farm types have the least of them all in terms of farm area, labor employment, and number of livestock owned. It was realized from the data analysis that these farmers are more landless farmers, meaning farmers that rent all their lands. In a nutshell, we have two major zones and three different farm types.

#### **4.6.1 Data Sources**

The necessary data for the development of the model were obtained from several data sources. The crop yields in the region from 2000 to 2007, and input prices from 2000 to 2007 were obtained from Ministry of Food and Agriculture (MOFA). Other data sources such as crop allocations were obtained from the Glowa Volta Project CSF II<sup>12</sup>. The data set was collected in 2005.

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<sup>12</sup> The full document on “GLOWA-Volta Common Sampling Frame Selection of Survey Sites” can be found in the document by Thomas Berger, Felix Asante and Isaac Osei-Akoto, 2002.



This study used the same data set from the communities and villages for its modeling in the MATA model, as its enumeration areas encompassed the Volta basin area. To ensure that the data was not outdated or irrelevant, a focus group discussion was carried out in almost all the above regions to make sure that the data was valid enough to be used and that the data in the various enumeration areas were relevant enough to be used in 2007 economic modeling building and to know that it would give an almost close estimation to the real world scenario. The focus group discussion was also done to ascertain that most households are still there, and that agricultural activities have not changed in these areas as much and that the data in the common sampling two could still be relevant for use without fear of it being outmoded. As other data requirements were also needed for the modeling that were not included in the data set, the focus group discussion came in handy to fill in these data gaps such as labor time survey and crop budget of the various major crops that were under consideration.

**Table 4.9: Enumeration Areas for the GLOWA-Volta Household Survey, 2005**

Village/Community	Region	District
Ejura	Ashanti	Sekyere-Odumasi
Abrakaso	Ashanti	Afigya Sekyere
Akutuase	Ashanti	Asante-Akim North
Ayeredo	Brong Ahafo	Nkoranza
Atebubu	Brong Ahafo	Atebubu
Kusawgu	Northern	Central Gonja
Bagabaga	Northern	Tamale
Gbangbanpon	Northern	Saboba
Biu	Upper East	Kassena Nankana



Dusabligo	Upper East	Bolgatanga
Gowrie	Upper East	Bongo
Benguri	Upper East	Bawku East
Kpalwega	Upper East	Bawku East
Mirigu	Upper East	Kassena Nankana
Doba	Upper East	Kassena Nankana
Tanga	Upper East	Bawku West
Pwalugu	Upper East	Bolgatanga
Binaba	Upper East	Bawku West
Kandiga	Upper East	Kassena Nankana
Kpando Torkor	Volta	Kpando

**Source: GLOWA Volta project report, 2005**

\*\* In all a total of 183 enumeration areas were identified and 530 households were interviewed. In Table 4.9 are the final enumeration areas that were used for the data collection in the GLOWA-Volta project in the common sampling II as well as the focus group discussion survey in 2007 for purposes of building the MATA model. In all, for the focus group, a total of more than thirty communities were visited with more than 450 households participating in the overall focus group discussions. The focus group discussion was done with a prepared questionnaire of about 32 questions that covered all the areas included in the GLOWA Volta questionnaire so it could be very fair to use it in updating the data. Ghana Living Standard Survey 4(GLSS4) data were also employed in the modeling process.

### ***Institutional Interview Survey***

A number of institutions heads were interviewed in this study. Institutions that were sampled were done on the basis of water related, irrigation related and institution that were associated with





the agricultural sector or the farming community. Table 4.10 presents institutions that were interviewed. Data collected from interviews were discussed and used to model in this study. Secondary data were collected from these institutions as well as some literatures.

**Table 4.10: Institutions for Secondary Data Collections**

<b>INSTITUTIONS</b>	<b>DATA DESCRIPTION</b>
Community Water and Sanitation Agency (CWSA)	Data on community water tariffs and water usage conditions and water access.
Council for Scientific and Industrial Research (CSIR)	Crop budget and crop water requirements
Ghana project areas. Irrigation Development Authority (GIDA)	Different irrigation projects in Ghana and their locations as well as investment and budget for irrigation and development projects in the various regions of the country)
Public Utilities and Regulatory Commission (PURC)	Prices of water resources over the period and their form of regulations
Volta River Authority (VRA)	Hydropower consumption of water and irrigation water produced by the authority and crops that were irrigated around the area
Water Resources	Ghana water policies over the years and what are being done to improve water use



Commission (WRC)	sustainability.
Food and Agricultural Sector Development Strategy (FASDEP)	Production and yields of agricultural products and agricultural sector policies
Environmental Protection Agency (EPA)	Agricultural and its effect on water pollution
Ministry of Finance and Economic Planning (MFEP)	Budget for agricultural activities and what the government is doing to increasing irrigation in terms of budget allocation
Ministry of Food and Agriculture (MOFA)	Farm input ,production data and quantity and value of production, average yields at the various regions and district levels
International Water Management Institute (IWMI)	Water management strategies and socio economic and agronomic information at the district, regional and national level as well as information the Volta basin of Ghana
Bank of Ghana	Data on deposit rate, interest rate, savings rate, amount of credit allowed to agricultural workers, and banks that give credit to farmers.
FAO	Data on human nutrition and international agricultural policies

**Source: Own Compilation, 2009**

#### 4.6.2 Data Description

##### *Data Requirement and Description for the MATA Model*

Two types of data are needed to build the MATA production module: data that are accurate at the agro-ecological zone level such as yield's, wages, prices and data that are specific to the farming systems determined by the typology such as land, labor and capital etc(Gérard,1998).

The first step is to determine the number of cropping seasons, for the two zones that have been selected to be used for the study, the first Zone which is the guinea savannah ecological zone, has two major seasons, as it has a uni-modal season, so for this zone we have one rainy season and then a dry season. The Semi Deciduous Forest which is at the southern part of the country has a bi-modal season, having two major rainy seasons and then a dry season so in this zone we identify three different seasons as shown in the Table 4.11.

The second step is to make a list of the possible crops in the study area chosen even if some farmers are not producing them. Below we have identified crops grown in these two major zones and clearly defined which crops we would be using in the model.

**Table 4.11: Crops in Various Zones, Type Of Land Occupied and Seasons**

Guinea savannah	Season 1	Season2	Semi Deciduous Forest	Season 1	Season 2	Season3
RICE	X	X	RICE	X	X	X
MAIZE	X	X	MAIZE	X	X	X
SORGHUM	X		CASSAVA	X	X	
YAM	X		ONIONS	X	X	X
MILLET	X		COCOA	X		
GROUNDNUT	X		TOMATOES	X	X	X
TOMATOES	X	X				
ONIONS	X	X				

**Source: Own Compilation, 2009**



But for purposes of this study, crops that are common to both regions and are cultivated in all seasons are considered and these are rice, maize, and vegetables.

## **4.7 Data Requirement**

### **4.7.1 Data at the Agro-Ecological Zone**

**Yields:** Average yield is measured in tons per hectare. Average yield per hectare is estimated for every one type of land, for every type of irrigation, for every single type of equipment and for each season. If a crop is grown with two different techniques, such as rice with or without transplanting, it is considered as two activities. If two crops are cultivated together in the same field (multi-cropping), it is considered as one activity (Gérard et al, 1998).

**Prices:** crop prices are identified from the focus group discussions and CSF II data set and are basically averages. Also, mean and deviation are considered.

**Variable Cost:** Data were collected from about 530 farms and also from all irrigation farmers in the region. Inputs can be more or less disaggregated if the need arises. Inputs are taken according to the crop need per season. From planting till harvesting, inputs are mainly separated between pesticides, fertilizers, seeds, transport, labor (manual, animal, machinery), and water (simulated price of water to be parameterized from 0 to 20 cedi/m<sup>3</sup>) and others. With some inputs in cedi/kg, while others are in kg/ha.

**Labor Requirements:** Field operations are divided broadly into four major categories: soil preparation, sowing, weeding and



harvesting, Labor requirement for soil preparation depends mainly on the technological level (hoe, animal traction, tractor power) and the type of crop, Labor requirements are in terms of human labor that is manual labor, human and animal labor and human and mechanical labor and are in man-day per hectare. Also price for hired labor for each activity is in cedi/day. The model also considers in terms of labor, Opportunities of off-farm labor, types of off-farm labor, limits. The price of off-farm labor is wages in currency/day or hour.

**Land:** The existence of land market is also considered in the model, whilst the purchase, sale and hire of land in cedi/ha was also taken into consideration.

**Credit:** the data considered is its availability, interest rates (short and long term), and collaterals.

#### **4.7.2 Data Collected at the Farm-Level**

**Land:** for each type of farm type, land owned, land rented in land rented out. Type of land technically irrigated or rain fed is specified in the model.

**Labor:** family size, number of active persons, number of days worked by season is also considered in the model.

**Machine:** number of machines, number of days of availability per season is accounted for in the model.

Cash at the beginning of the period: seldom available in surveys, this data is evaluated by the amount of money needed to manage the activities of the first season. Data on this parameter is also



obtained through focus group discussion with the farmers as well as secondary data and survey data.

### **Consumption:**

There are three different types of consumption used in this model we have:

- **Minimal Consumption per Head:** it is the amount of money necessary for the survival of the family (food, health care and school).
- **Consumption Propensity:** it is the percentage of the income that will be used by the family.
- **Self-Consumption:** type of product, quantities, differences for these products between selling and buying markets.

These data needs were collected both from the GLOWA Volta surveys, and also mainly from secondary data sources from the Ministry of Food and Agriculture and GLSS 4.

**Water Needs in M<sup>3</sup> per Hectare:** The data for the water demand in m<sup>3</sup> per hectare for different cropping activity and different ecological zones come from agronomist's estimates (using CROPWAT).

### **4.8 CROPWAT (Water Requirement)**

The data for the water requirement in m<sup>3</sup> per hectare of the different crops come from agronomist estimates using the crop water requirement and the software CROPWAT<sup>13</sup> are carried from the FAO to calculate the crop water requirement and irrigation water requirement for each crop in the study.

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<sup>13</sup> Procedures for calculation of the crop water requirements and irrigation requirements are based on methodologies presented in FAO Irrigation and Drainage Papers No. 24 "Crop water requirements" and No. 33 "Yield response to water".



## 5.0 Empirical Overview of the MATA Model

### 5.1 Basic Equations for Farming System Model

This chapter aims at describing the mathematical programming model used in the analysis. We start by discussing the objective function of the model, followed by a mathematical description of the model equations. The chapter ends with a section on solving, calibrating, and validating the model.

#### 5.1.1 Objective Function of the MATA Model

Maximization of the expected utility of wealth is the objective function of the MATA model. The wealth (WH) is calculated in the equation wealth established by the summing all assets owned at the end of the period, multiplied by their prices. Some penalties are included to consider transaction costs. Here wealth is used as a proxy for the total value of the farm, because the model is dynamic but the optimization is static. In order to take into account the risk associated with agricultural activities, is to assume that utility increases with expected wealth and decreases with expected risk. So cropping activities are associated with risk on crops ( $XZIGC_{act,s}$ ), land with risk on land ( $XZIGL$ ), off farm activities with risk on returns ( $XZIGW$ ) and cash with financial risk ( $ZIGCA$ ). The level of utility ( $FONC^{14}$ ) is determined according with Von Neumann - Morgenstern representation of decision taking under risky<sup>15</sup> situation.. Therefore, for the objective function we maximize:

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<sup>14</sup> Where (act) is cropping activity, equipment used (equi) and season (s),

<sup>15</sup> The risk aversion parameter is calculated as  $A = 1/coef*WH$



$$\text{FONC} = \text{WH} - 1/2 (\sum_{\text{act},s} \text{XZIGC}_{\text{act},s} * \text{XAL}_{\text{exags,eqi,act}_{\text{act},s}} * \text{XMEY}_{\text{act},s})^2 + (\text{XLAOWN} * \text{XLPR} * \text{XZIGL})^2 + (\sum_s \text{NAGWA}_{\text{sure}',s} * \text{XLAS}_s * \text{XZIGW}_{\text{sure}',s})^2 + (\sum_s \text{NAGWA}_{\text{unsure}',s} * \text{XLAOFF}_s * \text{XZIGW}_{\text{unsure}',s})^2 + (\text{XCUMCASH} * \text{XZIGCA})^2$$

Where:

WH	Wealth of the farmer
XAL	Land allocation
XMEY	Level of yield (function)
XLMAX	Land availability
XLAOWN	Land owned
XLPR	Land price sale
NAGWA <sub>sure</sub>	Non-agricultural wage sure
XLAS	Labor used in agriculture
NAGWA <sub>unsure</sub>	Non-agricultural wage unsure
XLAOFF	The amount of labor in off-farm activity
XCUMCASH	Cash to be transferred to the next year

## 5.2 The Constraints in the Model

### *Land use*

Land allocation is constrained by the availability (XLmax) representing the land under control for the given farm. There is also an opportunity of buying and renting and selling of land that is captured in the equation. Land rented in and out (XLRIN and XLROUT), selling (XLS) or buying (XLR) land. These activities are defined by seasons.

$$\sum_{\text{act}} \text{XAL}_{\text{exags,eqi},s} + \text{XLROUT}_{\text{exags},s} + \text{XLS}_{\text{exags},s} \leq \text{XLAOWN}_{\text{exags},s} + \text{XLRIN}_{\text{exags},s} + \text{XLP}_{\text{exags},s} \quad (4.13)$$





If only the equation (2a) constrains the land allocation, nothing specifies that land rented in cannot be sold. To avoid this possibility which would lead to unbounded solutions, a second equation has to be specified: land sold (XLS) and rented out must be owned (XLAOWN and XLP).

$$XLS_{exags,s} + XLR_{OUT_{exags,s}} \leq XLAOWN_{exags,s} + XLP_{exags,s} \quad (4.14)$$

Because purchase and selling of land is possible in each season, LAOWN has to be updated each season.

$$XLAOWN_{exags,s} = (nfa_{exags} * XLMAX_{exags}) + XLAOWN_{exags,s-1} + XLP_{exags,s-1} - XLS_{exags,s-1} \quad (4.15)$$

Land owned at the beginning of the next period has to be updated in order to become a starting parameter for the next period. Equation (2d) calculates the land owned at the end of the period considered for optimization.

$$XLAOFIN_{exags} = XLAOWN_{exags,"s3"} - XLS_{exags,"s3"} + XLP_{exags,"s3"} \quad (4.16)$$

Usually, because of the spatial characteristics of agricultural activity and of transportation cost, exchange of land has to be balanced at the village level. Nevertheless, this affirmation should be checked and qualitative analysis should determine which logical operation has to be used (equal, larger than or less than).

$$\sum_{exags} XLR_{IN_{exags,s}} = \sum_{exags} XLR_{OUT_{exags,s}} \quad (4.17)$$



$$\sum_{exags} XLP_{exags,s} = \sum_{exags} XLS_{exags,s} \quad (4.18)$$

### ***Labor Use by Crop***

Cropping activity (XAL) requires labor (XLA) determined by technical coefficient (Xluse).

$$XLA_{act,s} = \sum_{equi} XLAND_{act,equi} * XLUSE_{act,equi} \quad (4.19)$$

### ***Labor balance***

For each season (s), the use of labor in farm (LA) or off-farm activities, for more or less risky activity (XLAS and XLAOFF) is constrained by availability of active persons (activ).

$$\sum_{act} XLA_{act,s} + XLAS + XLAOFF \leq activ_s \quad (4.20)$$

Cropping activities require labor (XLA) determined by the technical coefficient (XLUSE). Equation XLABAL calculates the family labor which should be devoted to cropping activities and takes into account the fact that labor can be hired and that it is possible for the family labor to work on other farms. XLTOT expresses the labor constraint at the house level. The workforce (XLAMAX) is allocated between agricultural activities (XLA) and off- farm activities. Two kinds of farm activities are considered: XLAS (not risky) and XLAOFF (risky). The XLABOUT equation expresses the balance at the village level between labors rented in and out. Off-farm activities are constrained by opportunities at the village level (XTOFF and XOTOLA).



### ***Water Balance***

Describes the constraint related to the availability of irrigation water so that total water use in a season must not exceed water availability in that season.

$$\sum_{act} XAL_{reg,exags,tti,equi,s} * XWR_{reg,exags,tti,equi,s} \leq TNIW_{reg,tti,s} \quad (4.21)$$

$$\begin{aligned} \sum_{act} XIRWD_{reg,exags,tti,season} &\leq XWATRA_{reg,exags,tti,s-1} - XWATRA_{reg,exags,tti,s-1} + XWAINI_{reg,tti,s} \\ &+ \sum_{exags,act} XAL_{reg,exags,equi,s} * PE_{reg,s} \end{aligned} \quad (4.22)$$

The water requirement by activity (XWR=XNCWD& XIRWD) has to be met by surface water (XSWDP), or dam (TNIW) or rain (PE) water. Water available from the dam at the beginning of the optimization period (XWAINI) can be transferred through the seasons (XWATRA). The calculations of these variables have been described in the previous section.

### 5.3 Yield Water Response

Actual yield is a function of expected mean yield, and a projected non-price exogenous trend factor. The trend factor reflects productivity growth driven by technology improvements, including crop management research, conventional plant breeding, wide-crossing and hybridization breeding, and biotechnology and transgenic breeding. Other sources of growth considered include private sector agricultural research and development, agricultural extension and education, markets, infrastructure, irrigation, and water. Annual production of a commodity  $i$  in the country  $n$  is then estimated as the product of its area and yield.

$$YC_{ti} = \beta_{ti} * (C_{fi} * X_n) * (1 + gCY_{ti}) - \Delta YC(WAT_{ti}) \quad (4.23)$$

$YC_{ti}$  = Crop Yield

$i, j$  = commodity indices specific for crops

$t$  = time index

$gCY_{ti}$  = growth rate of crop yield

$\beta_{ti}$  = crop yield intercept

$C_{fi}$  = random coefficient of yield

$X_n$  = expected yield

$\Delta YC$  = crop yield reduction due to water stress

$WAT_{ti}$  = water variable



### 5.3.1 Incorporation of Water in Crop Yield Function

Reduction of crop yield  $\Delta YC$  is calculated as:

$$\Delta YC = YC^i * k_y^j * (1 - ETA^i / ETM^i) * \left[ \frac{\min_{t \in growthstages} \left( (1 - ETA_{nt}^{it} / ETM_{nt}^{it}) \right)}{(1 - ETA^i / ETM^i)} \right]^\beta \quad (4.24)$$

In which  $\beta$  is the coefficient to characterize the penalty item which should be estimated based on local water application in crop growth stages and crop yield. Here crop yield reduction is calculated based on seasonal water availability (that is, seasonal ETA), but is “penalized” if water availability in some crop growth stages (months) is substantially below the seasonal level. All other items have been previously defined.

Where:

$ETA$  = Actual crop evapotranspiration in the crop growth season

$ETM$  = Potential crop evapotranspiration in the crop growth season

$k_y$  = Crop response coefficient to water stress (determined by random coefficient)

### 5.4 Calibration and Validation of the Model Results

A model is as good as the results it produces. Two measures are used to access how good a model is. The first measure is the degree to which the model can accurately describe a relevant part of reality. This measure, commonly called robustness, can be applied to different time scales. A model may be robust in the short term if the model reproduces reality when current values of the



exogenous parameters are utilized. A model is considered robust in the long run if the trend in results coincides with the trend in historical evidence (Gideon Kruseman, 2000). The second measure is the Validation of model results.

Several methods exist to calibrate the model parameters so that the reality is reproduced as much as possible. In some calibration models, additional constraints are utilized for instance technology, price, crop rotation, and policy constraint are then introduced to force the model to reproduce as closely as possibly the observed situation (McCarl, 1982). In others such as the Positive Mathematical Programming (PMP), Nonlinear terms or equations are added in the objective function so as to force the model to exactly reproduce the observed situation (Richard Howitt, 1995).

With reference to the previously discussed, that the objective function of our model is maximizing expected utility of wealth. Except for data on risk aversion coefficients, all data required to calculate the objective function are available in the model, we assume that utility function of farmers are characterized by constant absolute risk aversion. Hence, these coefficients are assumed to reflect farmers' attitudes towards risk, the higher is the coefficient the more risk averse the farmer is. Several ways of estimating risk aversion coefficients have been so far proposed in literature. In this study, we adopt the method proposed by McCarl (2003) and Hazel & Norton (1986), since it is consistent with basic conjecture of the model and it is easy to perform. It is based on estimating the risk aversion coefficient such that the difference between the observed behavior and the optimal solution is minimized. This requires solving the model for each farm type for several values of risk aversion coefficient, and then we decide on



the value that gives the cropping activity closest to the observed one. According to the expected utility theory, the value of an absolute risk aversion coefficient increases as risk aversion increases. In addition, the theory predicts that risk aversion decreases as wealth increases. In this study, the risk aversion coefficient is used as the calibration parameter in the model. In the study, the parameter of the constant relative Risk Aversion Coefficient (Alpha) is adjusted to calibrate the model results to the observed situation.

Since the crop allocation at the farm level is one of the most stable parameter in the model, it is used for the calibration and validation of the model result. Different levels of the risk aversion coefficient were experimented in order to find the best fitting outcome to the activity levels observed in the crop allocation. The risk aversion coefficients tested were 10, 20, 11, and 22. The one that gives the cropping activity closest to the observed one is 10. As the model is a dynamic model, the trends in the results of the simulation and observed are calculated.

**Table 5.1: Calibration Results for a dynamic model**

<b>CROPS</b>	<b>R-SQUARED(R<sup>2</sup>)</b>
<b><u>EXP1(LARGE-SCALE FARMS)</u></b> RICE	0.9319
MAIZE	0.9769
VEGETABLE	0.9394
<b><u>EXP2(MEDIUM-SCALE FARMS)</u></b>	0.9709



RICE	
MAIZE	0.8715
VEGETABLES	0.9127
<b><u>EXP3(SMALL-SCALE FARMS)</u></b> RICE	0.9419
MAIZE	0.9487
VEGETABLES	0.8851

**Source: Own estimation and Compilation**

From the Table 5.1, the  $R^2$  is greater than 50%, meaning the simulations of the current situation and the observed situations are small enough to allow the simulation of other policy scenarios.

#### **5.4.1 Model Validation Robustness**

Model validation or test of robustness refers to evaluating the ability of a model to represent the reality or observed situation. This involves comparison of model results with empirical evidences such as actual crop land allocation, incomes and consumption. If model results are closer to the reality, then the model is considered to be a good model and can be used as a base for subsequent analysis.

To assess the long run robustness, the following statistically robust test procedure, proposed by Kleijnen and Sargent<sup>16</sup> (1997) and applied by Kruseman (2000) and Borner (2005), is followed.

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<sup>16</sup> If the model is robust in the long run the trends indicated by the model should coincide with trends in empirical evidence. This is a second type of model validation for which the same data set as before can be used. The only difference is the type of modelling applied.





In this type of Validation method of model results, model outcomes and empirical evidence are often regressed on one another. Using a regression technique which can be formalized as:

$$Y^e = \alpha + \beta Y^m + \mu \quad (4.25)$$

Where  $Y^e$  is empirical evidence, and  $Y^m$  are model results, the assumption are that  $\alpha$  is zero and  $\beta$  is one, when the model is valid. But there were some criticisms to this form of validation so in 1998, Kleijnen proposed a different test that is statistically robust:

$$Y^m - Y^e = \alpha + \beta(Y^m - Y^e) + \mu \quad (4.26)$$

Where the null hypothesis is  $\alpha=0$  and  $\beta=0$ , there is no significance difference, (and the alternative hypothesis H1: there is significance difference). This can be tested with the standard F-test. For the model Validation of the model, the farm survey data collected are used. Land allocation is used for all cropping activities.

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Short-run robustness validates the model by comparing model outcomes for each set of input parameters. The long-run robustness looks at the whole period. This type of validation is especially important for dynamic models. The farm household model presented here is static, yet determining its long-run robustness is useful, because the short-run validation runs into real world variability. If the object of the model is not primarily aimed at reproducing the empirical evidence, but geared more towards determining rhythm and directions of change, testing long-run robustness of the static model is useful. This implies that the model is run recursively with changes in input parameters as a result of model outcomes explicitly used. Unfortunately no consistent long-term data were available



**Table 5.2: Calibration, the Regression Parameters**

	Coefficient	Standard Error	T stats	F test
$\alpha$	0.057	0.199	-0.853	1.488
$\beta$	0.419	0.049	1.220	

**Source: Own Compilation**

Table 5.2 shows that the null hypothesis is not rejected, meaning there is no statistical difference (at 95% confidence interval) between the observed and empirical observations therefore, the model results are assumed to correspond to the observed situation. Hence, at the typical farm type level the simulation model is robust.

### **5.5 The Model Limitations**

The model has several limitations. In the model, the various zones are considered jointly as well as the objectives of all producing farmers, but in reality, there are differences in the objective of individual farmers in each ecological zone.

As a result of data unavailability, the model is not able to incorporate the use of groundwater as another means of water supply into the model.

Finally, the model required so much data that not all data were gotten from primary sources and as a result, most of the important calculations were derived from a secondary data sources instead of primary calculation such as some water supply data.



## **6.0 Analysis of Empirical Model Results and Interpretation**

### **6.1 Introduction**

This chapter presents results that have been attained from the MATA Model computed. The results to be discussed include those obtained from the baseline and policy simulations. The discussions are concentrated on impacts of various policy scenarios relating to economic, social, and environmental variables of the agricultural sector.

In order to analyze the economic impact of the policies that are simulated, changes in variables associated with agricultural income, and the total wealth of the farmer are the main indicators considered. As discussed earlier, agriculture is the main source of livelihood for the rural poor in Ghana. So any alteration in policy will have a great impact in the social structure of these rural people, hence the need to analyze the social impact of simulated policies. For environmental impact, the analysis relates to water demand (water consumption).

The policies and their expected impacts are captured in the Table 6.1 which describes the policy and its subsequent effect on the expected variables in the model.



**Table 6.1: Brief Description of Policy Scenarios**

No	Scenario name	Scenario description
1	Baseline Scenario	This scenario examines the expected utility of wealth, income, cropping activity and water demand under the normal farming conditions. The base run replicates the actual situation of the Volta Basin.
2	Water Pricing	In this scenario, changes in water demand and income of farmers are explored under a higher level of water pricing.
3	Water Scarcity	This scenario is important to the case where farmers experience drought, water supply is scarce, and the expected amount of water in the area is lower than in the baseline scenario. Its consequent impact on income is explored.
4	Changes in Input Prices	This scenario gives insight into input market liberalization, when subsidies are taken off farming inputs and their subsequent impacts on income and cropping activities are explored.
5	Credit Availability	This is a scenario where credit is made available to farmers and we explore its impact on income and wealth of the farmers as well as cropping activities of the farmers.
6	Price Expectation	This scenario indicates farmers' decisions, when they expect prices of a particular crop to increase. This scenario explores its impact on production of that particular crop and income.
7	Land Reform	In this scenario, an increase in land availability without any transaction cost is



		explored and its impact on income and cropping activity would be assessed.
8	Change in Technology	This scenario investigates the impact of an introduction of a new irrigation and water saving technology and its impact on income yield and water efficiency.

**Source: Own Compilation, 2010**

## **6.2 Baseline Model Scenario**

The baseline scenario serves as a benchmark for all subsequent policy scenarios. At the baseline, farmers are growing crops that are profitable to them, there is an ineffective agricultural production practice that encourages soil deterioration; there is only traditional crops without new type of crop diversities; inefficient resource use at the farm level, where there are no access to credit from the banks, fluctuating and low prices for farmers output, and high prices for agricultural inputs. At the base year, the average household has ownership of more than one plot of land, the compound garden and the main plots with distance to the farms between 2- 8km and more.

Farm lands are usually bought or rented from the Tidana's, chiefs and family heads who are custodian of the land. In recent times, cash is given for land and occasionally hire charge in terms of cola, fowl, and a proportion of yields are given in kind as rent. Land is also sold and bought. Family labor is not the only source of farm labor as labor is also hired, although family labor is the principal labor supply. Storage of farm produce are usually done on the farms in farm barn houses.



At the base year, farmers do not pay any market price for water; meaning at the base year, water price is equivalent to zero. But farmers do pay a nominal fee for irrigation water; this fee is mainly for the cost of distribution, maintenance of infrastructure, control and administration among others. In Ghana, apart from dams that are owned by water users association, the bigger irrigation dams are managed by a company known as the Irrigation Company of Upper Region Ltd. (ICOUR). ICOUR is an institution or company that government owned, with the goal to enable growth in production in the agricultural sector of Ghana and is in charge of the maintenance and management of the large and commercial irrigation schemes. It is mainly in the three northern regions and is in charge of the administration of the biggest dams and irrigation in the area.

An amount of money is charged for a hectare of land making sure that all year round water is supplied for that land; the cost is also given on basis of the type of crop grown. As a matter of fact, the farmers tend to believe that they have control over the supply of available water, because they believe that for paying for the piece of irrigated land they are automatically paying for the cost of water, but that is not true as the water being consumed is out rightly free as water is said to be a public good in Ghana. But the money being paid is for maintenance of the dams and distribution cost of water from the irrigation facilities. But in recent times, as a result of water resource scarcity world-wide due to climate change, water is now being re-defined as an economic resource for rural development.

Also reflected in the baseline scenario, farmers are currently cultivating crops with either flood and furrow irrigation while



alternative irrigation schemes such as drip and spring irrigation are done on experimental basis. The model results on five vital variables obtained from the baseline data are aggregated over 480 farms.

### **6.3 Policy Simulations and Their Impact on Water Demand and Farm Performance**

Since the agricultural sector and water resources are very important to the development and growth of the economy of Ghana, it is necessary to assess the consequences of some policies on the sector.

The selected sets of agricultural policies consist of the most discussed policies that might be necessary for implementation in the near future. The diverse scenarios are formulated when making an allowance for the difficulties under review in the study. As discussed earlier in this chapter, the first scenario would simulate water pricing as a mechanism for reducing water demand in the area. The second scenario would look at the availability of water; the third scenario would concentrate on changes in input prices and their impact. Price expectation as a scenario would also be considered, land reform would also be simulated, and this would be followed by change in technology scenario. Graphs and tables are used for most of the analyses as it is a dynamic model.

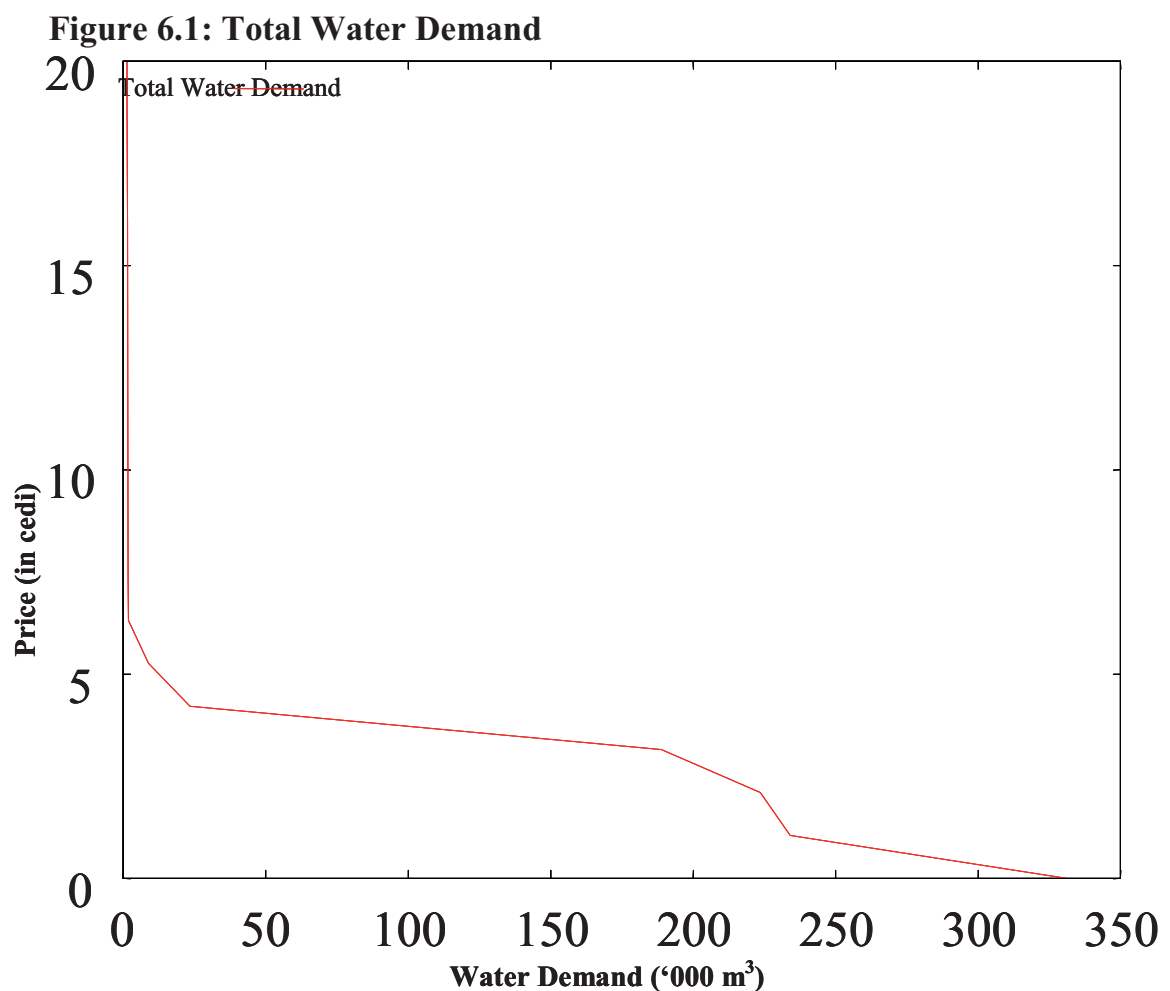
### **6.4 Water Pricing Scenario**

The introduction of water pricing has proven to be an effective economic instrument for improving water use efficiency worldwide and reducing the wastage of water by farmers (Perry, 2001 & Gomez-Limon, 2000). A price for water is not only important for creating water saving incentives, but also for



providing means of improved financial support for organizations involved in water management. This also helps in the maintenance of structures that have been built for irrigation over the years.

For the water pricing scenario, we optimized the system by maximizing expected utility of wealth. By varying the price of water from its present value of zero to 20 cedis per m<sup>3</sup>, the result is presented in Figure 6.1.



**Source: Own Compilation**

Figure 6.1 presents a typical demand curve which reveals how farmers adapt to increases in the cost of some production inputs like water. This water demand curve can be described in three





segments. In the first segment, the demand for water is relatively inelastic; this is so because at lower price levels (0-2 cedi/m<sup>3</sup>) the farmer does not make any much change to respond to the increase in price of water, thus he keep up his existing crop distribution and demand for water. At this stage, we say the percentage change in quantity demanded is less than percentage change in price.

In the second segment, water demand is elastic at relatively moderate price levels (2-5 cedi /m<sup>3</sup>), in this segment, farmers respond to price by reducing the demand for water; here crop plans are changed by growing crops that do not consume more water than crops that consume more water. At this stage, farmers begin to reduce the quantity demanded for water.

Water demand becomes perfectly inelastic at higher price levels (>5 cedi/m<sup>3</sup>), in that irrespective of the price change, the quantity demanded of water does not change. At this point farmers change crop plans by growing crops that consume a smaller amount of water as well, meaning that there is no response to price increase by farmers in this segment. This segment is also referred to as the non-efficient segment.

#### **6.4.1 Crop Choice**

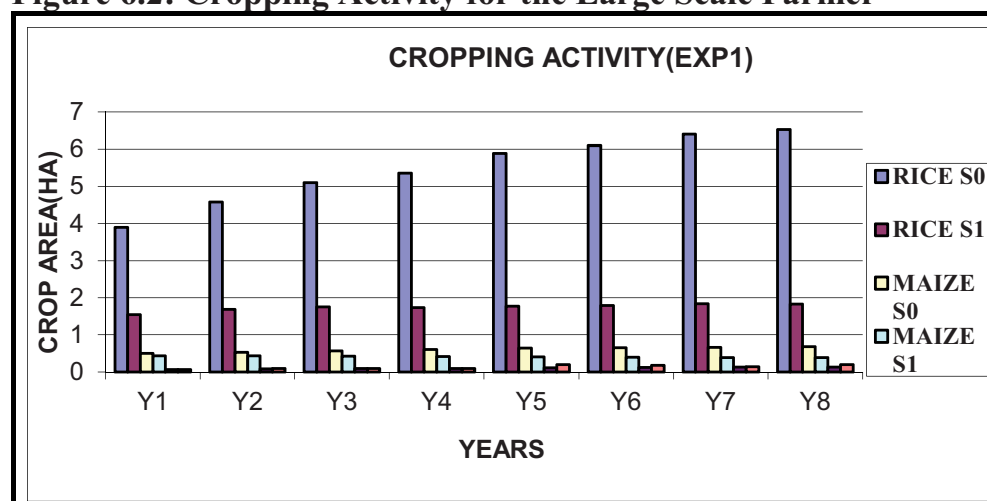
Change in water demand behavior as a result of price increase is also illustrated with the graph, with changes in the choice of crop as an adaptation to the rising cost of water. The adaptation pattern is shown below in the various graphs, by each farm type.

The graphs below show an eight year period, this period was chosen because of data availability for calibration purposes and the memory limit of the programming model used.



From the model results that at lower price levels (0-2 cedis/m<sup>3</sup>) there is no change in the crop choice, farmers continued to grow the same type of crops they were used to. But as price of water further increases, from Figure 6. 2, it is shown that, for large scale farmers (EXP1), the land allocated to rice decreases in year one (Y1), from 3.892 ha to 1.54 ha indicating about 60 percentage decrease as price of water increased, maize crop area also decreased from 0.503 ha to 0.432 ha that is also a 14 percentage point decrease. Vegetables increase slightly from 0.062 to 0.065 showing a 4.8 percentage point increase, whilst in year eight (Y8) rice decreased more drastically from 6.52 ha to 1.82 ha also indicating a 72 percentage point decrease much higher than in year one, maize also decreased more from 0.679 ha to 0.392 ha that is about 42 percentage point decrease. The cropping area of vegetables also increased from 0.131 ha to 0.193 ha in year eight also accounting for a 47 percentage point increase, in land allocated towards the cultivation of vegetables. These changes are attributed to the fact that, as water becomes more expensive, large scale farmers' shift from the production of high water consuming crops to low water consuming crops.

**Figure 6.2: Cropping Activity for the Large Scale Farmer**



**Source: Own Compilation**

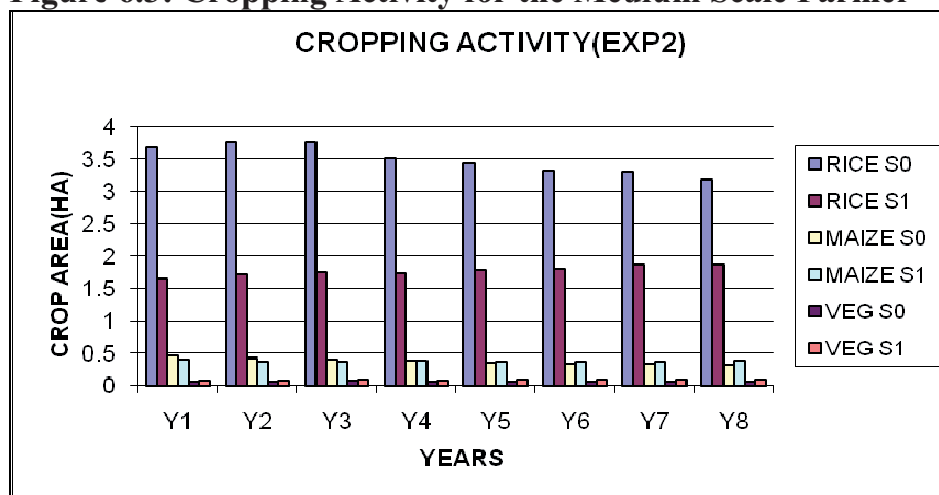


In Figure 6.2<sup>17</sup> as water price increases from year 1 through to year 8 the simulated cropping area of rice (RICE S1) also increases although at a decreasing rate whilst the percentage decrease also increased as well. This phenomenon is well clarified with the statement that water saved by increasing irrigation efficiency as a result of water price increases, over the period gets used to expand the cultivation of some of the crops such as rice, as rice is one of the most profitable crops in the area. This increase can also be ascribed to the fact that farmers begin to utilize other water saving technology such as water harvesting. The available water is then used to increase the production of the most profitable crop, this scenario can also be compared to a study by Ahmad Sadiddin (2009), who realized that as a result of irrigation efficiency, when water is saved up, cultivation of some intercalary crops gets expanded over the period. Also from the Figure 6.2 its evident that, in the long run, farmers' decision towards increasing the cultivation of less water demanding crops in place of more water demanding crops becomes prominent as the cropping area increased from 4.8 percent to 42.0 percent for vegetables, whilst percentage decrease of crops such as rice increases over the period. An example is that of rice for which the percentage change increases from 60 percent to 72 percent from year 1 to year 8 respectively, as farmers realize that the cost of water is getting higher and cost of production is also increasing.

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<sup>17</sup> where S0= Base line years(2005) ,S1= Simulated line years

**Figure 6.3: Cropping Activity for the Medium Scale Farmer**

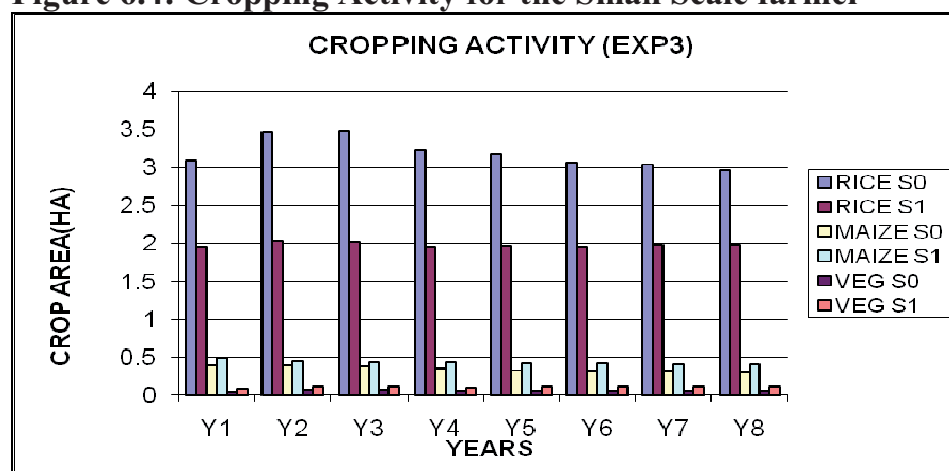


**Source: Own Compilation**

As seen from Figure 6.3, for the medium scale farmer (EXP2), as the price of water increases, the land allocated to rice decreased in year one from 3.373 ha to 1.647 ha that is a 55.2 percentage decrease, maize from 0.468 ha to 0.409 ha indicating a 12.6 percentage decrease and vegetable increased from 0.06 ha to 0.077 ha representing a 28.3 percentage increase. Meanwhile, in year eight (Y8), rice is further reduced from 3.182 to 1.866 signifying a 41.4 percentage decrease, whilst vegetable increase from 0.066 ha to 0.105 ha indicating a 59.1 percentage increase. This is so because rice as compared to vegetables demands more water. But maize started increasing from year 5, so in year 8, there was a percentage increase of 19.4 percent. Indicating that with the medium scale farmer, as water price rises over a period of time and realizing that his income is decreasing as a result of decrease in both rice and maize cultivation, he finds alternative ways of saving water or using water more efficiently in order to increase production of maize and increase profitability. This decrease in cropping area of crops with high water demand to crop with less water demand can also be related with a study by Varela- Ortega et al, 1998, which shows that as water price increases farmers in

Syria also shifted production from high water demanding crops to low water demanding crops in order to reduce their cost of production. The study on “the impact of water and agriculture policy scenarios on irrigated farming systems in Italy” by Bartolini et al, 2007, also confirmed the fact that as water price increases farmers are forced to have a crop mix, as the production of high water demanding crops like rice becomes unprofitability.

**Figure 6.4: Cropping Activity for the Small Scale farmer**



**Source: Own Compilation**

Figure 6.4 evidently shows the crop choice that farmers make as the price of water is increased. In Y1, rice was reduced from 3.098 to 1.952, illustrating a 37 percentage point decrease; whilst maize was increased from 0.395 to 0.477 also demonstrating a 21 percentage point increase and that of vegetable increased from 0.05 to 0.09ha showing an 80 percentage point increase. In Y8, rice is further replaced by maize and vegetables as the price of water increases.<sup>18</sup> Rice cultivation decreased from 2.978 ha to 1.975 ha, showing a 33.2 percentage point decrease, whilst maize increased from 0.303 ha to 0.403 ha indicating a 33 percentage point increase

<sup>18</sup>.where S0= Base line years(2005) ,S1= Simulated years



and vegetables also having a 82 percentatge point increase in year eight.

From the different farm types, it is realised that the large scale farmer (EXP1) due to water price increases decreased the cultivation of both rice and maize and rather increased the cultivation of vegetables. The medium scale farmer also decreased the cultivation of rice and maize in the early years, but increased the cultivation of maize in the fifth year. The small scale farmer however decreased the cultivation of only rice but increased the cultivation of both maize and vegetables. These changes could be attributed to the fact that, for the large scale farmer the impact of water price increases on cost of production would be very high and he would feel the pitch the most. As a result, he would switch to less water demanding crops in the short run since this would be the best way to go in order to cut down on production cost. In the long run, he would find other water saving technology to supplement his high demand for water. This could also be a reason he would be increasing his rice cultivation overtime although insignificantly so as to break even in production. But the medium and small scale farmers reduced rice production and increased the cultivation of maize and vegetable but the cultivation of vegetables was increased much more than that of maize, especially for the small scale farmer, as can be seen in the percentage differences.

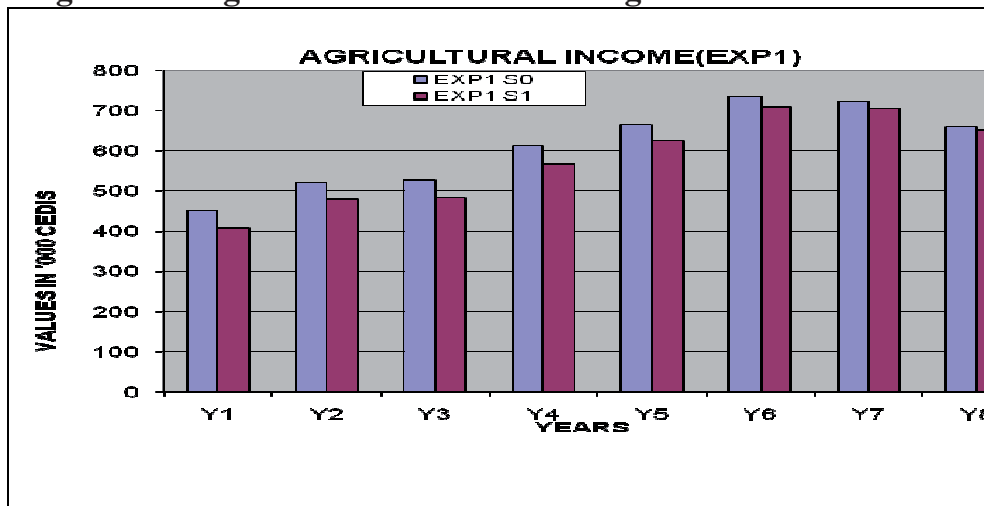
#### **6.4.2 Economic Impact**

The water pricing scenario results in a decline in the income of the farmer due to the fact that two factors are working in the same direction, the responds of the farmer to increases in price of water is by reducing his consumption of water through changes in crop plans, presenting crops that are less profitable as substitutes for



crops that are more valuable and demands more water. The change considerably decreases farmers income. Secondly, as price increases, the cost of production of the farmer also increases and consequently affecting the profit of the farmer and hence a decline in income. Finally, as farmers pay for water from their private funds into the government coffers, public revenue is increased and thus private funds decreased. However, these funds to the government is later used for maintaining the environment.

**Figure 6.5: Agricultural Income for Large Scale Farmers**



**Source: Own Compilation**

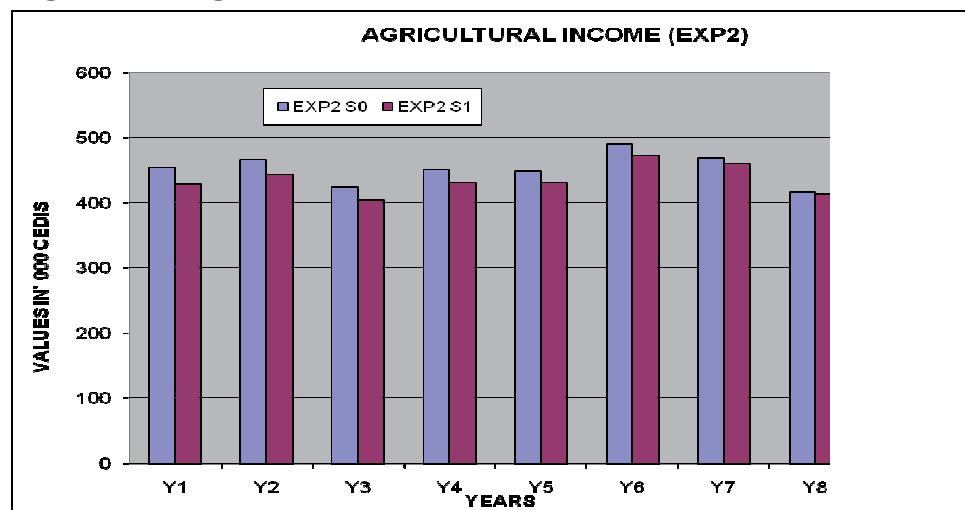
Figure 6.5 reveals the change in agricultural income for large scale farmers(EXP1) indicating a consistent decrease in income over the years as the price of water increases at the segment where demand is elastic and perfectly inelastic, and at the stage where the farmer replaces high water demanding crops for less consuming water crops. Income in the first year decreased from ¢449,867.00 to ¢407,990.00 (9.3%), whilst in the eighth year, agricultural income declined to ¢649,952.00 from ¢658,782.00 about 1.3 percentage decrease. This is as a result of the fact that in the long run farmers become innovative and find other means of saving water in order to increase their income such as seen in Figure 6.5 that cropping



activity for simulated rice increase slightly over time. Hamdane (2002) study on water demand also indicates that in cases where prices have to increase substantially before water demand is reduced substantially farmers income is adversely affected in the process.

For the medium scale famer (EXP2) ,as price of water increases the income of the farmer decreases.

**Figure 6.6: Agricultural Income for Medium Scale Farmers**



**Source: Own Compilation**

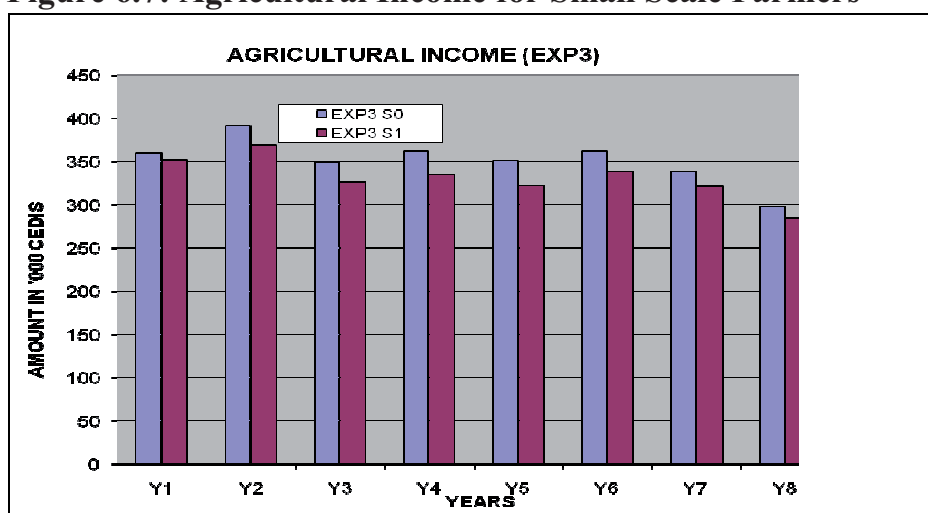
In year one (Y1), income decrease from ¢454,081.00 to ¢429,074.00 (5.5%) as well as in year eight(Y8), income of agriculture famers decreased from ¢416,565.00 to ¢413,059.00 showing a 0.8 percent decrease. This decrease might also be as a reason for farmers to increase the production of both maize and increase the cultivation of vegetables to about 19.4 percent and 59.1 percent respectively in year eight. Another reason could be given that the medium scale farmer might have rented his own labour to another farmer for wages or even rented some of his land



for rent. These reasons could account for the percentage decrease in agricultural income in year eight.

For the small scale farmer, income decreased from €359,666.00 to €351,942.00 (2.1%) in year one (Y1) through to year eight. This could be explained by the significant percentage increase in vegetables overtime. From the three different farm types it is realised that the percentage decrease in income is reduced overtime, consistent with earlier observations that, in the long run farmers find alternative ways of increasing income through renting or selling labour or land, or saving water to increase other profitable crops.

**Figure 6.7: Agricultural Income for Small Scale Farmers**



Source: Own Compilation

Furthermore, after analysing the effect on farm income as described earlier, we will realise some differences, the decrease in income in the first segment is more severe, with an aggregate reduction fluctuating from 10% to 30% the income missing in the private sector is reassigned straight to the public sector through the revenue from water for the reason that in the first segment, crop



budget are not significantly modified, and demand for water is preserved.

These outcomes from the analysis are very vital for policy because, if in the country the government decides to use water pricing as the single tool for reducing water demand by farmers, then it has to take note that at lower price levels water demand is inelastic, meaning that farmers would not respond to price increases until it gets to a level of 5.8 cedis per m<sup>3</sup>, until then water demand will not be affected by decreasing cropping activity associated with a significant decrease in farm income.

Taking into consideration the second segment, this segment reveals with evidence that variations and substitutions in crop plans happens only due to an increase in water price. This indicates that in this particular segment decrease in farm income is mainly as a result of crop substitutions and in a lesser proportion indirectly due to transfer from private farmer funds to public revenue. Here, the growth in public revenue as a result of income from water prices increases at a slower rate than in the first segment.

As a final point, the behaviour of farmers in the third section, proposes that prices of water have been raised too high that farmers are unable to pay for the water as production becomes unprofitable. The third segment, is very inefficient from the economic and political viewpoint, this is so because, as demand for water is perfectly inelastic, it is unable to respond to continuous price increases, hence as price continues to increase, demand for water remains the same. These results can also be related to other studies done on water pricing by De Fraiture and Perry (2004) that also had similar results; as water price increases the income of the



farmer decreases. A study by Berbel et al (2000) in Spain on water pricing also confirms this effect of a reduction in income to farmers as a result of water price increases, from this study it is indicated that farm income will need to fall by 25 to 40 percent before an increase in the price of water would lead to a significant decrease in water demand. In a case in Iran, water price would have to be raised from \$4/1000m<sup>3</sup> to \$20/1000m<sup>3</sup> to reduce demand significantly and in the process farmers income is affected negatively(Perry 2001).

#### **6.4.3 Social Impact**

From the literature it is noticeable that less water demanding crops are less labour intensive like vegetables compared to more water demanding crops such as rice which is labour intensive.

Logically, the first segment, which is characterized by farmers not changing their crop plans, does not see any decrease in labor input. On the other hand, the second segment, which is characterised by crop plan changes points to significant decrease in labor input.

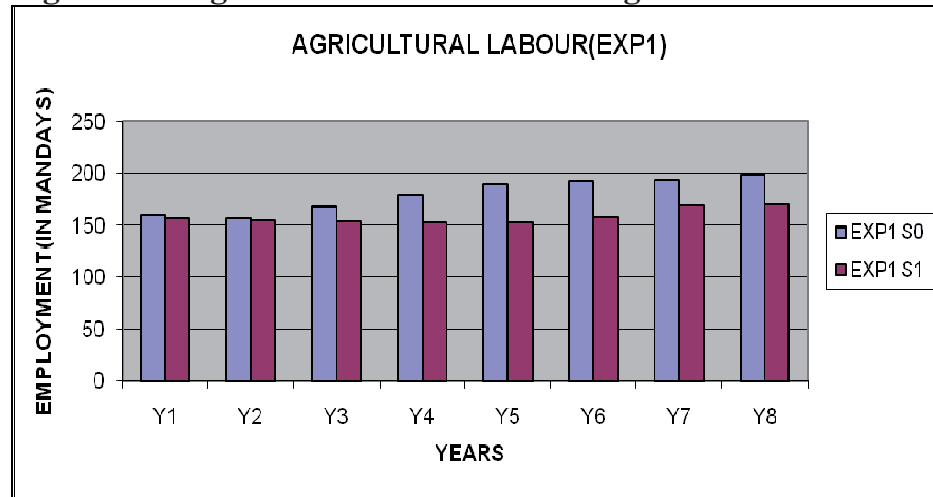
Nonetheless, we may say that in the second and third segment as a bulk of the people in the Volta basin area depend on agricultural employment as its key source of employment an increase in price of water leading to a reduction in the farmers income as discussed earlier (i.e prices beyond 4-20cedis/m<sup>3</sup>) will drastically affect rural employment . This outcome is illustrated in Figure 6.8.

From Figure 6.8 below, its obvious how an increase in price of water has affected employment negatively. For all the farm types especially that of small scale farmers(EXP3) employment on the farm has reduced drastically as a result of the price increase.Thus



affecting the welfare conditions of the farmers and increasing the poverty rate as and result result in increase in output prices too.

**Figure 6.8: Agricultural Labour For Large Scale Farmers**



**Source: Own Compilation**

From Figure 6.8, for the large scale farmer(EXP1), in year one, labor(in man days) decreased from 159.426 man days to 156.43 man days showing about 1.9 percentage decrease, whilst further in year eight, employment decreased by about 14.7 percent. This is supported with the fact that as cropping area are decreased, labor would also be decreased concurrently.

**Figure 6.9: Agricultural Labour For Medium Scale Farmers**

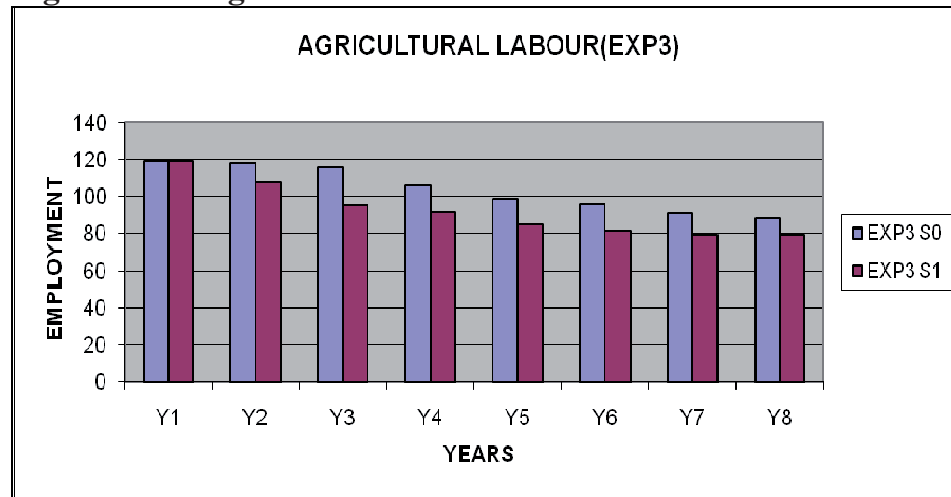


**Source: Own Compilation**



From Figure 6.9 above, for the medium scale farmer(EXP2), in year one, labor man days decreased from 124.799 man days to 117.824 man days indicating about 5.5 percentage decrease, whilst it further increase in year eight to 6.3 percentage decrease, showing a consistent decrease over the eight year period.

**Figure 6.10: Agricultural Labour For Small Scale Farmers**



**Source: Own Compilation,2010**

From Figure 6.10 above, for the small scale farmer(EXP2), in year one, there was a 0.1 percentage point decrease followed by a 9 percentage point decrease in year two where labor man days decreased from 118.004 man days to 107.434 man days. Furthermore, in year eight, labour man days decreased further by 10.13 percent. From the various farm types it is realised that the number of labour man days has decreased over the period and this decreased can be supported with evidence from other studies from, Syria by Ahmad Sadiddin (2009), who also reported a decrease in labour as a result of water price increase. Gomez-limon 1999 also confirms the effect of water pricing on labour employment. It is evident from his results that as water price increases, and farmers change from more water demanding crops to less water demanding crops, the impact on employment is adversely related. A study

from Italy by Bazzani (2007), also confirms this decrease in employment when water price increases.

#### 6.4.4 Non Agricultural Employment

As agricultural employment is decreased in all the farm types, non-farm employment however, increased, as most of the agricultural farmers went into off farm employment and those doing off farm farming in part time has increased the hours or doing it full time in all the farm types as shown below.

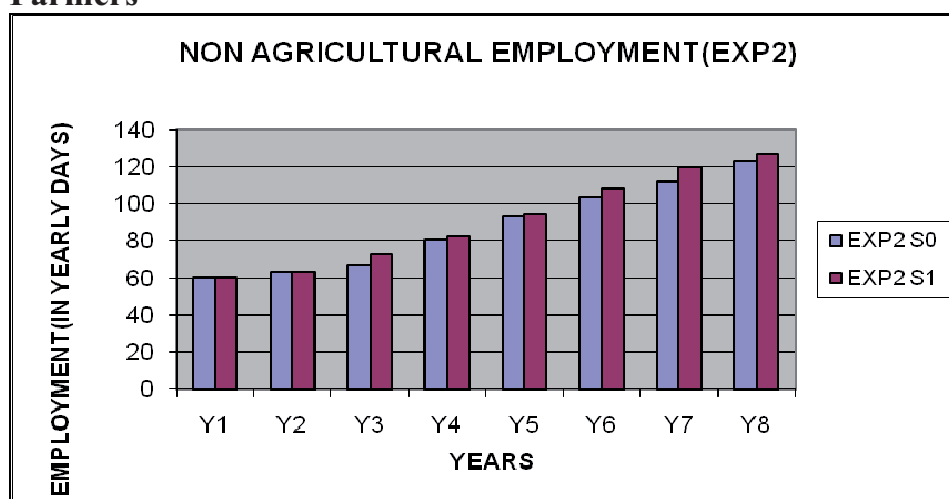
**Figure 6.11: Non-Agricultural Labour For Large Scale Farmers**



**Source: Own Compilation**

However, not all the excess labor was employed, in year's one non agricultural labor increased from 227.061 man days to 230 man days for the large scale farmers illustrating about 1.3 percent increase in off farm employment . In year eight, the percentage increase for off farm employment was about 9 percent.

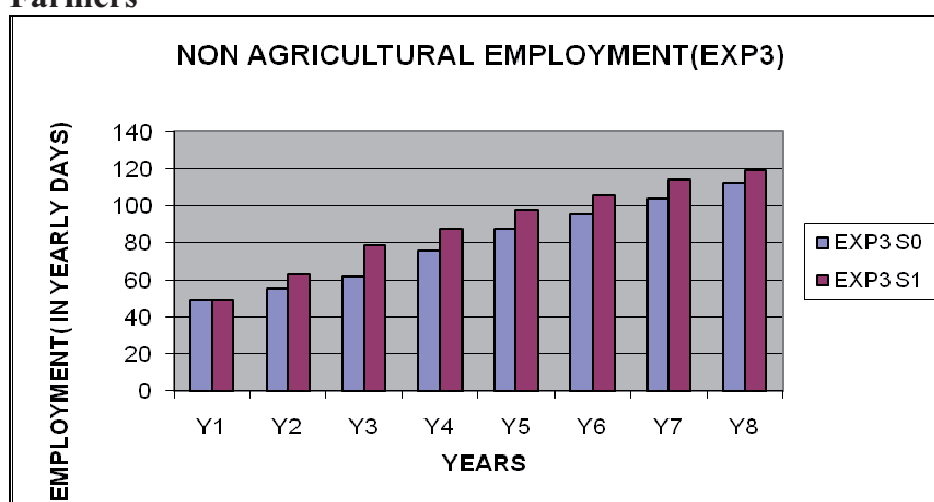
**Figure 6.12: Non-Agricultural Labor For Medium Scale Farmers**



**Source: Own Compilation, 2010**

For the medium scale farmer in the first two years, the increase was not quite significant but from year three, non-agricultural labors increased from 66.693 man days to 72.692 man days showing a 9 percent increase, coupled with a further increase in year eight of about 3.6 percent. These changes could be supported by the percentage decreases in the agricultural labor leading to non-agriculture labor increases.

**Figure 6.13: Non-Agricultural Labour For Small Scale Farmers**



**Source: Own Compilation, 2010**



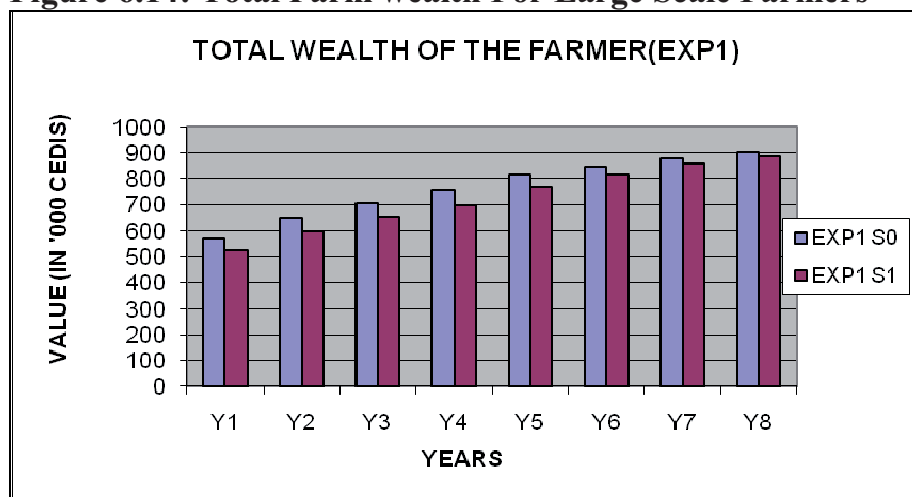
For the small scale farmer, in year one, the decrease was very insignificant but from year two, non-agricultural labors increased from 55.279 man days to 63.24 man days, indicating a 14 percent increase but in year eight the percentage decrease was 6.1 percent. This might be because the percentage decrease in agricultural employment was about 10 percent, so non-farm employment could not be more. The figure above indicates a transfer of labor from the farm sector to non-farm sector. Thus showing that as the income of the farmers decrease, they would move unto a higher income producing activity as rational individuals.

#### **6.4.5 Total Wealth**

As the price of water affects income, employment, and water demand of the farmers, it also affects their total wealth. The wealth of the farmers is decreased over the years as the price of water increases. For the large scale farmer, the total wealth decreased from a total of 572,433.00 in the base year to a total wealth of 522,220.00 in the simulated year. For year one (Y1), this is about an 8.8 percent change. For year eight, the percentage decreased reduced to 1.3 percent, this can be related with the change in agricultural income.



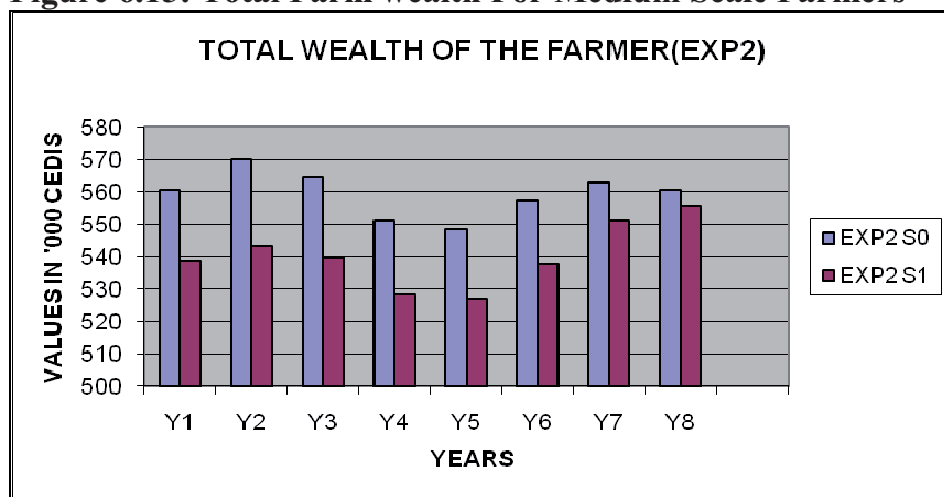
**Figure 6.14: Total Farm wealth For Large Scale Farmers**



**Source: Own Compilation,2010**

For the medium scale farmer, the total wealth decreased from a total of 560,339.00 in the base year to a total wealth of 538,692.00 in the simulated year. For year one (Y1), this is about a 4 percentage point change, with 0.85 percentage point decrease in year eight.

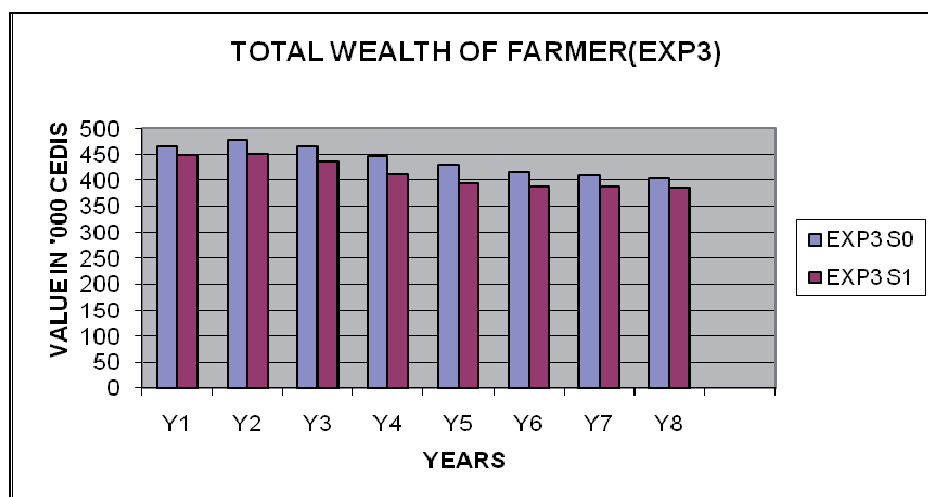
**Figure 6.15: Total Farm wealth For Medium Scale Farmers**



**Source: Own Compilation**

For the small scale farmer, the total wealth decreased from a total of 466,699.00 in the base year to a total wealth of 448,224.00 in the simulated year for year one (Y1). This is about a 3.95 percentage decrease. The figure below indicates that total wealth falls continuously over the years, with a 4.4 percent decrease in year eight.

**Figure 6.16: Total Farm wealth For Small Scale Farmers**



**Source: Own Compilation, 2010**



From the three different farm types, it is shown that the decrease in total farm wealth is highest with the large scale farmer, followed by the Medium scale and then finally the small scale farmer.

### **6.5 Environmental impact**

Water pricing can positively affect the environment, as farmers substitute crops in order to save water, fertilizer use might also decrease. Decrease in the quantity of fertilizer use begins in the second and third segment, where crop plans are changed and water demand is reduced. With a decrease in fertilizer use the environment would be impacted positively.

### **6.6 Summary**

In summary it can be said that using water price to reduce water demand in the agricultural sector would be challenging, as using it as a single tool without any other alternative has a negative impact on farm income, employment and wealth of the farmer. From our results, it is clear that for the large scale farmer with water price increase, he decreases the cultivation of both rice and maize and increases that of vegetables but for the medium and small scale farmers, they decrease the cultivation of only rice and increase the cultivation of vegetables. In terms of labor for all the farm types, labor is decreased across board in year one but in the long run that is year eight, the percentage decrease from year one to eight for the large scale farmer is the highest, followed by the small scale farmer and then the medium scale farmer. This could be attributed to the fact that there are more small scale farmers than medium scale farmers in the area. Also in terms of the impact on agricultural income, the percentage decrease is highest for the large

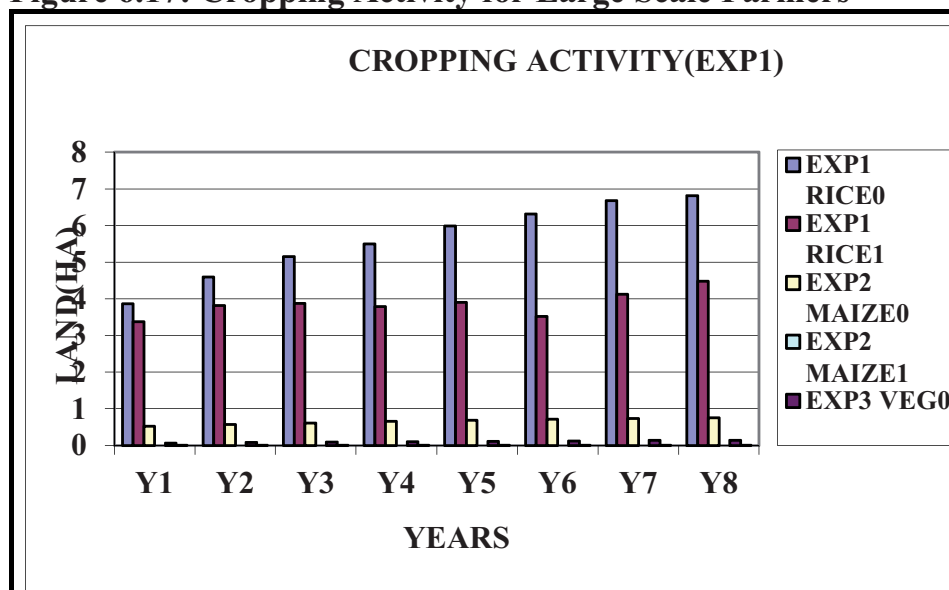


scale farmer followed by the medium scale farmer and consequently by the small scale farmer. In terms of the impact on agricultural income, this is also true for the total wealth of the farmer and also for off farm employment.

## **6.7 Water Availability Scenario**

The impacts of water scarcity are particularly acute in countries where the economy is heavily dependent on irrigated agriculture, as well as rain-fed agriculture, such as Ghana. Up to 40 percent of GDP in Sub Saharan Africa (SSA) is generated by the agricultural sector which depends almost exclusively on water availability from the Volta Basin. Rain is the main source for covering water demand in rain fed agriculture (FAO, 2003). Availability of rain water is considered as the main uncertainty factor as it is fully dependent on natural atmospheric conditions in the region. As a result of recent concerns for climate change, this scenario became very important. This scenario is implemented as a result of the recurrent drought over the years. An example of such drought was between the years of 1981 and 1983, and also the concern for future droughts. This scenario, therefore made use of all the average rainfall data, the surface water data and dam water data that prevailed in those years between 1981 and 1983.

**Figure 6.17: Cropping Activity for Large Scale Farmers**



**Source: Own Compilation, 2010**

From Figure 6.17, as a result of drought in the country, water availability has declined; therefore, there is water scarcity in Ghana, this resulted in a decline in rice cropping area, the cropping area reduced from 3.859 ha to 3.369 ha in year one showing a 12 percent decrease, and 0.519 ha to 0 ha for maize, indicating a 100 percent decrease and 0.063 ha to 0.005 ha for vegetables also indicating a 92 percent decrease. Also noting that the percentage decrease in rice fluctuated over the eight year period reaching its highest 44 percent in year six, in year eight, rice further decreased from 6.821 ha to 4.477 ha that is a 34.4 percent decrease, maize decreased from 0.747 ha to 0 ha also showing a 100 percent decrease, and vegetables decreased from 0.138 ha to 0.008 ha a 94 percent decrease. The low percentage decrease in rice could be attributed to the fact that as a result of the drought farmers decided to use all their available water( both from irrigation & rainfall) on the production of rice as the price and demand for rice has increased considerably, and it might be the most profitable crop at the time(Ofori Sarpong, 1986). The production of Maize was virtually zero and that of vegetables was quiet insignificant. This



result is validated with the real life issue in 1983 in Ghana, where the production of maize was almost zero, and any maize that was sold in the country were mostly imported from other countries. Rice production was quite high comparatively but not high enough for the available demand, and food shortage was widespread (Clark Nancy, 1994). Most of the foods available were brought in by foreign donors, others were imported by the government resulting in an increase in trade deficit, and real GDP of agriculture fell by 7 percent in 1983 alone, with its resulting decrease in capita food availability by 30 percent in 1983 lower than in 1974. For vegetables, only the rich could afford to buy and eat vegetables, and some vegetables were even produced with the use of waste water.

This is also true for the medium scale farmers, from Figure 9.1 in Appendix 10, the unavailability of water resources resulted in a decrease in the cropping area of rice, the hectare of rice declined from 3.647 ha in the base year to 1.834 ha in the simulated year one, showing a percentage decrease of 50 percent, and a 100 percent decrease for maize with a reduction from 0.454 ha to 0 ha. For vegetables a 51 percent decrease from 0.062 ha to 0.030 ha for vegetables. And in year eight, there was a further decrease of rice from 3.161 ha to 2.753 ha showing a 12.9 percent decrease, maize 0.35 ha to 0 ha indicating a 100 percent decrease, and vegetables from 0.065 ha to 0.004 ha a 93 percent decrease. This scenario clearly shows the devastating impact of water resource scarcity over a period of time, resulted in decreases in all the crops and food availability. Similar situation has occurred before in 1983, where men as well as children and women died from hunger as a result of food shortage in the country.



Furthermore from Figure 9.2 in Appendix 10, a shortage in water resources for the small scale farmer resulted in a decline in rice cropping area from 2.982 ha to 1.557 ha in year 1, illustrating a 48 percent decrease, and 0.397 ha to 0 ha for maize indicating a 100 percent decrease and 0.057 ha to 0.032 ha for vegetables showing a 37.3 percent decrease. In year eight, rice further declined from 2.145 ha to 1.063 ha showing a 50 percent decrease, maize from 0.245 ha to 0 ha indicating a 100 percent decrease and vegetables 0.055 ha to 0.004 ha showing a 93 percent decrease. These results are attributed to a decrease in rainfall and a decline in surface water as well as irrigation water.

Comparing the differences and similarities in the farm types, it is seen that maize cultivation was virtually zero for all farm types in all the years, this might be because the price of maize was not high enough to attract its production and also because its quiet easy to get imported maize from other neighboring countries. Another reason might be that maize might be cultivated only for home consumption and not for commercial purposes or sale. Rice experienced a percentage increase for large scale and small scale farmers from Y1 to Y8, but for the medium scale farmer it experienced a percentage decrease from 50percent to 12.9 percent. This decrease might be attributed to increase in other irrigation farming or ground water usage. The percentage decrease in vegetable cultivation was highest for the large scale farmer followed by the medium scale and then the small scale farmer. This might be attributed to the fact that the large scale farmer might not be able to keep to its large scale production as a result of the water shortage.



### **6.7.1 Impact on Agricultural Income**

From Figure 9.3 in the Appendix 10, as a result of a drought or natural conditions, water has become scarce in Ghana, and cropping areas has decreased over the years. This has consequently affected agricultural income of the large scale farmer, in year 1, his income decreased from 450.777cedis to 299.301cedis per hectare showing a 34 percent decrease in a year one. In year eight, a further decrease from 697.211cedis to 368.188cedis indicating a 47.2 percent decrease. From Figure 9.4 in the Appendix 10, for the medium scale farmer, income decreased from 398.310 cedis to 216.911 cedis in year one indicating a 46 percent decrease, and further decrease from 314.715 cedis to 268.479 cedis in year eight also showing a 14 percent decrease. From Figure 9.5 in Appendix 10, for the small scale farmer, income decreased 329.948 cedis to 203.654 cedis in year one indicating a 38.3 percent decrease, and further decrease from 211.370 cedis to 173.632 cedis in year eight showing a 18 percent decrease. This decrease in income as a result of a fall in the water resources demonstrates some of the importance of water management, in that if water is not managed well, and water scarcity occurs, income of the farmer would be decreased and this results can also be compared with studies done by Ihtiyor Bobojonov, 2008 who found that expected income of the farmers on aggregate declined for about 12 percent in Uzbekistan as a result of expected water scarcity.

### **6.7.2 Impact on Employment**

The model results indicated that as a result of water unavailability, cropping area and agricultural income decreased for all crops as compared to the base line years over time, this decrease consequently affected agricultural employment because when





production is low, farmers might not need to employ more people because there is decrease in the cropping area and so therefore unemployment is increased, from Figures 9.6 and 9.7 in Appendix 10, it is shown that as agricultural employment for all the farm types decreased, the Agricultural employment for the large scale farmer declined from 165.83mandays to 3.747man days in year 1 showing a 97.7 percentage decrease, but non agricultural employment increased from 220.272man days to 253man days in year 1 indicating a 15 percent increase. And also in year eight a decrease from 217.467man days to 5.064man days for agricultural employment demonstrating a 97.6 percent decrease. Meanwhile non agricultural employment showed an increase from 256.515man days to 355.996man days that is a 39 percent increase. The increase in non agricultural employment shows that as unemployment in the agricultural sector increases, empolyment in the non agricultural sector increases as labour moves from the agricultural sector into the non agricultural sector. This is also valid for the medium scale farmer,from Figures 9.8 and 9.9 in Appendix 10, it is shown that as agricultural employment decreased from 122.602man days to 2.1547man days in year 1 showing a 98.2 percent decrease, but non agricultural employment increased from 60 man days to 164.04man days indicating a 173.4 percent increase in year 1. In year eight, a decrease from 107.857man days to 3.42man days for agricultural employment showing a 97 percent decrease and an increase from 110.001man days to 203.935man days a 85 percent increase for the non agricultural employment. For the small scale farmer,from Figures 9.10 and 9.11 in the Appendix 10, it is shown that as agricultural employment decreased from 122.044man days to 2.469 man days in year 1 showing a 98 percent decrease, and non agricultural employment increased from 49man days to 128man days a 161.2



percent increase in year 1. And also in year eight, a decrease from 105.729man days to 3.102man days for agricultural employment showing a 97 percent decrease and an increase from 95.596man days to 180.109man days for non agricultural employment indicating a 88.4 percent increase. The decrease in agricultural employment can also be compared to a study by Moghaddasi, R. 2009 also found a decrease in agricultural employment as water becomes scarce by 16 percent, another study by Hamdan M.R 2006 in his paper the impact of irrigation water scarcity on the socio-economic of agricultural sector and food security in Jordan, in the main finding of the paper states that as water supply decreased by 20 percent employment also declined and went further to state that the reduction in the employment will be accompanied by a direct and indirect loss in income too. Janakarajan , S 2009 also confirmed this result..

### **6.7.3 Impact on Agricultural Farm Wealth**

For the Large scale farmer, it can clearly be seen that as water becomes scarce, total farm wealth has also decreased, from Figure 9.12 in Appendix 10 considerably, in year 1, total farm wealth decreased from 573.866 cedis to 503.797 cedi showing a 12.21 percent decrease. In year eight, there was a further decrease from 950.057 cedis to 642.496 cedi indicating a 32 percent decrease. This decrease is attributed to the decrease agricultural income propelled by a decrease in cropping area of all crops and consequently a decrease in production. The same can also be said for the medium scale farmer, from Figure 9.13 in Appendix 10, it indicates that as water becomes scarce, total farm wealth has also decreased considerably. In year 1, total farm wealth decreased from 503.300 cedis to 272.599 cedis indicating a 46 percent

decrease. In year eight, there was a further decrease from 427.100 cedis to 393.611 cedis showing an 8 percentage decrease. Meanwhile for the small scale farmer, total farm wealth decreased considerably, from Figure 9.14 in Appendix 10, it shows that as water supply is reduced considerably, total farm wealth has also decreased. In year 1, total farm wealth decreased from 442.05 cedis to 251.967 cedi showing a 43 percent decrease. In year eight, there was a further decrease from 321.425 cedis to 272.870 cedi indicating a 15 percent decrease.

Comparing the water scarcity scenario with that of water pricing scenario, it can be seen that the impact of water scarcity on the cropping area and other variables are more severe than that of the water pricing scenario. This makes it very important for the country to concentrate on water management activities, so as to reduce the demand for water, reduce wastage in the system, and save enough water for the future, so as to avoid as much as possible the impact of drought or water scarcity in the future and its consequences.

## **6.8 Changes in Input Prices**

Inputs in this study consist of fertilizer, pesticides, water, seed, and others. In this scenario the changes in prices applies to the fertilizer input. The prices of other inputs are kept constant. Fertilizers in Ghana are subsidized meaning the real market price of the fertilizer determined by demand and supply are not prevailing in the market at the moment. This scenario looks at the instances where the fertilizer market is liberalized and prices are determined by demand and supply, as the government is considering re-establishing market prices for the fertilizer. This scenario is to look at the impact on the agricultural sector as well as on cropping activities if the prices of fertilizer are increased by 25 percent. This



percentage is used because subsidized prices are about 25 percent less than market prices (Own Calculation, 2009).

Fertilizer crop use in Ghana is quite very low as compared to other countries such as China, Pakistan and Brazil. This has also accounted for the low yields from crops in the agricultural sector. In Ghana, most farmers are not able to afford the recommended quantity of fertilizer for crop growth; as a result, farmers apply below the recommended quantity by the Ministry of Food and Agriculture (Sarah Grant, 2008). The impact of fertilizer price increase on the crops would be quite high because as they are even not using the required quantity at subsidized prices a further increase would affect the usage even more.

From Figure 9.15 in Appendix 11, as the price of fertilizer increases, the large scale farmer (EXP1) decreases the size of cropping area for rice from 3.859 ha to 2.496 ha in year 1 indicating about 35.3 percentage decrease, and also consequently decreases from 6.821 ha to 3.986 ha in year eight showing a 42 percent decrease, indicating a decreasing trend over the years in cropping area of rice when fertilizer prices are increased, compared to the <sup>19</sup>base year. The same trend applies to maize and vegetable, in year 1, maize cropping area decreased from 0.519 ha to 0.432 ha showing a 16.76 percent decrease whilst in year 8, there was a decrease from 0.747 ha to 0.639 ha demonstrating a 14.45 percent decrease. For vegetables, the cropping area decreased from 0.063 ha to 0.024 ha in year 1 indicating 61.9 percentage decrease and from 0.138 ha to 0.046 ha in year 8 showing a 66.67 percent decrease. These decreases in the cropping area of crops for the large scale farmer are attributed to the fact

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<sup>19</sup> Rice0 is the base year and Rice1 is the simulated scenario



that as price of fertilizer increases, the cost of production of the large scale farmer goes up. Therefore in order to make some profit, he decides to reduce the cultivation area of the crops and also to reduce the usage of fertilizer on the crops and this thus affects his yields in the long run.

Figure 9.16 in Appendix 11 follows the same decrease in trend as that of the large scale farmer; it is shown that as price of fertilizer increases, the medium scale farmer also decreases the cropping area for rice, maize and vegetables. The percentage decrease is also high in year 1, 3.647 ha to 1.819 ha for rice showing a 50.4 percent decrease, and 0.454 ha to 0.256 ha for maize also indicating a 43.61 percent decrease and 0.062 ha to 0.017 ha for vegetables showing a 73 percent decrease. In year 8, there was also a decrease in rice cropping area from 3.161 ha to 2.293 ha showing a 27.4 percent decrease, for maize from 0.350 ha to 0.276 ha indicating a 21.14 percent decrease and vegetable cropping area consequently decreased from 0.065 ha to 0.027 showing a 58.46 percent decrease due to an increase in fertilizer price as a result of liberalization. From Figure 9.16 in Appendix 11, it can be seen that after year five, the percentage change also decreases for all the crops, this could be as a result of the increase usage in manure and other methods of fertilizing the soil that the medium scale farmer might have discovered overtime.

For the small scale farmer, the increase in price of fertilizer affected them too but not as much as that of the medium scale and large scale farmers. This is mainly so because, the small scale farmer use of fertilizer for crops are largely minimal and he does not usually use the required quantity for production. As a result, when the price of fertilizer increases in year 1, the cropping area



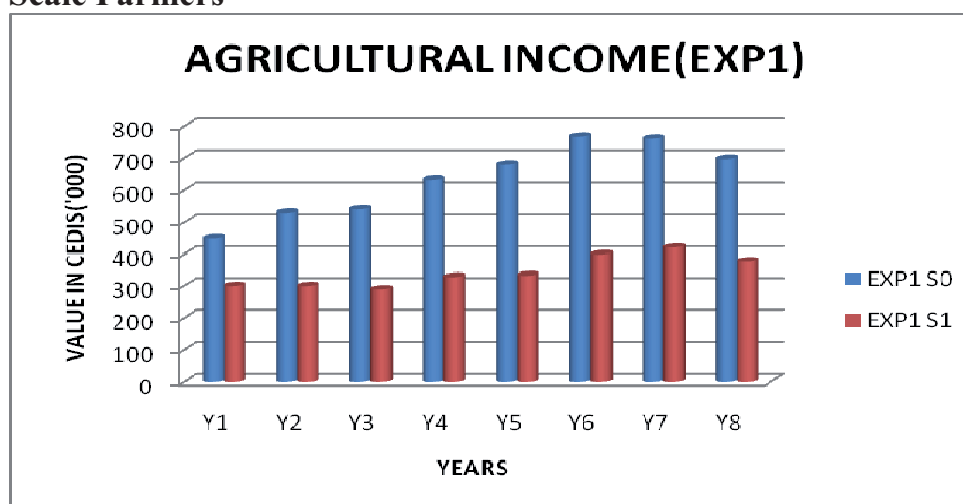
for rice decreases from 2.982 ha to 2.075 ha showing a 30 percent decrease, and the cropping area for vegetables also decreased from 0.057 to 0.026 ha indicating a 54 percent decrease. Also, maize in year 1 decreased from 0.397 ha to 0.232 indicating a 42 percent decrease. For year eight, rice further decreased 2.145 ha to 2.011 ha also showing a 36.05 percent decrease. For maize the cropping activity decreased from 0.345 to 0.184 indicating a 47 percent decrease whilst that of vegetables also decreased from 0.058 to 0.03 also showing a 31 percent decrease (these can be seen in the Figure 9.17 in Appendix 11). This section demonstrates the importance of fertilizer input in the agricultural sector, comparing this scenario to that of water scarcity and water pricing. The percentage decrease in cropping area for fertilizer is much higher under this scenario compared to water pricing due to a situation of water scarcity in the region. The result of this scenario can also be supported by study done by Krussman, 2000 which also analyzes that an increase in the price of fertilizer input decreases the cropping activity of all crops and consequently yield and production is also affected. Another study by Ali, M 1990, states that a 10 percent increase in the price of fertilizer will decrease the production of rice by about 1.7 percent in Pakistan.

#### **6.8.1 Impact of Input Price Increase on Agricultural Income**

For the large scale farmer (EXP1), as a result of the increase in price of fertilizer, the income of the agricultural farmer decreases; it is also as a result of high production cost and the fact that he has reduced the cropping area of the various crops. From the graph below, as price of fertilizer increases for year 1, the agricultural income of the farmer decreased from 450.777 cedis to 298.902 cedis per hectare showing a 34 percent decrease. And from 697.211 cedis to 377.522 cedis in years eight also indicating a 46

percent decrease, these decreases point out that as the price of fertilizer increases, the income or profit of the agricultural farmer declines. This outcome can also be supported by a study done by Basil Manos et al, 2007 in Bangladesh, using the multi-criteria programming model also showed that a policy of increased fertilizer price would have a very important impact on farm income and employment. Another study by Jonas .N. Chianu, 2008 on Sub Saharan Africa also confirmed in his study that a 10 percent increase in fertilizer price would result in a 3.5 percentage decrease in demand for and use of fertilizer, and consequently also reduce farm income.

**Figure 6.18: Scenario for Increase in Fertilizer Price for Large Scale Farmers**



**Source: own compilation**

From Figure 9.18 in the Appendix 11, the impact of the increases in fertilizer prices also has a decreasing impact on the income of the medium scale farmer. In year 1, their income decreases from 398.310 cedis to 216.543 cedis representing a 45 percent decrease. It further decrease in year eight from 314.715 cedes to 210.452 cedes also indicating a 33.12 percent decrease, showing a continuous decrease in trend over the eight years period. This is





also true for the small scale farmer, in Figure 9.19 in Appendix 11 the income of small scale farmers also decreased as a result of an increase in the price of fertilizer, in years one the income decreased from 329.948 cedis to 234.453 cedis showing a 28.94 percent decrease and also in year eight there was a decrease in farm income from 211.370 cedis to 173.158 cedis indicating an 18 percent decrease. This minimal decrease is mainly as a result of the fact that the small scale farmer uses far below the recommended quantity of fertilizer (MOFA, 2005).

### **6.8.2 Impact of Input Price Increase on Non-Farm Employment**

As the price of fertilizer, input increase and farmers reduce their cropping area, agricultural employment also shift to non-farm employment. From Figure 9.20 in Appendix 11, it is shown that as input price increases, off farm employment also increases indicating that agricultural employment decreases. Meaning, the number of days used for off farm activities increases, indicating a shift from the agricultural employment. From Figure 9.20 in Appendix 11, it indicates that in year 1, as input price increases farmers move from agricultural activity to non-farm activity, the number of man days increases from the base year of 220.272 man-days to 253 man-days indicating a 15 percent increase, whilst in years eight it also increases from 256.515 to 355.996 man days also showing a 38.78 percent increase.

This also applies to the medium scale farmer as depicted in Figure 9.21 in the Appendix 11, as the cost of agriculture production increases, farmers shift from agricultural activities to off farm activities. Employment also decreases from agricultural production to off farm employment, off farm employment in year one





increases from 60 man-day's to 148.179 man-day's indicating about 146 percent increase, also in year eight there was a further increase from 110.001 man-day's to 190.277 man-day's also showing about 73 percent increase. The situation is not different for small scale farmers where there is a shift from agricultural employment to off farm employment, Figure 9.22 in the Appendix 11 indicates an increase from 49 man-day's to 103 man days amounting to a 111 percent increase in year one, whilst in year eight, there is an increase from 95.596 man-day's to 154.631 man-day's also showing a 61.75 percent increase.

### **6.8.3 Impact of Input Price Increase on Farm Wealth**

As crop area decreases, farm employment decreases, income decreases and nonfarm employment increases, total wealth of the farmer also decreases. From Figure 9.23 in Appendix 11, it is indicated that from the base year of the large scale farmer there had been a decrease in the total wealth of the farmer. In year one, farm wealth decrease from 573.866 cedis to 401.317 cedis amounting to a 30 percent decrease whilst that of year eight also decreased from 950.057 cedis to 589.678 cedis also indicates a 38 percent decrease. For the medium scale farmer (see Figure 9.24 in Appendix 11), in year one, farm wealth decreased from 503.300 cedis to 282.715 cedis indicating a 43 percent decrease, whilst that of year eight also decreased from 436.782 cedis to 310.932 cedis also showing a 29 percent decrease.

And also for the small scale farmer as shown in Figure 9.25 in Appendix 11, total farm wealth decreases from 442.050 cedis to 324.704 cedis in year one, representing a 27 percent decrease, for year eight, there was a continuous decrease from 321.425 cedis to 305.889 also showing a 4.8 percent decrease. It can be seen that the rate of percentage decrease declines over time; this could mean



that as the years pass by, the small scale farmer found other ways of increasing his farm wealth. This could be so because since his production is quiet minimal comparatively, or he might decide to shift production from fertilizer usage crops to non-fertilizer usage crops, or total shift from farm activities to non-farm activities.

## **6.9 Impact of Increase in Credit Availability**

Credit availability is a very crucial area in the economy of Ghana. This is so because credit to agricultural farmers is usually on the low, as discussed in chapters two and three, most financial institutions do not like to give loans to agricultural workers as a result of the risky nature of the agricultural sector. It is therefore quiet important for the government to put in a policy that obliges the financial institutions apart from the Agricultural Development Banks to give loans to the agricultural workers. This scenario assumes a 50% increase in initial cash of the farmer as a result of credit availability to the farmer, with a low interest rate and a long period of repayment.

From Figure 9.26 in Appendix 12, an increase in credit availability of the farmer results in a very small percentage increase in the cropping area of rice, maize, and vegetables. It can be shown that the percentage increase in money available to the large scale farmers is greater than the percentage increase in the cropping area of the crops. From Figure 9.26 in Appendix 12, as credits are made available to large scale farmers, the cropping area of rice increases from 3.859 ha to 4.001 ha, representing a 4 percent increase. The increase in maize is from 0.519 to 0.566 ha showing a 9 percent increase and that of vegetables increases from 0.063 ha to 0.064 ha also showing a 2 percent increase. The increase is quiet small and this is the trend over the years, also in year eight the increase in



rice was from 6.8 ha to 6.947 ha indicating a 2 percent increase, and that for maize and vegetables was 0.747 ha to 0.767 ha a 3 percent increase, 0.138 ha to 0.140 ha showing a 1.4 percent increase respectively. From Figure 9.26, it is realized that the percentage increase in maize was quiet higher than that of rice and vegetables, this could be attributed to the fact that maize is a staple food in the area, and although the profitability is not as much as rice, the demand for maize is higher than that of rice in the basin area and therefore would lead to an increase in its supply. This difference might also be ascribed to the price differences between maize, rice, and vegetables encouraging consumers to demand more maize thus conforming to the law of demand. The question would then be asked that, where did the money that was made available to them go, or what was it used for in this case? It can be said that the large scale farmer might have diverted the available credit into other sectors other than the agricultural sector. This can also be supported with a study on developing countries by Frank Ellis 1992, who found that in developing countries, credit made available in the form of cash or money does not directly increase agricultural cultivation or production partly because farmers after receiving the money use it for other activities other than agriculture (termed fungibility of credit). The term fungibility as Ellis 1992 says refers to the interchangeability of the uses to which credit can be put. Ellis 1992 also stated that, diversion and substitution can occur even when credit is delivered in physical form, and that credit even given in the form of a bag of seed can still be sold in order to buy a pair of shoes.

For the medium scale farmer in Figure 9.27 in Appendix 12, after he has received a credit worth about 50 percent increase in his initial cash, it is shown that he rather decreases the cropping area



of the production of rice, and maintains/increases insignificantly that of maize and decreases that of vegetables. In year one, after credit is made available, rice decreases in area from 3.647 ha to 3.555 ha representing a 2.5 percent decrease, maize increases from 0.454 ha to 0.462 ha also showing a 2 percent increases and vegetable decreases from 0.062 ha to 0.058 ha indicating a 6 percent decrease. In year eight, there is a reduction for rice from 3.161 ha to 3.114 ha shows a 1.4 percent decrease and for maize from 0.350 ha to 0.348 ha showing a 0.6 percent decrease whilst that of vegetables further decreases from 0.065 ha to 0.064 ha also indicating a 1.5 percent decrease.

This could be attributed to the fact that as a result of the available credit, the medium scale farmer realizing the risk in the agricultural decides rather to invest the money in non-agricultural activity so that he could earn more profit and be able to pay back the credit and interest when it is due. Hence spending more time on the off farm activity and decreasing the cultivation of other time consuming crops such as rice and vegetables and rather increasing the cultivation of maize also as a result of its availably ready market and high demand. The medium scale farmer does this in the first three years but from the fourth year, he starts to decrease the cultivation of maize also but at a minimal rate. This decrease in crop cultivation can be supported by findings of Suparmoko, 2002. In his paper the impact of the WTO agreement on agricultural in the rice sector of Indonesia, Suparmoko, 2002 stated that the volume of credit subsidies was increased tremendously but a significant amount of the credit was diverted to non-agricultural uses thus contributing to the drop in domestic rice production in 1998. A paper by Kompas, 2000 also supported this fact.



From Figure 9.28 in Appendix 12, the small scale farmer increases his cropping activity as a result of an increase in credit availability. But the percentage increase in credit available is greater than the percentage change in the cropping area of all the crops. In Figure 9.28, in year 1, rice increases from 2.982 ha to 3.03 ha showing a 2 percent increase and maize from 0.397 to 0.399 indicating a 0.5 percent increase and vegetables 0.057 to 0.058 illustrating a 1.7 percent increase. For year eight, it can also be shown that there was a slight increase in the cropping area for rice from 2.145 ha to 2.208 ha indicating a 2.2 percent increase, that for maize also increases from 0.245 ha to 0.255 ha indicating a 4.08 percent increase whilst that of vegetables increases from 0.055 ha to 0.056 ha showing a 1.8 percent increase.

From the three different types of farms, it is pointed out that, the percentage increase in credit availability is greater than the percentage increase in cropping activity. From the focus group discussion in the field survey, it was realized during the discussion that credit was not given when it is most needed, for instance most of the farmers complained about the fact the credit given to them usually comes after the rains are over or are given to them at the wrong time of the farming season, so they are not able to invest it directly into agricultural production. Others also mentioned that the period of payment and high transaction cost also discourages them to solely invest the credit into agriculture as a result of its risky nature. It therefore concludes that credit made available to farmers in the form of physical cash is all not directly invested into agricultural activities but mostly diverted in the Volta basin area.



### **6.9.1 Impact of Credit Availability on Agricultural Income**

The main reason that government would want to put in a policy to increase credit availability to farmers would be to increase their income so that their standard of living will increase through the increase in production. In Ghana, farmers are assumed to be the ones with very low income and standard of living, so government would like to make the agricultural sector lucrative enough for even the young to want to go into the agricultural sector.

From Figure 9.29 in Appendix 12, an increase in credit availability for the large scale farmer increases his income in year 1 from 450.777 cedis to 474.280 cedis indicating a 5.2 percent increase and in year eight from 697.211 cedis to 708.538 cedis also showing 1.6 percent increase.

From Figure 9.30 in Appendix 12, it is shown that as credit is made available for medium scale farmers their agricultural income decreases in year 1 from 398.310 cedis to 391.831 cedis indicating a 1.6 percent decrease. Also in year eight there was a minimal decrease from 314.715 cedis to 310.365 cedis indicating a 1.3 percent decrease. This result could be attributed to the fact that money given to farmers as a result of credit made available to them was not invested in agricultural activities; it was diverted into different areas in the life of the farmer. Either to pay debt they owe, or pay school fees for children or marrying more wives or other non-farm activities thus showing a reduction in the cropping activities of rice and vegetable and later on maize. So it can be seen clearly that the agricultural income of the medium scale farmer was not affected by the increase in credit availability.



From Figure 9.31 in Appendix 12, as credit availability is increased, agricultural income of the small scale farmer increases from 329.948 cedis to 336.832 cedis in year 1 showing a 2.08 percent increase and also from 211.370 cedis to 215.919 cedis in years eight also indicating a 2.2 percent increase. From the study, it is realized that credit availability in terms of physical cash does not necessarily increase agricultural farm income significantly as expected in theory. This can also be supported by studies done by Taslim Sjah, 2003, on “Factors Contributing to the performance of Agricultural Credit in Lombok, Indonesia”.

### **6.9.2 Impact of Credit Availability on Agricultural Employment**

From Figure 9.32 in Appendix 12, it illustrates that, as credit availability increases, for the large scale farmer, agricultural employment is increased, in year one agricultural employment increases from 165.83 man-days to 182.207 man-day indicating a 9.8 percent increase. Whilst in year eight there was an increase from 217.467 to 224.383 of agricultural employment showing a 3.18 percent increase. It might be that in year eight, the large scale farmer started finding other lucrative ways of investing the available credit hence a reduction in the percentage increase. But in Figure 9.33 in Appendix 12, the story is different, non-agricultural sector employment is decreased in year one, from 220.272 man-day's to 203.986 man-days showing a 7.3 percent decrease. Also in year eight, there was a further decrease from 256.515 man-days to 247.705 man-days indicating a 3 percent decrease. This scenario is as a result of increased credit availability to farmers that resulted in an increase in the cropping area of all crops and consequently an increase in employment for farmers to cultivate the additional land.





For the medium scale farmer, as credit availability is increased, agricultural employment is decreased and non-agricultural employment is increased. In year one, agricultural employment decreased from 122.602 man-day's to 121.816 man-days indicating a 0.6 percent decrease whilst non-agricultural employment increased from 60 man-days' to 61 man-days also showing a 1.6 percent increase. Meanwhile, in year eight agricultural employments decreased from 107.857 maydays to 106.841 man-days which are about a 0.94 percent decrease whilst non-agricultural employment increases from 110.001 man-days to 110.384 man-days indicating a 0.3 percent increase. This is well illustrated in Figures 9.34 and 9.35 in Appendix 12 respectively. This reduction in employment for the medium scale farmers generates from the fact they reduced their cropping area for agricultural crops indicating that they (medium scale farmers) further invest in nonfarm activities and this also is shown by increases in their non-farm employment.

Consequently, from Figure 9.36 in Appendix 12, it indicates that with an increase in credit availability, agricultural employment for the small scale farmer increases. In year one the increase is from 122.044 man-day's to 123.034 man-days indicating a 0.8 percent increase and a further increases in year eight from 105.759 man-days to 110.074 maydays showing about 4 percent increase. This is also from the fact that, the small scale farmer increased his cropping area for all crops and hence the increase in employment. But nonfarm employment also decreased slightly from 49 to 48.98 man-days about 0.04 percent decrease and remained almost the same in subsequent years.





### **6.9.3 Impact of credit Availability on Non Agricultural Consumption**

From Figure 9.37 in Appendix 12, as more credit is made available, non-agricultural consumption increases for the large scale farmer from 372.107 cedis to 389.607 cedis indicating a 4.7 percent increase and this trend follows through till year eight which also increases from 579.112 cedis to 587.407 cedis. Also showing about 1.4 percent increases in consumption. This shows that as credit is made available, farmers divert some of the cash received into the consumption of non-agricultural consumption. As a result of increased income, the taste of the consumer changes from agricultural consumption to non-agricultural, thus confirming the theory of consumer behavior. Also, from Figure 9.38 in Appendix 12, as credit availability increases non-agricultural consumption increases for the medium scale farmer from 317.925 cedis to 320.742 cedis showing a 0.88 percent increase and this trend follows through till year eight which increases from 257.559 cedis to 294.122 cedis also indicating a 14.1 percent increase. This shows that as credit was made available, farmers divert some of the cash received from increasing cropping areas into non-agricultural consumption.

From Figure 9.39 in the Appendix 12, as credit availability increases non-agricultural consumption increases for the small scale farmer from 342.941 cedis to 348.448 cedis indicating a 1.6 percent increase, and this trend follows through till year eight which increases from 254.213 cedis to 257.367 cedis also showing a 1.2 percent increase. This shows that, as credit was made available, farmers divert some of the cash received from increasing cropping areas into non-agricultural consumption as a result of change in taste and preferences.



### **6.10 Price Expectations**

The impact of a policy on the economy depends on the public's expectations about that policy. The fact that output selling price is not known, when input decisions are made, and the resulting need for farmers to make decisions on output prices based on expectations of future prices have been suggested as the main reasons for rational expectations (Eckstein, Z. 1984).

The rational expectations specifications assumes that, producers use all currently available information's to form expectations about both the mean and the variance of prices (Satheesh, V. Aradhyula, 1988). Producer price expectations underlie much of agricultural supply analysis, decisions made by farmers under conditions when the decisions relate to production ventures the outcomes of which are not known with certainty. The most important phase of this uncertainty are associated with the passing of time and include weather, insects and diseases, and costs and price variations, as well as more personal aspects such as length of life, health and in more recent times, institutional factors such as the chances of being subjected to economic controls. Hence, price movements have a significance effect on farmer's decisions. It is of interest now to find out whether a rational expectations model that accounts for some technological aspects of agricultural production can interpret well the properties of Ghana data using the MATA model.

In the model, we assume rational expectation for farmers; in this scenario, we assume that farmers expect an increase in the price of rice over the years by 10 percent, with a risk 10 percent as well. The implication on economic variables are discussed as follows: As a result of expected price increases in rice, for the large scale



farmer (EXP1), cropping activity for rice has increased, meaning that more land had been allocated to the production of rice as compared to that of maize and vegetables, that land has been taken from the production of other crops to the production of rice. From Figure 9.40 in Appendix 13, an increase in price expectation of rice resulted in an increase in the cropping activity of rice in year one, from 3.859 hectares to 3.961 hectares that is 2.6 percent increase in hectares and in year eight, the hectare of rice increased from 6.821 hectares to 7.564 hectares that is a 6.8 percent increase in hectares. From Figure 9.40, it is evident that the percentage increase in acreage in year one is the lowest at 2.6 percent as compared to that of the year eight at 6.8 percent. This can be explained by the fact that as farmers realize that their expectations have materialized, they kept increasing their percentage of acreage of land towards rice production. And that of maize and vegetables were decrease as a result, maize decreased in year one about 0.2 percent, and decreased further to about 50 percent in year eight, this is also true for vegetables, in year one there was about a 0.1 percent decrease and about a 11 percent decrease in year eight.

For the medium scale farmer, it is evidently clear that the cropping activity toward the production of rice has increased. From Figure 9.41 in Appendix 13, land allocated to rice increased significantly for the medium scale farmer even than the large scale farmer. In year one, hectares of rice increased from 3.647 ha to 3.976 ha, an 8.2 percent increase as a result of price expectation of increase rice prices, as well as in year eight, rice acreage increased from 3.161 to 4.683 hectares, a 32.5 percent increase as compared to maize that decreased in year eight from 0.35 to 0.23 hectares. This shows clearly that, as farmers continue to correctly predict the price of rice, their confidence in their forecasting ability is increased,



enabling them to increase the percentage or shift more to the increase in acreage of rice production.

For the small scale farmer, it follows that, as the expectation of the farmers is that, price of rice in the future would increase their decision towards the production of rice changes. They decide to increase the acreage of land allocated to the cultivation of rice as compared to other crops under cultivation as well. In year eight, land acreage for rice increased from 3.582 hectares to 4.017 hectares a 10.8 percent increase in hectares. And also in year eight, the land allocated to rice increased from 3.145 to 4.303, a 26.9 percent increase in acreage. Showing a 16.1 percent increase from year one to year eight, this is clearly illustrated in Figure 9.42 in appendix 13, meanwhile there is a continuous decrease in the cropping activity of maize and vegetables.

These analyses indicate how price expectations of farmers are very vital to the agricultural sector and decisions of the farmers in terms of productions. The evidence of this result is consistent with a real case study in Ghana in the earlier 2000, when the president announced an increase in price and a ready market for the cassava starch plant, for the subsequent seasons after the announcement, farmers increased the cultivation of and the production of the cassava starch. There was also new entry of other farmers as well. It was so serious that even food crops suffered and thus causing a little shortage in some regions for staple foods (Ghana Web, 2000). Also a study by Danh Thanh , 2007 in Vietnam also confirmed the results of this study, by using the dynamic adaptive adjustment and rational expectations model, stated that rice farmers were rational in forming price expectations behavior, and that output supply and marketed surplus were positively responsive to price expectations,



he also concluded by saying that price expectations played an important role in decision making of rice farmers and that an appropriate price policy becomes an alternative way to enhance rice production in the country. A third study by Huang, 1992 in his paper on the effect of government programs on rice acreage decisions under rational expectations, the case of Taiwan states that the marginal effects of a price –support program on acreage decline as soon as targeted price is no longer increasing.

#### **6.10.1 Impact on Yearly Agricultural Production**

The expected price increases of rice prices, yearly farm production for rice increases for large scale farmers, medium scale farmers and small scale farmers, mainly result in increase in land acreage of rice. As shown in Figure 9.43 in Appendix 13, the production of rice has increased significantly as a result of price expectations of farmers concerning the price of rice, compared to other crops grown in the same season with no price expectations. From years one through eight, there was an average increase of about 12 percent, whilst that of maize decreased by an average of 45 percent and vegetables also decreased by an average of 8 percent for the large scale farmer. For the medium scale farmer in Figure 9.44 in Appendix 13, there is also an increase of rice on the average of about 30 percent, and that of maize decreased on the average for about 46 percent and vegetables also decreased for about 6 percent. But for small scale, farmer in Figure 9.45 in Appendix 13, an average increased for rice was 53 percent and an average decreased for vegetables was 4 percent. From the production figure it is realized that the percentage increase is highest for the small scale farmer followed by the medium scale farmer then the large scale farmer. This could be attributed to the fact that, it is usually possible for the small scale farmer to take



more risk in production than the large scale farmer, because the large scale farmer would lose more if the expectations do not become a reality.

#### **6.10.2 Impact on Agricultural Income**

Price expectations also affect the income of the farmers. From Figure 9.46 in Appendix 13, in year one, the change in income for the large scale farmer, as a result of price expectation was quite insignificant indicating an increase from 450.777 cedis to 451.738 cedis showing a 0.21 percent decrease, over the years. Although price expectation increased production, agricultural income did not reflect this pattern, maybe due to either over production of rice as a result of the expected price rise, or it might also be due to the fact that the percentage decrease in the cultivation of the other crops like maize and vegetables is not well compensated by the percentage increase in rice. From Figure 9.46 in Appendix 13, from year one to year three, income increase was very insignificant, but as the rate of production increases for all the farm types, there might have been increase in the supply of rice in the market with a constant demand, therefore there would be excess supply than demand, if provision is not made by the government to purchase the excess or store for farmers in order to resell in the lean season. This would consequently affect the agricultural income causing it to reduce in the subsequent year where there are more entry of new farmers into the rice market as a result of the rise in price. The policy of price expectation of rice, increases income in the early years of production and policy implementation, and decreases income in the later years of the policy implementation. As shown in year eight, when there was a decrease from 697.211 to 580.085 showing a 16.7 percent decrease in income for the large scale farmer. For the medium scale farmer in Figure 9.47 in Appendix 13, as a result of price expectation his



income increased over the years, in year one his income increased from 398,310 cedis to 419,410 indicating an increase of 5.2 percent and there was a further increase in year eight from 314,715 to 664,808cedis also showing a 16 percent increase. For the small scale farmer in Figure 9.48 in Appendix 13 his income increased over time. This might be because he produced less so is not affected as much , his income increased from 329.948cedis to 389.939cedis showing an 18 percent increase, and also in year eight he also gained about 58 percent increase in income. This is consistent with a study by Kwang Dong Cho,1996 , who foud that 1 percent increment in government purchase price of rice , increases income per farm by about 1.9 percent.

In conclusion, our results suggest that, price expectations work better for the medium and small scale farmers than the large scale farmer after the first three years. This could be attributed mainly to their farm size.

### **6.11 Land Reform Scenario**

Land acquisition in Ghana comes with a very high transaction cost as a result of the way land is owned in Ghana. As discussed in earlier chapters, it is difficult to acquire very large amount of land for plantations and large scale farming for international large scale export. This is one of the big limitations to the expansion of the agricultural sector and self-food sufficiency for the country. As a matter of fact the land tenure in Ghana has to be reformed, various suggestions and empirical work has been put in the domain of the government to implement so as to enable, easy access to large scale land acquisition. Some of these studies (Ernest Aryeetey & Chris Udry 2010) suggested land banks, as a way of acquiring land on a large scale and reducing the transaction cost that comes with





land acquisition. This scenario comes in to further emphasize the need for a reform in the land tenure system of Ghana. In this scenario, it is assumed that there is no transaction cost to land acquisition and land has increased in availability by 10 percent. The following effects are what the model established.

From Figure 9.49 in the Appendix 14, as a result of land reform policy and increased access and availability to land, the cropping activity increased for rice from 3.859 ha to 5.315 ha indicating a 38 percent increase, maize cropping activity also increased from 0.519 ha to 0.760 ha also showing a 46.4 percent increase, whilst vegetables also increased from 0.063 ha to 0.084 ha in year one indicating a 33 percent increase, and this increases continued through the year till year eight, where rice further increased from 6.821 ha to 7.41 ha showing an 9 percent increase, and maize increased from 0.747 ha to 0.811 ha showing a 8.5 percent increase and finally vegetables also increased from 0.138 ha to 0.148 ha indicating a 7.2 percent increase for the large scale farmer. Consequently from Figure 9.50 in Appendix 14, for the medium scale farmer, a 10 percent increase in land availability results in an increase of cropping activity for rice from 3.647 ha to 4.432 ha indicating 21 percent increase, maize increased from 0.454 ha to 0.557 ha showing 22 percent increase and vegetables also increased from 0.062 ha to 0.071 ha in year one also indicating 14.5 percent increase. Thus, there was a further increase in year eight, where rice cropping activity increased from 3.161 ha to 3.675 ha showing a 16.26 percent increase, whilst maize increased from 0.350 ha to 0.403 ha indicating a 15.14 percent increase and vegetables increased from 0.065 to 0.077 ha also showing 18.4 percent increase for the medium scale farmer.





Also from Figure 9.51 in Appendix 14, the small scale farmers experienced an increase in the cropping activity of rice from 2.982 ha to 3.679 ha indicating 23.3 percent increase, maize increased from 0.397 ha to 0.481 ha demonstrating a 21 percent increase and vegetables 0.057 to 0.064 ha in year one showing a 12.2 percent increase, as a result of increased in land availability with the new land policy reform in Ghana. Also in year eight, rice increased in cropping activity from 2.145 ha to 2.843 ha indicating a 33 percent increase, maize from 0.245 ha to 0.321 ha is showing 31 percent increase and finally vegetables increased from 0.055 ha to 0.080 ha also indicating 45.4 percent increase. From the three different farms, it can be seen as a result of land availability, there was an increase in all the cropping activities, for the large scale and medium farmer, the percentage increase in maize was higher. This could be as a result of maize being a staple food in the area and the demand for maize might be higher than the other food crops, but for the small scale farmer, the percentage increase for rice is about two percent higher than that of maize in the first year, this might be as a result of the high price of rice. The small scale farmer would want to increase his income or profit since he has a smaller amount of land area.

#### **6.11.1 Impact on Agricultural Income**

Figure 9.52 in appendix shows that, as a result of high land availability, the agricultural income of the large scale farmer increased considerably from 450.777 cedis to 596.384 cedis in year one indicating a 32 percent increase. Whilst a further increase in year eight is from 697.211 ha to 758.586 ha, indicating an increasing trend over the eight years period with a 9 percent increase. Also demonstrated in Figure 9.53 in Appendix 14, the



agricultural income for the medium scale farmer increased as a result of the favorable land reform policy, income increased from 398.310 cedis to 487.263 cedis in year one showing a 22.3 percent increase, and in year eight, an increase in agriculture income from 314.715 cedis to 357.502 cedis also indicating a 14 percent increase in the income of the medium scale farmer.

For the small scale farmer, there is an increase in agricultural income from 329.948 cedis to 429.449 cedis indicating a 30 percent increase. In year eight, there was a further increase from 211.370 cedis to 273.547 cedis also showing a 29.4 percent increase, this is shown in Figure 9.54 in Appendix 14. These results are also consistent with other studies that have shown that increase in land availability increases farm or agricultural income. A national report on Kenya, presented at the international conference on agrarian reforms and rural development, 2006 also confirmed that, access to land has contributed greatly to increased incomes and agricultural production.

Mao (1987) discussed the land reform program implemented in the 1950s in Taiwan, which brought about a radical change in the distribution of land. Since land was the major source of farm income, land reform contributed to a redistribution of income, which improved the social and economic status of farmers and reduced the unemployment in rural areas. The reform program provided production incentives to farmers and facilitated the implementation of complementary agricultural measures, such as credit, extension, and other supportive services. Agricultural performance after the land reform, productivity growth, inputs, and technology and increased agricultural output were indications of the positive spin-off effects of land reform. Mao concluded that



land reform was the major factor in establishing the initial conditions conducive to an equitable growth in Taiwan's agriculture. A study by Salam Memon on The Impacts of Land Reform on Farm Production and Income Distribution in the Agricultural Sector of Sindh Province of Pakistan, 1993 supported the study that, contrary to expectations that farm income was expected to decrease as farm size increases, all the coefficients for farm size are positive, suggesting that as farm size increases, farm income also increases. This indicates that there is a positive relationship between land availability, farm size, and agricultural income.

#### **6.11.2 Impact on Employment**

From Figure 9.55 and 9.56 in Appendix 14, as a result of an increase in land availability, agricultural employment increases as non-agricultural employment decreases. Throughout the eight year period, this trend has been consistent. In year one, for the large scale farmer, agricultural employment increases from 165.83 man-days to 282.969 man-days indicating about a 70 percent increase but non-agricultural employment decreases from 220.272 man-days to 115.928 man-days indicating a 47 percent decrease. In year eight, agricultural employment increases from 217.46 7 man-days to 238.725 man-day's showing a 9.7 percent increase whilst there is a decrease of non-agricultural employment from 256.515 to 239.152 man-days also indicating a 6.7 percent decrease.

From Figure 9.57 and 9.58 in Appendix 14, as a result of increase in land availability, agricultural employment increases as non-agricultural employment decreases. Throughout the eight year period, this trend has been consistent. In year one, for the medium



scale farmer, the agricultural employment increases from 122.602 man-days to 124.695 man-days showing a 1.7 percent increase, at the same time as non-agricultural employment in year one is the same at 60 days. But further, in year five to eight, the decrease was reflected with a decrease from 78.693 man-days to 72.930 man-days indicating a 7.3 percent decrease. In year eight, agricultural employment increases from 107.857 man-days to 128.623 man-days showing a 19 percent increase. There is a decrease of non-agricultural employment from 110.001 man-days to 90.978 man-days indicating a 17 percent decrease.

From Figure 9.59 and 9.60 in Appendix 14, as land reform policy is implemented, and land is made more accessible and available, agricultural employment increases considerably over the years. In year one, agricultural employment increases from 122.044 man-days to 124.214 man-days indicating a 1.7 percent increase, whilst non-agricultural employment decreases or remains the same. In year one, non-agricultural employment remains the same at 49 man-days. In year six, there was a decrease from 66.671 man-days to 62.538 man-day's showing a 6 percent decrease. In year eight, agricultural employment increases from 105.729 man-days to 133.911 man-days indicating a 26 percent increase. Non-agricultural employment decreases from 95.596 man-days to 70.545 man-days showing a 26 percent decreases.

### **6.11.3 Impact on Total Farm Wealth**

From Figure 9.61 in the Appendix 14, total farm wealth increases over the period of eight years as a result of a 10 percent land availability. In year one, for the large scale farmer, total farm wealth increases from 573.866 cedis to 754.004 cedis indicating a 31.3 percent increase, also in year eight total farm wealth increases from 950.057 cedis to 1027.599 cedis showing an 8.16 percent



increase. Referring to Figure 9.62 in Appendix 14, for the medium scale farmer, total farm wealth increases from 503.300 cedis to 609.389 cedis indicating a 21 percent increase. Also in year eight, it increases from 427.100 cedis to 483.751 cedis showing a 13 percent increase. This increase is attributed to a 10 percent land availability thus this increases farm income, cropping activity, farm employment, and hence also showed an increase in the total wealth of farmer. This is also true for the small scale farmer. From the Figure 9.63 in Appendix 14, total farm wealth increases from 442.050 cedis to 566.695 cedis showing a 28 percent increase. Also in year eight, it increases from 321.425 cedis to 402.975 cedis indicating a 25.3 percent increase. These increases demonstrate the impact of land availability on the economic, social and welfare of the farmers.

## **6.12 Change in Technology Scenario**

The principal goal of this scenario was to analyze the change in income, water use and crop allocation, in the situation that new water saving technologies are made available for the agricultural farmers in the Volta basin area.

The most common irrigation practice in the area is flooding the fields with seasonal water gravity fed systems, and furrow/canal irrigation which cannot produce year round crops or diesel/fuel pumps, which is neither efficient nor cost effective.

Faludi, 2007 stated in his study that the amount of water wasted by inefficient irrigation is around four times the total amount of water used by commercial and residential buildings. Therefore, in order to save water for other uses, it is very vital to reduce the inefficiencies in water use in the agricultural sector by introducing



efficient irrigation methods. Hence, increasing water use efficiency and decreasing water demand in the Volta basin is crucial for ensuring water availability for maintaining or improving crop yields and farmers' income and standard of living.

The conversion of the old running water irrigation system into drip irrigation technology would save tons of water that goes into the air as evaporation. With the system of drip irrigation; the plants need certain quantity of water per day so we can control the amount of water supply. And hence a reduction in the number of times water is pumped and consequently a reduction in the use of energy.

The use of a new irrigation technology is a way that water can be used efficiently. One of such technologies proposed in this study is the drip irrigation technology (Ghanaweb, 2009). The drip irrigation system is believed to cut down water use by 60% as compared to the furrow system and could therefore help prolong farming activities in the dry season's periods and also increases yields by over 50%, higher than the furrow or canal, flooding, and pumping methods of irrigation (EWB report, 2009).

The use of drip irrigation technologies have actually been tried on pilot basis and are used only for the production of vegetables on a small scale level at the moment.

Some of the side effect of using drip irrigation may be the accumulation of salt in the root zone. The cost of installing drip irrigation is also very high and thus this could also be a limiting factor. The cost of introducing a drip irrigation system per one acre



was estimated to cost about \$800 to \$1600 per acre (Jeremy Faludi, 2007) in the region, with an average life span of eight years.

For the purpose of this scenario, it was assumed that drip irrigation is used for vegetables only. This is because in Ghana, data could only be gotten for vegetables as this is done on a small scale basis and not yet expanded and used for other crops. More-over, crops with less profit are not considered as a result of the high expenses related to investment in these technologies. Also, for the purpose of the model estimations, the cost was assumed to be equally distributed over the life span with an additional span for depreciation and maintenance cost each year after the first year.

From the model, when drip irrigation was introduced, water use was 60 percent lower than under the conventional furrow irrigation because less water was required under this alternative irrigation method.

From Figure 9.64 in Appendix 15, as a result of the use of drip irrigation the crop area allocated to vegetable increased dramatically in year one from 0.063 ha to 0.1 ha for vegetables indicating a 58.7 percent increase. And the crop area allocated to vegetables further increased from 0.138 ha to 0.223 ha in year eight also showing a 62 percent increase.

#### **6.12.1 Impact on Agricultural Income**

The use of drip irrigation system consequently affected the agricultural income of the farmer as well. From the figure 9.65 in Appendix 16 shown that as a result of the use of drip irrigation, the income of the farmer increased in year one from 452.188 cedis to 471.662 cedis showing a 4.3 percent increase and also in year eight increases from 690.815 cedis to 730 cedis also indicating a 6





percent increase. It is realized that the percentage increase in income is not as significant as the percentage increase in the cropping activity. This might be because, after taking the cost of the drip irrigation, and its depreciation, the income left would not be much, but after the eight year, when the farmer has finish paying the cost of the irrigation, the income might increase significantly (this can be seen in Figure 9.65 in Appendix 15).

### **6.12.2 Impact on Agricultural Employment**

As a result of the use of drip irrigation from Figure 9.66 in Appendix 15, agricultural employment increased in year one from 165.83 man-day's to 168.602 man-days showing about 2 percent increase. In year eight, agricultural employment decreased from 217.467 man-days to 217.152 man-days also indicating a 0.14 percent decrease. The increase in the first years might be as a result of the expansion of the cropping area and the employment of labor for the use and maintenance of new technology, but the decrease in the eighth year might also be as a result of the drip irrigation. Farmers do not need a lot of labor for irrigation as a result of the fact that drip irrigation system is not labor intensive. This can be supported with evidence from Jain Irrigation system limited that which shows that drip irrigation assists in savings in labor and fertilizer costs. A study by Leon New and Roland E. Roberts (2007) on "Drip Irrigation for Greenhouse Vegetable Production", stated that more labor is required for its installation in the first years, but consequently the drip irrigation reduces labor employment.





### **6.12.3 Impact on Farm wealth**

From Figure 9.67 in Appendix 15, the total wealth of the farmer increased as a result of the use of drip irrigation. In year one, total wealth increased from 573.866 cedis to 593.89 cedis indicating a 3.5 percent increase and also further increased in year eight, from 950.057 cedis to 994.739 cedis also showing a 4.7 percent increase. The increase in the total farm wealth of the farmer illustrates the impact that a new technology has on the farmer as it first increases its cropping activity, increases income and then the wealth of the farmer as a result of increases in the yield of the crops.



## **7.0 Summary, Conclusions and Recommendations**

### **7.1 Introduction**

The agriculture sector in Ghana is the backbone of the rural economy. Agriculture employs about 60 percent of the population and contributes extensively to the GDP of the country. It is also a major foreign exchange earner. However, low productivity and a non-efficient use of inputs coupled with high input prices has gone a long way to have a negative impact on the population that depend on this sector. The high water demand in the region for crop production renders farmers vulnerable to the periodic decline in water supply as a result of drought. Water availability from rainfall has decreased in recent times, as the rainy seasons have become shorter in days and the dry seasons have become longer. Expected declines in water availability in the near future are the result of increasing water demand in the regions, increase in population growth rate, continuous expansion of irrigated areas with the cultivation of high water demanding and more profitable crops, and the unpredictable effects of climate change.

Decreasing water demand and preserving a profitable agricultural sector is a major challenge to farmers in the Basin regions. The study aims to establish how water would not be used wastefully but sustainably for a thriving and viable agricultural sector now and in the future.

This study contributes to the understanding of key limitations and potential solutions to promoting sustainable development in the agricultural sector.



### **7.1.1 Analytical framework**

To achieve the above objective, 530 farm households were interviewed using the common sampling framework in the Volta Basin of Ghana from June 2005 to August 2008. A Focus group discussion as well as interviews with institutions concerned with water and agriculture resources were also considered. Methodologically, a non-linear programming model named MATA model was employed to achieve the stated objectives.

In spite of its limitations such as inadequate data and the fact that not all the wealth creating variables such as livestock and fodder crops of the farmer were used the study was still able to achieve its main objective.

The main objective of the study was to find or come out with policies that would support to reduce the inefficiencies in water use in the agricultural sector in Ghana, and also at the same time increase the income and production of the agricultural sector. In the study, one of the policies that was considered to reduce the demand for water in the agricultural sector was water pricing. This policy was further implemented through the MATA model using data both secondary and primary data collected over a period of time (2005-2008). The results obtained indicated that water pricing was a sure way to reduce the demand for water in the agricultural sector but it came along with some costs to the farmers and their standard of living. From the results, the point where the demand for water is reduced by the farmer is also associated with decreases in the income of the farmer, labor employment, total wealth and consumption of the farmer.



The second policy that was considered for reduction in water demand in the agricultural sector was the use of a new technology, such as the drip irrigation in order to reduce the wastage that is caused by the canal /furrow irrigation system. This policy was also implemented using the MATA model and the results indicate that the use of a new technology such as the drip irrigation would actually decrease the demand for water. Increased efficiency of water use in the agricultural sector increases the yield and its quality as well as the income and total wealth of the farmer. But it is also accompanied with a disadvantage which is the cost associated with the installation and purchase of this kind of new technology (Drip Irrigation). It is realized that, the cost of implementing the drip irrigation system is very high and that most farmers would not be able to use this system, as a large proportion of the farmers in the agricultural sector are subsistence farmers. Hence, the use of this system could only be achieved on a small scale basis and could not also be used for all types of crops because of its cost, unless government becomes the major provider of this technology. It is also recommended that the use of drip irrigation can also be encouraged when high water prices are introduced, this would enforce farmers to use less water by also changing their irrigation technology for a more water efficient one.

The repair and maintenance of the canal and furrow irrigation system was also recommended as from the model, it was realized that due to the breakage and poor maintenance of the canal irrigation, most of the water is wasted along the way before it reaches its main destination (farms). This is from losses during conveyance.



These policies were implemented in order to see the effect on the water demand in the country. However, the model further went on to demonstrate what happens when water is not used efficiently, with the vulnerability of climate change resulting in low rainfall consequently causing a reduction in water supply, thus causing water scarcity as predicted by various studies of what would happen in the future. This water scarcity scenario was also implemented in the MATA model and the results indicate that a decrease in water supply would result in a decrease in crop yield, a decrease in farmers' income as well as employment and total farm wealth. This scenario showed evidence of how important it is to reduce the inefficiencies of water use in the agricultural sector. This scenario, as compared to all the other scenarios run by the model has the most severe effect on the farmers, with regards to the percentage decrease in cropping activity, income, employment and total wealth. Indeed, its impact is about twice that of almost all the scenarios. This is also the only scenario that might bring hunger and consequently the demise of the population if care is not taken. Comparing this scenario of water scarcity to that of water pricing, it can be seen from the results that, it is better to use the water pricing policy in its early stages with its associated impacts on the farmer than to wait and experience the severe impact of water scarcity. Therefore, in order to curb the effects of this scenario, water harvesting and a reduction of water demand in the agricultural sector was recommended and this could be done by the introduction of the water pricing policy or the introduction of a new technology like the drip irrigation and other water saving technologies.

In the bid to increase agricultural production, the investment into irrigation facilities is recommended as this is also included in the



eight Millennium Development Goals (MDGs) in 2000. Government is therefore advised to invest more in small scale irrigation schemes than in large scale irrigation schemes for effective and efficient results. As an increase in irrigation in the country would increase production, increase yield and increase the income, employment and standard of living of the farmers (Dittoh, 1998).

The model also implemented the impact of credit availability on the agricultural sector. The results indicate that real cash given to farmers does not enhance production as expected. It was also found that as government increases credit availability in cash to farmers, most farmers instead of using the money to invest directly in agricultural activity used the money to increase their non-agricultural consumption, such as paying old debt, using the money to pay children school fees and investing in other nonfarm activities such as marrying more wives (evidence from focus group discussions in the various regions). This means that policy makers and the banking sector should find other more realistic ways to increase agricultural production by means of giving credit to farmers other than giving them physical cash.

It was also found that as farmers expect that prices of rice would increase in the future, more land is allocated to the production of rice and farm employment is increased as most farmers would employ more agricultural labor and there is a reduction in off-farm labor. So for the government to encourage the production of a particular crop, the expectation of farmers would be one area to concentrate on.



From the input liberalization scenario, it is also seen that a liberalized input market for fertilizer has a negative impact on the cropping activity of all farmers, employment, and total wealth as well as yield of the farmers. It is therefore recommended for the government to maintain the subsidies on fertilizer especially.

Finally, increase in land availability without any transaction cost increased the cropping area allocated to all crops, farmers' income, farm employment, and total wealth of the farmer. It also made it possible for farmers to be able to have infrastructures that are more permanent on the farm thus encouraging capital investment.

The study also went ahead to make some recommendations to the government in order to be able to implement some of these policies practically. The study recommends that as a result of the negative impact water pricing has on income and employment; it is advisable that it be used in combinations with other relevant policy instrument such as water harvesting and other water saving technologies alongside in order to achieve a meaningful result. It is proposed that a price of water (about 2 cedi/m<sup>3</sup>) might be of significance so as to let farmers be conscious of the scarcity of water resources, and to persuade farmers to take on other water saving technologies so as not to affect crop allocation. To get the full impact of water pricing as it has helped other countries, the revenues from the collection of the water prices should be administered by officials or water users associations for investment in the agricultural sector and new irrigation technologies, however proceeds that are not properly invested might be shifted to the Ghana Water Authority or to the newly formed Volta Basin Authority. Water transfer should also be encouraged in the regions, so that in the periods that there is water scarcity in one region the



other region that is water abundant can transfer water to the water scarce regions.

In terms of increasing credit availability to farmers, the study recommends that farmer should be given inputs instead of the physical cash. In that case, banks should also be able and prepared to support the farmers with some marketing, in that in times of bumper harvest, banks should be able to provide silos for farmers, so that their produce would be saved and then resold in lean season in order that, they would be able to make some profits and this would enable them pay the debt owed the bank.

The land tenure system in the country should be looked at in order to reduce the transaction cost in acquiring land so as to encourage the acquisition of more land for farm expansion. The policy of land banks and flexible leasing terms should be pursued so that farmers would be encouraged to do capital investment on the land as well as benefit from economies of scale as a result of large scale production.

## **7.2 Application to Real Life Situation**

This model can be applied to the real life situation because it has been calibrated and validated. Data used were also collected in the study area through focus group discussion. This makes it possible to get at least an average result. This is so because unlike in the normal household surveys where each household head would only tell you what you want to hear, validating this is at times not possible. In the focus group discussion, the farmers correct each other during the discussion, by saying, what a particular farmer is saying is far from the truth, or not realistic in the area in which they are working. In this way, the farmers are more accurate as





they know their colleague farmers are their “validators”. This method also comes with some disadvantages in that some questions are also not well answered. Questions on methods and times of cropping and on income are better dealt with using household surveys since most farmers would not want their other colleague farmers to know what they have done or how much they earn from their farms. This study also in view of the above, conducted household or farm-specific surveys. Finally, secondary data were also collected to see what has been done over the years and to fill in the gaps of data that earlier surveys were not able to provide.

These evidently show the amount of work that has been put into this work. Exclusion of livestock in the model process makes the model quiet incomplete, but the results of the model are as realistic as it can get. And can be used by policy makers in making policy decisions.

This study has contributed immensely to the general empirical literature on water demand management in the agricultural sector of Ghana. In general, all the results are consistent with literature. The strength of the thesis is the introduction of the water simulation model (emphasis water demand) and the inclusion of some variables such as, the introduction of new technology, water pricing and also incorporating climate change variable, which makes a significant difference in this work as compared to others.

### **7.3 Further Research**

The MATA model designed for the Volta Basin in this study allows one to investigate the economic, social and ecological impacts from policy and technology options expected to be



implemented in the near future in the Basin region. While the MATA model served as an appropriate tool for exploring the impact of water demand on farmers' income, some level of uncertainty in the model results remains due to existing data limitations.

Resource availability (e.g. water, labor) is a constraint in the model and is based on annual average availability of resources for the given farmers in the region. Higher frequency data would significantly improve the model specification. The number of crops could be increased in further research. The inclusion of livestock in the model should also be considered, this would give the model a more realistic nature.

Another area requiring further attention is with respect to water saving technologies in the region. The results from this study point to an increased need for additional, comprehensive research on various water saving technologies in the Basin. Region-specific data on various water saving technologies would allow for improving the model parameters with available data. The research on sprinkler irrigation and laser leveling irrigation scheme would be interesting for further research.



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## 8.0 APPENDICES

### Appendix 1: Crop Water Use for Maize

CROP WATER REQUIREMENT MAIZE			
LOCATION	CWR(mm/period)	IRRWR(mm/period)	FWR(l/s/ha)
ACCRA	396.07	166.56	0.2
ADA	396.2	219.33	0.27
AKUSE	410.68	78.59	0.1
AXIM	359.98	0	0
BOLE	397.33	18.15	0.02
HONUTA	389.44	22.91	0.03
KETE KRACHI	409.38	0	0
KUMASI	369.56	1.4	0
NAVRONGO	473.67	7.88	0.01
SALTPOND	382.97	108.15	0.13
SEFWI	360.63	0	0
TAKORADI	355.96	45.52	0.06
TEMALE	428.14	11.04	0.01
WA	445.57	15.95	0.02
WENCHI	377.16	48.23	0.06
YENDI	422.69	4.47	0.01

Source: Own Compilations

### Appendix 2: Crop Water Use for Vegetables

CROP WATER REQUIREMENT FOR VEGETABLES			
LOCATION	CWR(mm/period)	IRR WR(mm/period)	FWR(l/s/ha)
ACCRA	357.41	250.39	0.44
ADA	357.28	188.83	0.33
AKUSE	354.18	129.69	0.23
AXIM	322.67	60.17	0.1
BOLE	399.16	394.35	0.69
HONUTA	344.83	102.8	0.18
KETE KRACHI	352.22	122.48	0.21
KUMASI	297.03	67.75	0.12
NAVRONGO	436.04	436.04	0.76
SALTPOND	351.54	233.3	0.41
SEFWI	293.6	63.62	0.11
TAKORADI	318.83	166.92	0.29
TEMALE	434.01	434.01	0.76
WA	475.26	474.94	0.83
WENCHI	379.49	317.76	0.55
YENDI	479.19	476.61	0.83

Source: Own Compilations



### Appendix 3: Crops Budget for Various Agro-Ecological Zones

<b>Crop: ...Valley Bottom Rice</b>			
<b>Technology. . . . IMPROVED</b>			
<b>Ecological Zone . . . DECIDUOUS FOREST</b>			
ITEM / ACTIVITY	QTY OF RESOURCE	UNIT COST (¢)	TOTAL COST (¢)
<b>A. LABOR INPUT:</b>	<b>Man days unless otherwise stated</b>	<b>Cost/man-day</b>	<b>Per Acre</b>
1. Land Clearing (new land) dep. over 20 yrs)	Tractor/contract	1,600,000.0	80,000.0
manual field clearing	contract	20,000.0	20,000.0
3. Seed Nursing	5	25,000.0	125,000.0
4. Transplanting	20	25,000.0	500,000.0
5. Weeding:			
- 1 <sup>st</sup>	15	25,000.0	375,000.0
- 2 <sup>nd</sup>	10	25,000.0	250,000.0
6. Fertilizer application			
- 1 <sup>st</sup>	2	20,000.0	40,000.0
- 2 <sup>nd</sup>	2	20,000.0	40,000.0
7. Bird scaring	30	5,000.0	150,000.0
8. Harvesting	20	23,000.0	460,000.0
9. Drying	4	14,000.0	56,000.0
10 Threshing	3	23,000.0	69,000.0
11. Bagging	3	23,000.0	69,000.0
12. Transportation	No. of Unit(s)	Unit cost	Total Cost
- fertilizer, 50kg bags	2	3,000.0	6,000.0
- seed, 40kg bag	1	2,000.0	2,000.0
-carting of produce (84 kg bags)	25	3,000.0	75,000.0
<b>Sub - Total (A)</b>			<b>2,317,000.0</b>
<b>B. LAND RENT:</b>	<b>Per acre</b>	<b>160,000.0</b>	<b>160,000.0</b>
<b>C. VARIABLE INPUTS</b>	<b>No. of Unit(s)</b>	<b>Unit cost</b>	<b>Total Cost</b>
- improved seed, 40 kg bag	1	120,000.0	120,000.0



-fertilizer, 50 kg bags :			
- NPK	2	230,000.0	460,000.0
- SOA	1	250,000.0	250,000.0
<b>Sub - Total (C)</b>			<b>830,000.0</b>
D. TOOLS & EQUIPMENT			
- cutlass (depreciated over 2 yrs)	1	34,000.0	17,000.0
- hoe (depreciated over 2 yrs)	1	20,000.0	10,000.0
- sacks, depreciation over 2 seasons	25	8,000.0	100,000.0
Sub - Total (D)			127,000.0
<b>E. TOTAL (A+B+C+D)</b>			<b>3,434,000.0</b>
F. Contingency (5% of E )			171700.0
G. TOTAL (E+F)			3,605,700.0
H. Interest :			
- Bank rate, 35% p.a for 6 months			544,635.0
- others:			
GRAND TOTAL			4,150,335.0

**Source: Own Compilation & MOFA, 2010**

#### **Appendix 4: Crop Budget for Rice**

<b>Crop: . . . UPLAND RICE</b>			
<b>Technology . . . .IMPROVED</b>			
<b>Ecological Zone. . .GUINEA SAVANNAH</b>			
ITEM / ACTIVITY	QTY OF RESOURCE	UNIT COST (¢)	TOTAL COST (¢)
<b>A. LABOR INPUT:</b>	<b>man-day unless otherwise stated</b>	<b>Cost/man-day</b>	<b>Per Acre</b>
1. Land Clearing (new land) dep. Over 20 yrs)	Tractor/contract	1,200,000.0	60,000.0
2 Land preparation – ploughing	1	12,000.0	12,000.0
3. Planting, broadcasting	3	10,000.0	30,000.0
4. Weeding :			
- 1 <sup>st</sup>	8	12,000.0	96,000.0
- 2 <sup>nd</sup>	6	12,000.0	72,000.0
5. Fertilizer application	2	12,000.0	24,000.0



5. Bird scaring	20	3,000.0	60,000.0
6. Harvesting	20	12,000.0	240,000.0
7. Threshing	2	10,000.0	20,000.0
8. Bagging	4	10,000.0	40,000.0
9. Transportation	No. of Unit(s)	Unit cost	
- seed, 40kg bag	1	2,000.0	2,000.0
- carting of produce(80kg bags)	15	3,000.0	45,000.0
<b>Sub - Total (A)</b>			<b>701,000.0</b>
<b>B. LAND RENT:</b>	<b>Per acre</b>	<b>60,000.0</b>	<b>60,000.0</b>
C. VARIABLE INPUT	No. of Unit(s)	Unit cost	Total cost
- improved seed 40kg bag	1	150,000.0	150,000.0
-fertilizer :			
- NPK	1	202,000.0	202,000.0
- SOA	0.5	160,000.0	80,000.0
<b>Sub - Total (C)</b>			<b>432,000.0</b>
D. TOOLS & EQUIPMENT			
- cutlass (depreciated over 2 yrs)	1	35,000.0	17,500.0
- hoe (depreciated over 2 yrs)	1	25,000.0	15,000.0
- sacks (depreciated over 2 seasons)	15	10,000.0	75,000.0
<b>Sub - Total (D)</b>			<b>107,500.0</b>
E. TOTAL (A+B+C+D)			1,300,500.0
F. Contingency (5% of E)			65,025.0
G. TOTAL (E+F)			1,365,525.0
H. Interest :			
- Bank rate, 35% p.a for 6 months			231,984.4
<b>GRAND TOTAL</b>			<b>1,597,509.4</b>



## Appendix 5: Crop Budget for Maize

Crop: . . . MAIZE

Technology . . . TRADITIONAL

Ecological Zone... GUNINEA SAVANNA

ITEM / ACTIVITY	QTY OF RESOURCE	UNIT COST (¢)	<u>TOTAL COST</u> (¢)
<b>A. LABOR INPUT:</b>	<b>Man days unless otherwise stated</b>	<b>Cost/man- day/contrac t</b>	<b>Per Acre</b>
1. Land Clearing (new land) dep. Over 20 yrs)	Tractor/contract	1,200,000.0	60,000.0
2. Manual field clearing	8	12,000.0	96,000.0
3. Planting	2	10,000.0	20,000.0
4. Weeding :			
-1st	6	12,000.0	72,000.0
-2nd	6	12,000.0	72,000.0
5. Harvesting	6	12,000.0	72,000.0
6. Dehusking / Shelling	2	10,000.0	20,000.0
7. Winnowing / Threshing	4	10,000.0	40,000.0
8. Drying	2	10,000.0	20,000.0
9. Bagging	2	10,000.0	20,000.0
10. Transportation	<i>No. of Unit(s)</i>	<i>Unit cost</i>	Total cost
- carting of produce(maxi bags)	6	2,000.0	12,000.0
<b>Sub - Total (A)</b>			<b>444,000. 0</b>
<b>B. LAND RENT:</b>	<b>Per acre</b>	<b>60,000.0</b>	<b>60,000.0</b>
<b>C. VARIABLE INPUT</b>	<i>No. of Unit(s)</i>	<i>Unit cost</i>	
- improved seed, maize	4.5	7,000.0	31,500.0
- improved seed, sorghum, bowls	2	3,000.0	6,000.0
<b>Sub - Total (C)</b>			<b>37,500.0</b>
<b>D. TOOLS &amp; EQUIPMENT</b>			
- cutlass (depreciated over 2 yrs)	1	35,000.0	17,500.0
- hoe (depreciated over 2 yrs)	1	25,000.0	15,000.0





- sacks (depreciated over 2 seasons)	6	10,000.0	30,000.0
<b>Sub - Total (D)</b>			<b>62,500.0</b>
E. TOTAL (A+B+C+D)			604,000.0
F. Contingency (5% of E)			30,200.0
G. TOTAL (E+F)			634,200.0
H. Interest :			
- Bank rate, 35% p.a for 6 months			110,066.3
GRAND TOTAL			744,266.3

**Source : Own Compilations & MOFA, 2010**

### **Appendix 6: Crop Budget for Maize**

**Crop: . . . MAIZE**

**Technology . . . TRADITIONAL**

**Ecological Zone . . . DECIDUOUS FOREST**

ITEM / ACTIVITY	QTY OF RESOURCE	UNIT COST (¢)	TOTAL COST (¢)
<b>A. LABOR INPUT:</b>	<i>Man days unless otherwise stated</i>	<b>Cost/man-day/contract</b>	<b>Per Acre</b>
1. Land Clearing (new land) dep. Over 20 yrs)	contract	1,600,000.0	80,000.0
2. Land preparation			
- manual field clearing	6	20,000.0	120,000.0
3. Planting	7	20,000.0	140,000.0
4. Weeding :			
-1st	6	25,000.0	150,000.0
-2nd	5	25,000.0	125,000.0
5. Harvesting	12	25,000.0	300,000.0
6. Dehusking	3	15,000.0	45,000.0
7. Shelling	3	15,000.0	45,000.0
8. Drying	3	15,000.0	45,000.0
9. Bagging	2	15,000.0	30,000.0
10. Transportation	<i>No. of Unit(s)</i>	<i>Unit cost</i>	Total cost



- carting of produce(bags)	4	2,000.0	8,000.0
Sub - Total (A)			1088000.0
B. LAND RENT:	Per acre	160,000.0	160,000.0
C. VARIABLE INPUTS	No. of Unit(s)	Unit cost	Total cost
- improved seed, kg	5	5,000.0	25,000.0
- cassava sticks, bundles	9	20,000.0	180,000.0
Sub - Total (C)			205,000.0
D. TOOLS & EQUIPMENT			
- cutlass (depreciated over 2 yrs)	1	34,000.0	17,000.0
- hoe (depreciated over 2 yrs)	1	20,000.0	10,000.0
- sacks (depreciated over 2 seasons)	4	8,000.0	16,000.0
- basket (depreciated over 2 seasons)	3	5,000.0	7,500.0
Sub - Total (D)			50,500.0
E. TOTAL (A+B+C+D)			1,503,500.0
F. Contingency (5% of E)			75175.0
G. TOTAL (E+F)			1,578,675.0
H. Interest :			
- Bank rate, 35% p.a			501,453.8
GRAND TOTAL			2,080,128.8

**Source : Own Compilations & MOFA 2005-2008**

## Appendix 7: Crop Budget for Pepper

<b>Crop: PEPPER</b>			
<b>Technology. . . IMPROVED</b>			
<b>Ecological Zone. . . DECIDUOUS FOREST</b>			
<b>ITEM / ACTIVITY</b>	<b>QTY OF RESOURCE</b>	<b>UNIT COST (¢)</b>	<b>TOTAL COST (¢)</b>
<b>A. LABOR INPUT:</b>	<b>Man days unless otherwise stated</b>	<b>Cost/man-day/contract</b>	<b>Per Acre</b>
1. Land Clearing (new land) dep. Over 20 yrs)	contract	1,600,000.0	80,000.0



2. Land preparation :			
- manual field cleaning	6	20,000.0	120,000.0
- lining and pegging	4	20,000.0	80,000.0
3. Nursing of seedlings	5	25,000.0	125,000.0
4. Planting	8	20,000.0	160,000.0
5. Weeding			
-1 <sup>st</sup>	10	25,000.0	250,000.0
-2 <sup>nd</sup>	8	25,000.0	200,000.0
6. Fertilizer application			
-1 <sup>st</sup>	4	20,000.0	80,000.0
-2 <sup>nd</sup>	4	20,000.0	80,000.0
7. Mulching	4	20,000.0	80,000.0
8. Application of agro-chemicals	5	20,000.0	100,000.0
9. Harvesting	30	25,000.0	750,000.0
10. Bagging	5	15,000.0	75,000.0
11. Transportation			
- carting of produce	45	3,000.0	135,000.0
- fertilizer	2	5,000.0	10,000.0
Sub-Total (A)			2,325,000.0
<i>B. LAND RENT:</i>		160,000.0	160,000.0
<i>C. VARIABLE INPUT</i>			
-improved seed, sachets	50	5,000.0	250,000.0
- fertilizer			
- NPK	1	250,000.0	250,000.0
- SOA	1	160,000.0	160,000.0
others (karate lt)	1	75,000.0	75,000.0
Sub-Total (C)			735,000.0
<i>D. TOOLS &amp; EQUIPMENT</i>			
-cutlass(depreciated over 2yrs)	1	34,000.0	17,000.0
-hoe (depreciated over 2yrs)	1	20,000.0	10,000.0
-sacks (depreciated over 2 seasons)	10	8,000.0	40,000.0



-basket (depreciated over 2 seasons)	5	5,000.0	12,500.0
Sub-Total (D)			797,500.0
E. TOTAL (A+B+C+D)			4,017,500.0
F. CONTINGENCY (5% of E)			200,875.0
G. TOTAL (E+F)			4,218,375.0
H. INTEREST:			
- Bank rate, 35% p.a or 6 months			507,885.0
GRAND TOTAL			4,726,260.0

**Source : Own Compilations & MOFA, 2010**

## Appendix 8: Crop Budget for Okro

**Crop: OKRO**

**Technology. . . IMPROVED**

**Ecological Zone. . . .DECIDUOUS FOREST**

<u>ITEM / ACTIVITY</u>	<u>QTY OF RESOURCE</u>	<u>UNIT COST (€)</u>	<u>TOTAL COST (€)</u>
-	-	-	-
<b>A. LABOR INPUT:</b>	<b>Maydays unless otherwise stated</b>	<b>Cost/man-day/contract</b>	<b>Per Acre</b>
1. Land Clearing (new land) dep. Over 20 yrs)	contract	1,600,000.0	80,000.0
2. Land preparation :			
- manual field cleaning	10	20,000.0	200,000.0
3. Lining and pegging	4	20,000	80,000.0
4. Planting	6	20,000.0	120,000.0
5. Weeding			
-1st	10	25,000.0	250,000.0
-2nd	8	25,000.0	200,000.0
6. Application of fertilizer			
- 1st	4	20,000.0	80,000.0
- 2nd	4	20,000.0	80,000.0
7. Application of agro-chemicals	5	15,000.0	75,000.0
8. Harvesting	30	25,000.0	750,000.0
9. Transportation			



- carting of produce	27	3,000.0	81,000.0
- fertilizer	2	5,000.0	10,000.0
Sub-Total (A)			2,006,000.0
<i>B. LAND RENT:</i>		160,000.0	160,000.0
<i>C. VARIABLE INPUT</i>			
-improved seed, kg	1.5	5,000.0	7,500.0
- fertilizer			
- NPK	1	250,000.0	250,000.0
- SOA	1	160,000.0	160,000.0
others (karate lt)	1	75,000.0	75,000.0
Sub-Total (C)			492,500.0
<i>D. TOOLS &amp; EQUIPMENT</i>			
-cutlass(depreciated over 2yrs)	1	34,000.0	17,000.0
-hoe (depreciated over 2yrs)	1	20,000.0	10,000.0
-basket (depreciated over 2 seasons)	4	5,000.0	10,000.0
Sub-Total (D)			37,000.0
<i>E. TOTAL (A+B+C+D)</i>			2,695,500.0
<i>F. CONTIGENCY (5% of E)</i>			134,775.0
<i>G. TOTAL (E+F)</i>			2,830,275.0
<i>H. INTEREST:</i>			
- Bank rate, 35% p.a or 6 months			417,939.4
GRAND TOTAL			3,248,214.4

**Source : Own Compilations & MOFA, 2010**

## Appendix 9: Crop Budget for Vegetables

<b>Crop: VEGETABLES</b>			
<b>Technology. . . IMPROVED</b>			
<b>Ecological Zone. . . GUINEA SAVANNAH</b>			
<b>ITEM / ACTIVITY</b>	<b>QTY OF RESOURCE</b>	<b>UNIT COST (¢)</b>	<b>TOTAL COST (¢)</b>
-	-	-	-
<b>A. LABOR INPUT:</b>	<b>Man days unless otherwise stated</b>	<b>Cost/man-day/contract</b>	<b>Per Acre</b>



1. Land Clearing (new land) dep. Over 20 yrs)	contract	1,200,000.0	60,000.0
2. Land preparation :			
- ploughing		134,000.0	134,000.0
- bed preparation	1	0.0	0.0
3. Nursery preparation	2	20,000.0	40,000.0
4. Planting	3	14,000.0	42,000.0
5. Weeding			
-1st	2	21,000.0	42,000.0
-2nd	5	21,000.0	105,000.0
6. Fertilizer application			
-1st	2	12,000.0	24,000.0
-2nd	2	12,000.0	24,000.0
7. Application of agro-chemicals	2	12,000.0	24,000.0
8. Harvesting	8	10,000.0	80,000.0
9. Transportation			
- fertilizer	2	3,000.0	6,000.0
Sub-Total (A)			521,000.0
<i>B. LAND RENT:</i>		150,000.0	150,000.0
<i>C. VARIABLE INPUT</i>			
-improved seed, sachet	18	5,000.0	90,000.0
- fertilizer			
- NPK	1	195,000.0	195,000.0
- SOA	1	100,000.0	100,000.0
others (karate lt)	1	80,000.0	80,000.0
Sub-Total (C)			465,000.0
<i>D. TOOLS &amp; EQUIPMENT</i>			
-cutlass(depreciated over 2yrs)	1	32,000.0	16,000.0
-hoe (depreciated over 2yrs)	1	17,000.0	8,500.0
-basket (depreciated over 2 seasons)	4	7,000.0	14,000.0
Sub-Total (D)		5,000.0	38,500.0
<i>E. TOTAL (A+B+C+D)</i>			1,174,500.0



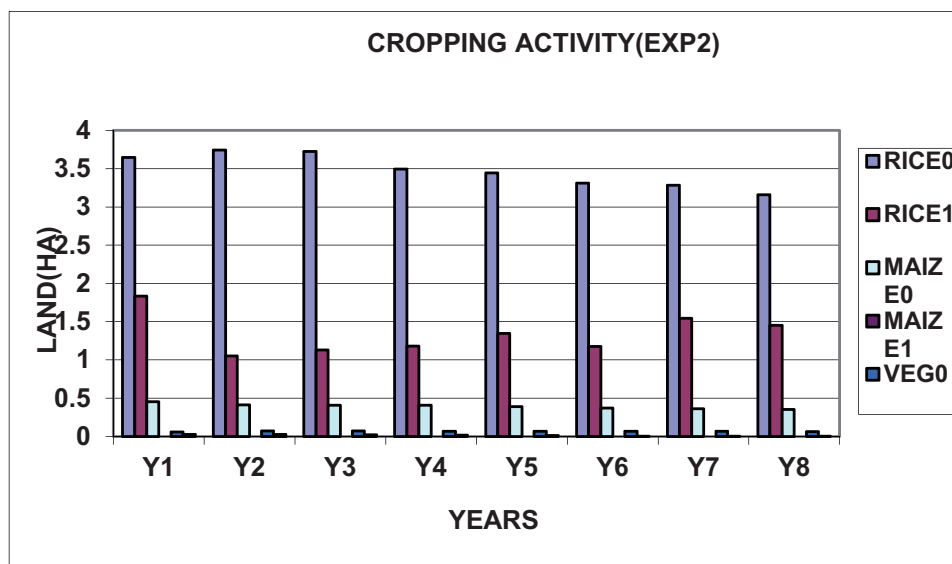
<i>F. CONTINGENCY (5% of E)</i>			58,725.0
<i>G. TOTAL (E+F)</i>			1,233,225.0
<i>H. INTEREST:</i>			
- Bank rate, 35% p.a for 4 months			143,876.3
GRAND TOTAL			1,377,101.3

**Source : Own Compilations & MOFA, 2010**

## Appendix 10: Water Availability Scenario

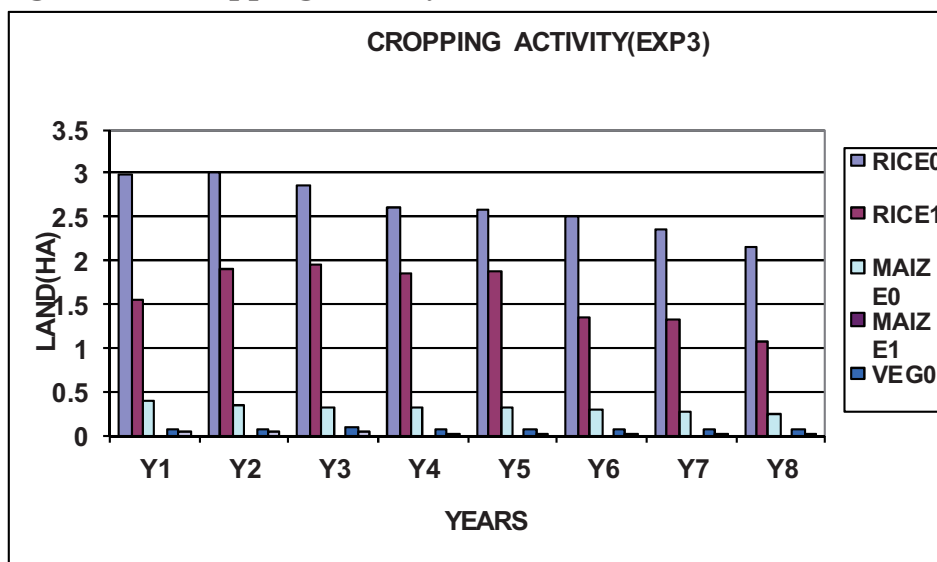
### *Impact on cropping activity*

**Figure 8.1: Cropping Activity for Medium Scale Farmers**



Source: Own Compilation

**Figure 8.2: Cropping Activity for Small Scale Farmers**

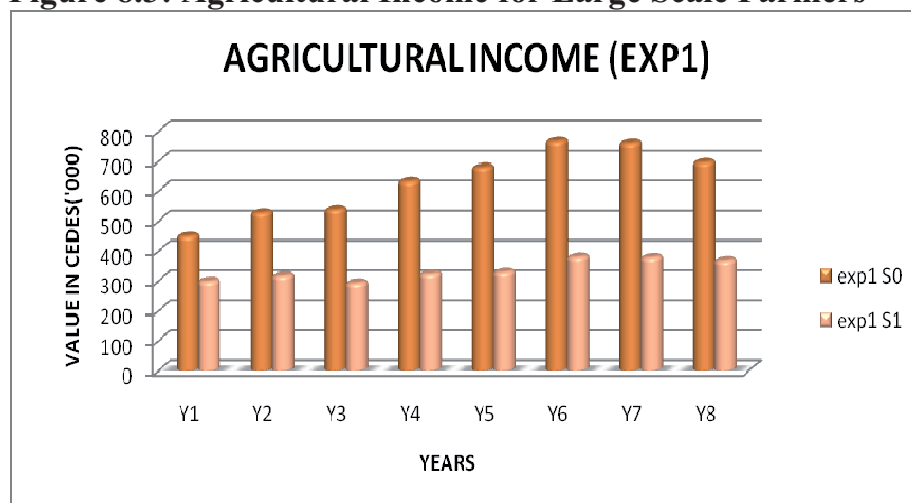


Source: Own Compilation



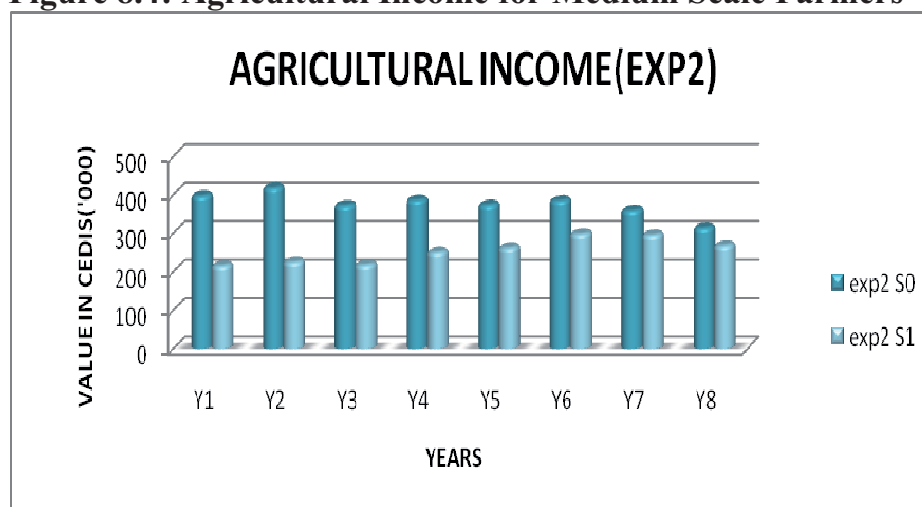
## Impact on Agricultural Income

**Figure 8.3: Agricultural Income for Large Scale Farmers**



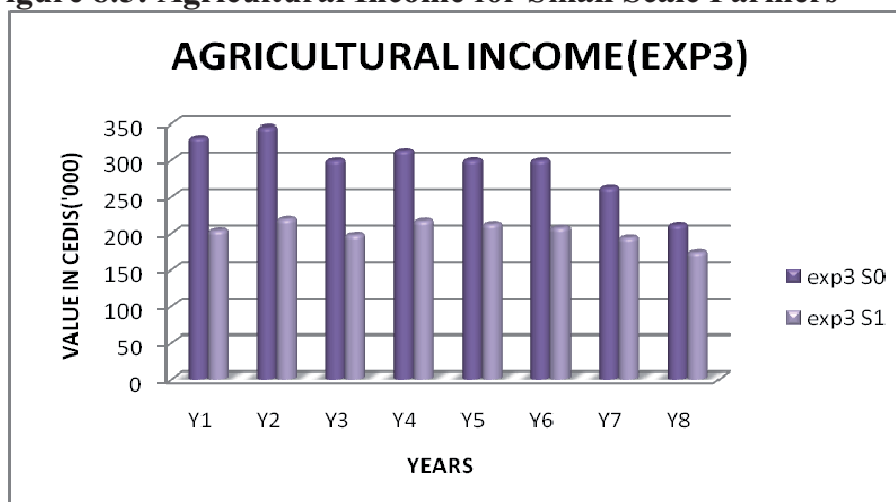
**Source: Own Compilation**

**Figure 8.4: Agricultural Income for Medium Scale Farmers**



**Source: Own Compilation**

**Figure 8.5: Agricultural Income for Small Scale Farmers**



**Source: Own Compilation**

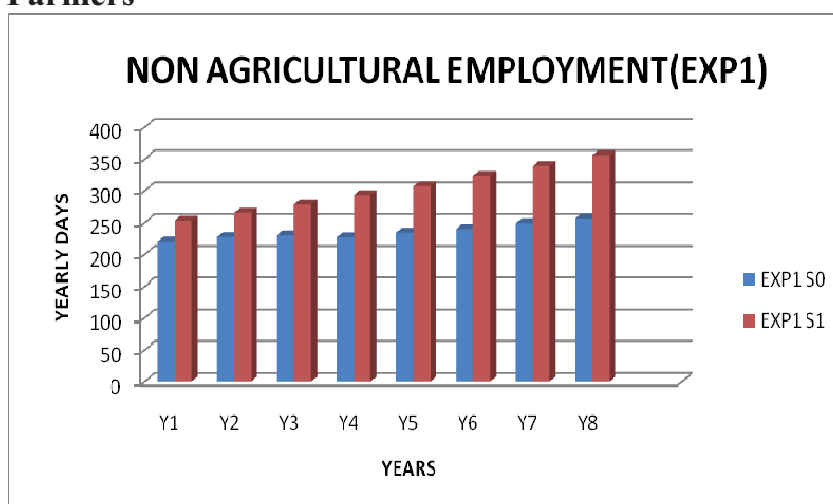
***Impact on Agricultural Employment and Non Farm Employment***

**Figure 8.6: Agricultural Employment for Large Scale Farmers**



**Source: Own Compilation**

**Figure 8.7: Agricultural Non Employment for Large Scale Farmers**



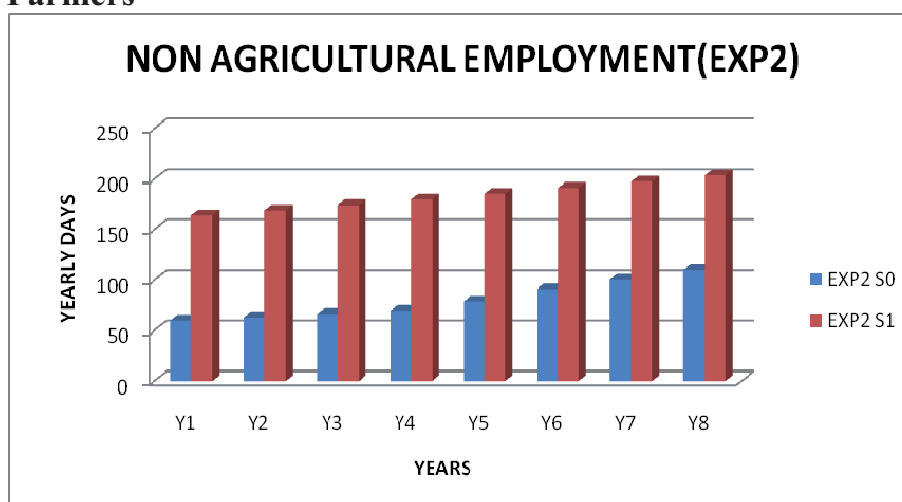
**Source: Own Compilation,2010**

**Figure 8.8: Agricultural Employment for Medium Scale Farmers**



**Source: Own Compilation, 2010**

**Figure 8.9: Agricultural Non Employment for Medium Scale Farmers**



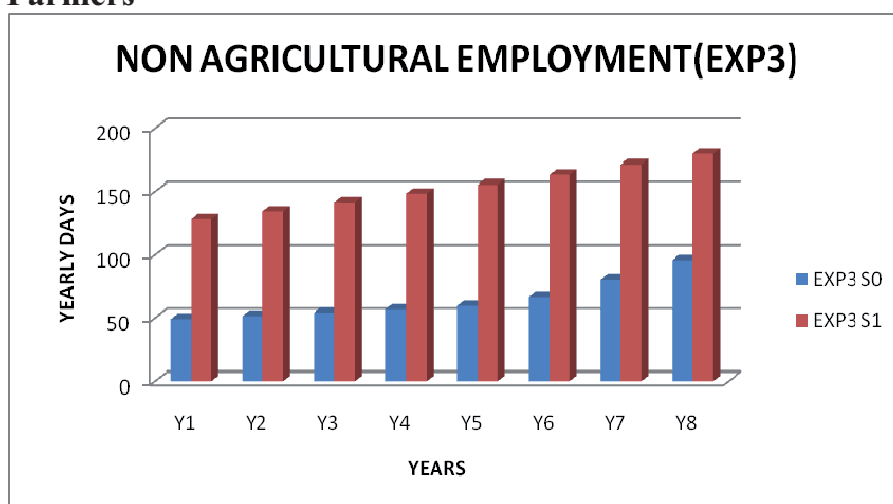
Source: Own Compilation, 2010

**Figure 8.10: Agricultural Employment for Small Scale Farmers**



Source: Own Compilation, 2010

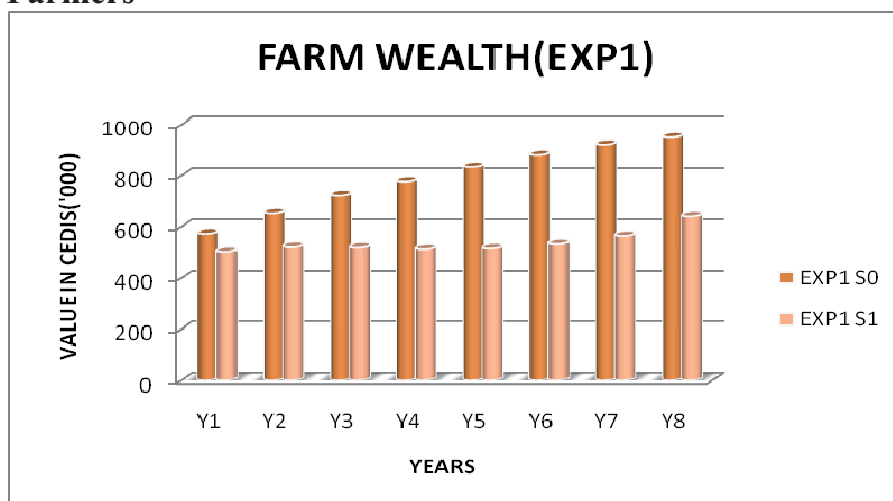
**Figure 8.11: Agricultural Non Employment for Small Scale Farmers**



Source: Own Compilation,2010

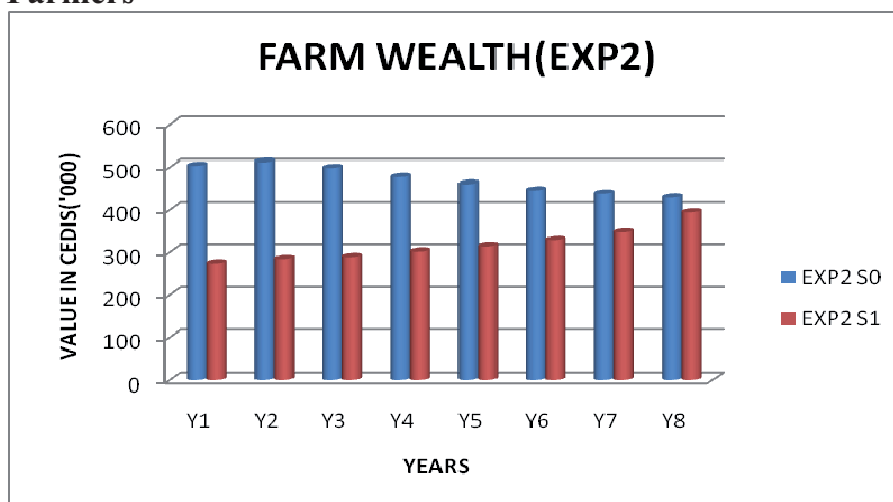
*Impact on Total Farm Wealth*

**Figure 8.12: Agricultural Farm Wealth for Large Scale Farmers**



Source: Own Compilation

**Figure 8.13: Agricultural Farm Wealth for Medium Scale Farmers**



Source: Own Compilation,2010

**Figure 8.14: Agricultural Farm Wealth for Small Scale Farmers**

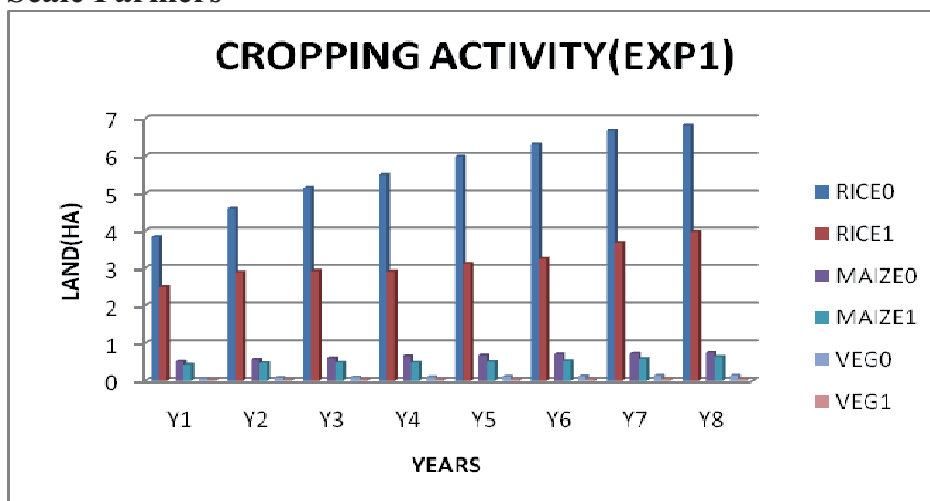


Source: Own Compilaton,2010

## Appendix 11: Changes In Input Prices Scenario

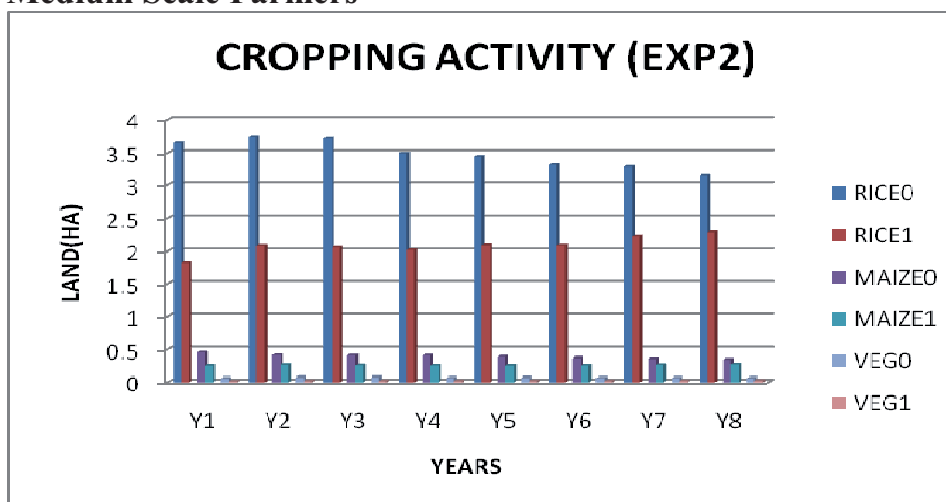
### *Impact on Cropping Activity*

**Figure 8.15: Scenario for Increase in Fertilizer Price for Large Scale Farmers**



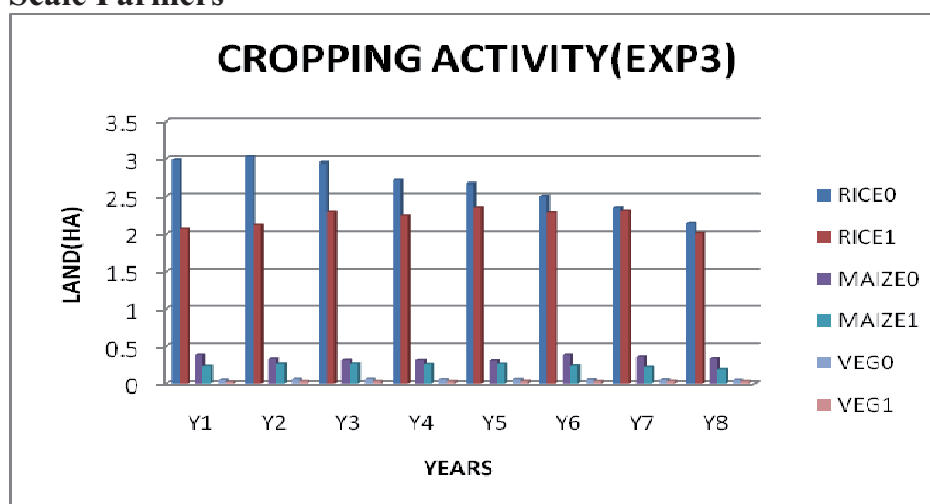
Source: own compilation

**Figure 8.16: Scenario for Increase in Fertilizer Price for Medium Scale Farmers**



Source: own compilation

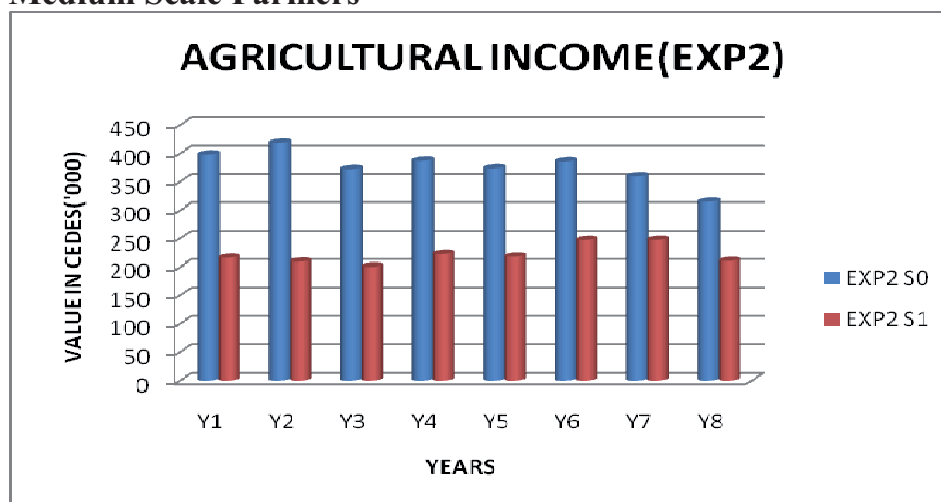
**Figure 8.17: Scenario for Increase in Fertilizer Price for Small Scale Farmers**



Source: own compilation

### *Impact on Agricultural Income*

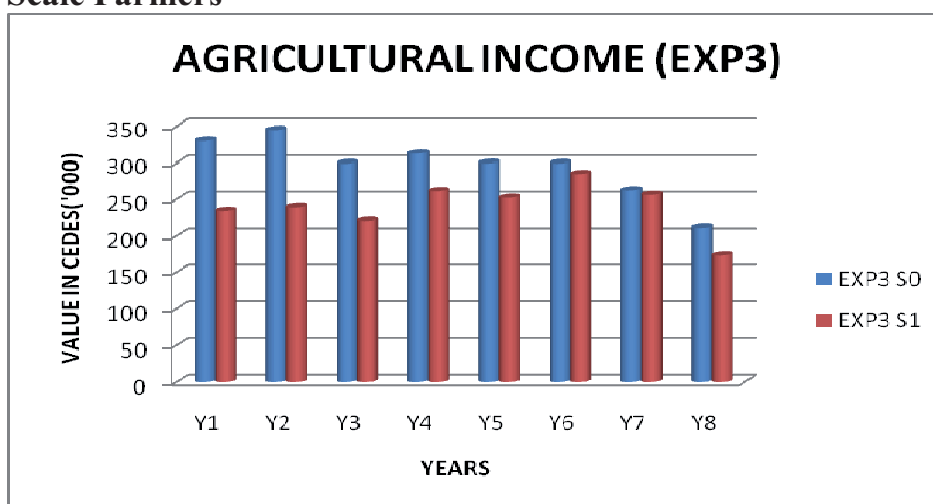
**Figure 8.18: Scenario for Increase in Fertilizer Price for Medium Scale Farmers**



Source: own compilation



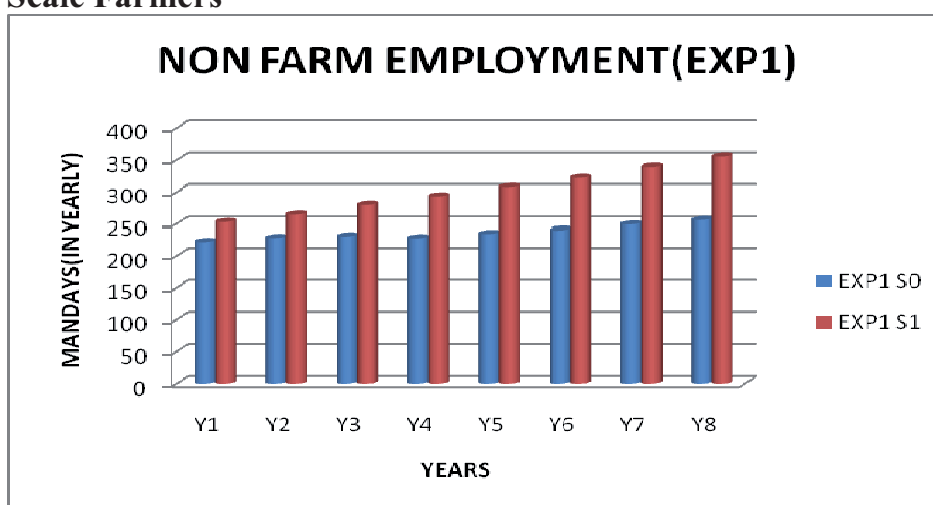
**Figure 8.19: Scenario for Increase in Fertilizer Price for Small Scale Farmers**



Source: own compilation

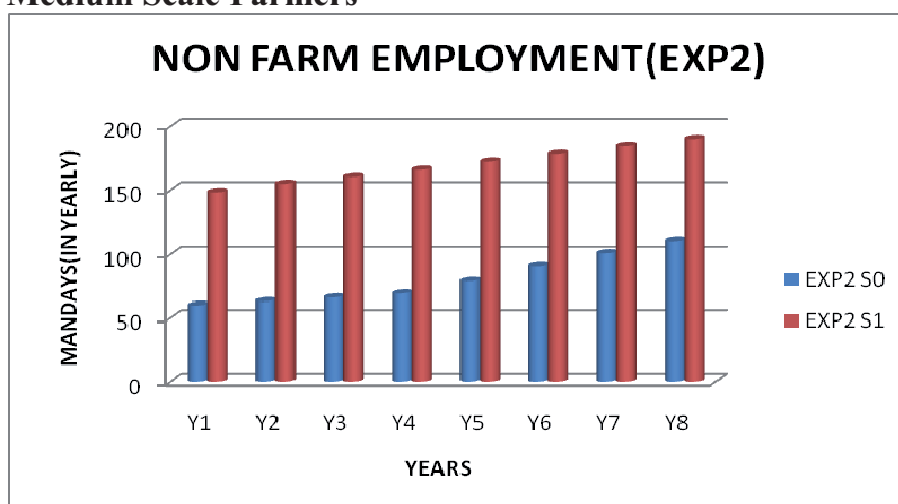
*Impact on Agricultural Employment and Non Farm Employment*

**Figure 8.20: Scenario for Increase in Fertilizer Price for Large Scale Farmers**



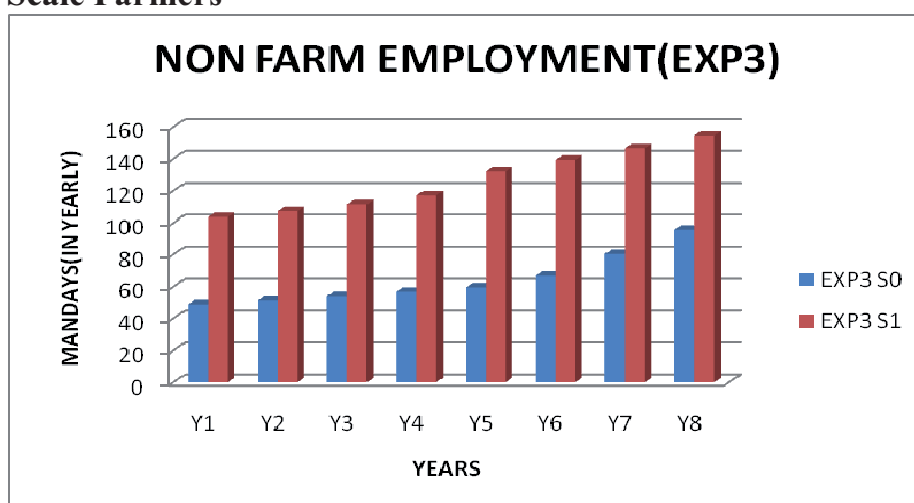
Source: own compilation

**Figure 8.21: Scenario for Increase in Fertilizer Price for Medium Scale Farmers**



Source: own compilation

**Figure 8.22: Scenario for Increase in Fertilizer Price for Small Scale Farmers**

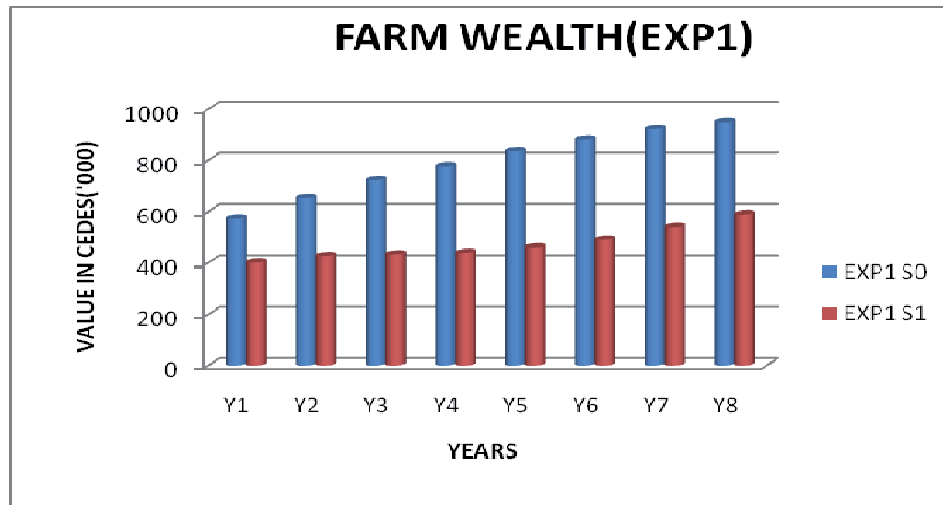


Source: Own Compilation, 2010



### *Impact on Total Farm Wealth*

**Figure 8.23: Scenario for Increase in Fertilizer Price for Large Scale Farmers**



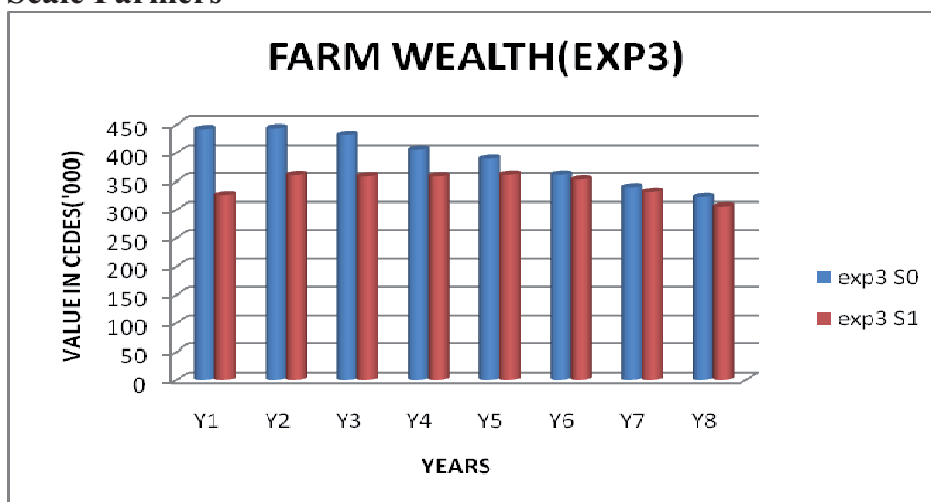
Source: own compilation

**Figure 8.24: Scenario for Increase in Fertilizer Price for Medium Scale Farmers**



Source: own compilation

**Figure 8.25: Scenario for Increase in Fertilizer Price for Small Scale Farmers**

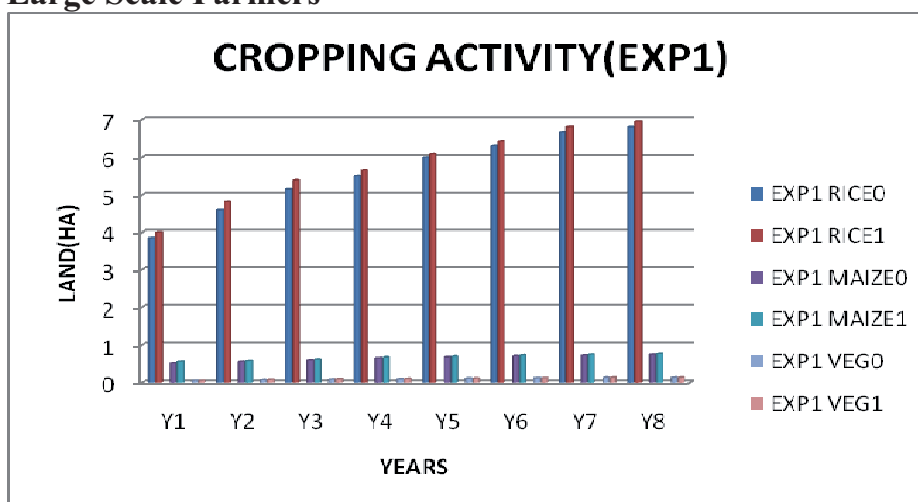


Source: own compilation

## Appendix 12: Impact of Increase in Credit Availability

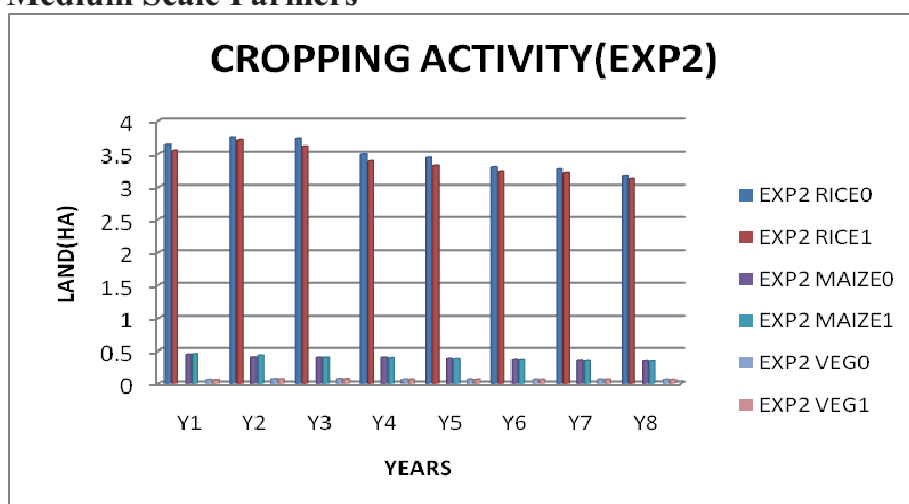
### *Impact on Cropping Activity*

**Figure 8.26: Scenario for Increase Credit Availability for Large Scale Farmers**



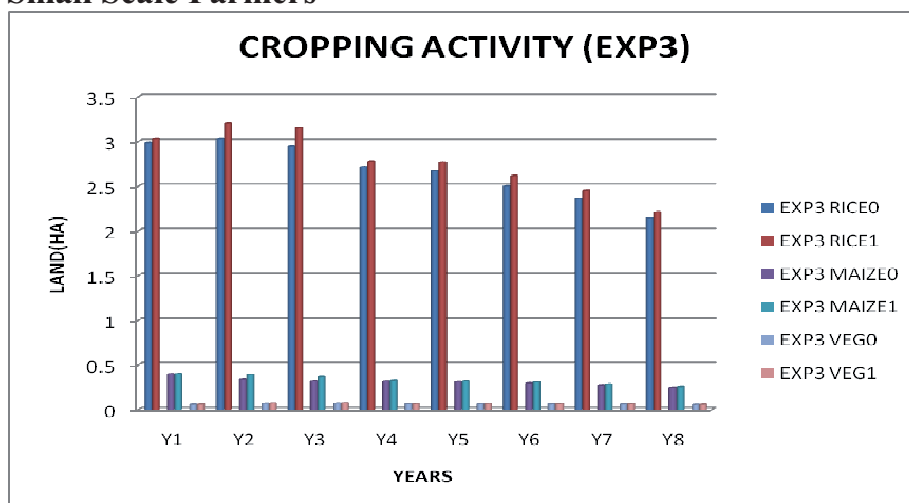
Source: own compilation

**Figure 8.27: Scenario for Increase Credit Availability for Medium Scale Farmers**



Source: own compilation

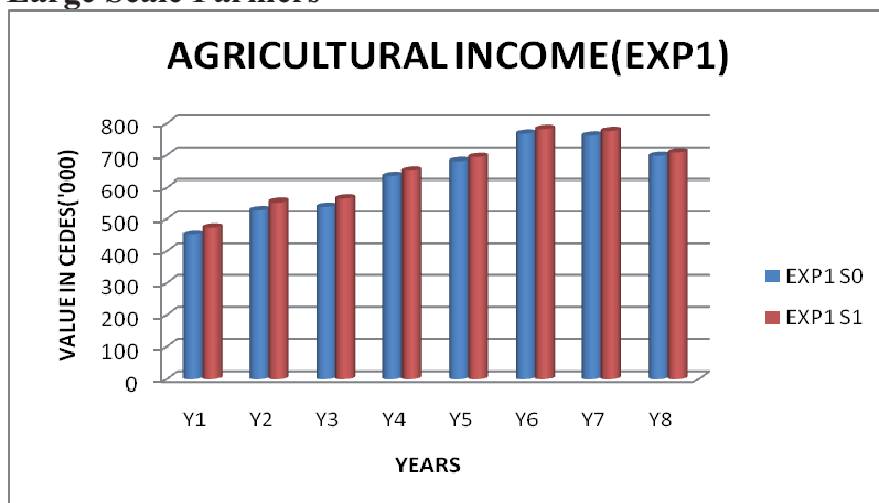
**Figure 8.28: Scenario for Increase Credit Availability for Small Scale Farmers**



Source: own compilation

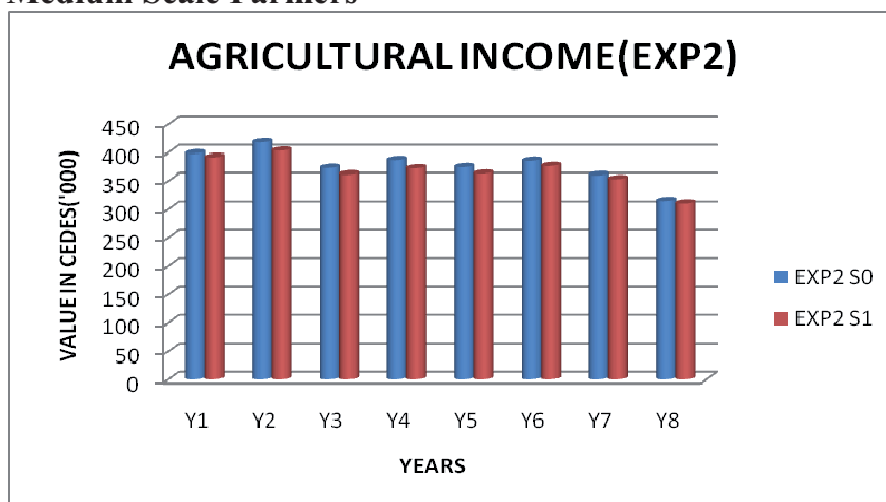
### *Impact on farm income*

**Figure 8.29: Scenario for Increase Credit Availability for Large Scale Farmers**



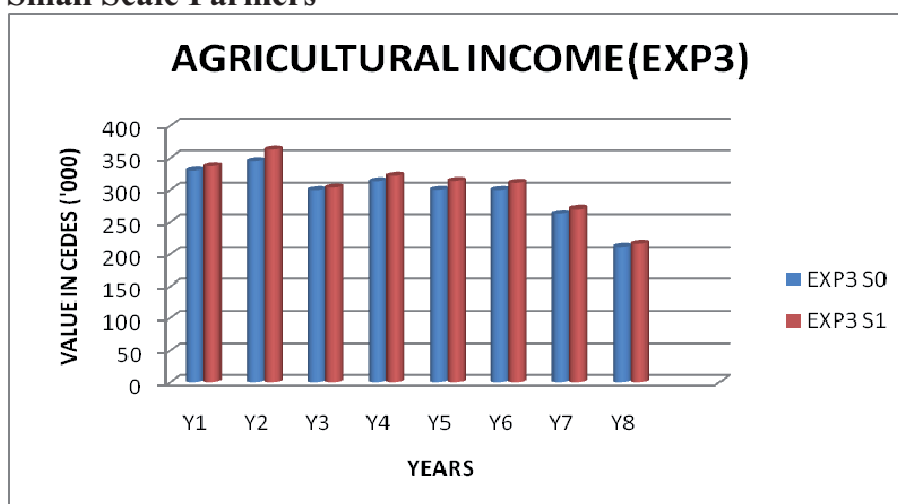
Source: own compilation

**Figure 8.30: Scenario for Increase Credit Availability for Medium Scale Farmers**



Source: own compilation

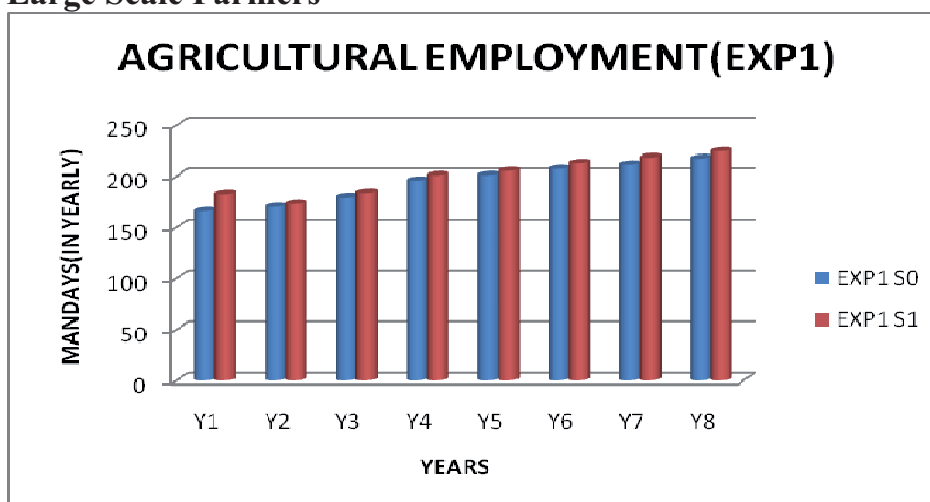
**Figure 8.31: Scenario for Increase Credit Availability for Small Scale Farmers**



Source: Own Compilation

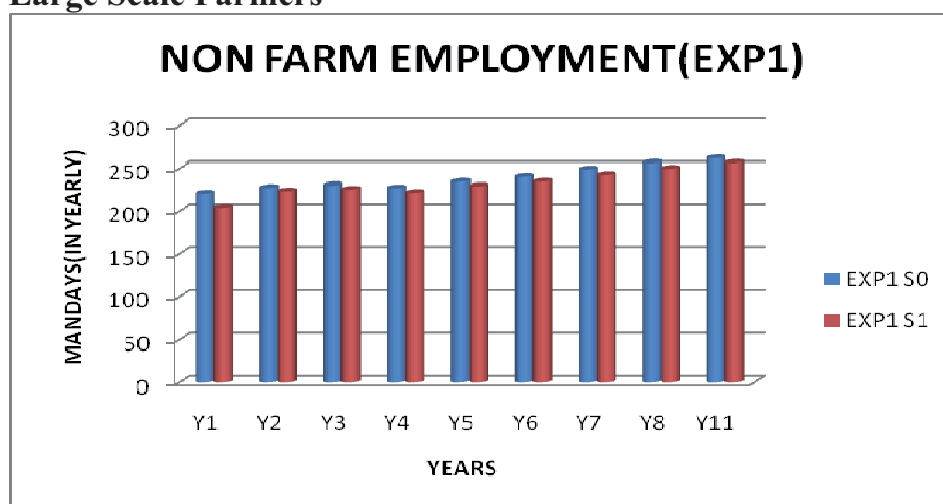
*Impact on farm employment and nonfarm employment*

**Figure 8.32: Scenario for Increase Credit Availability for Large Scale Farmers**



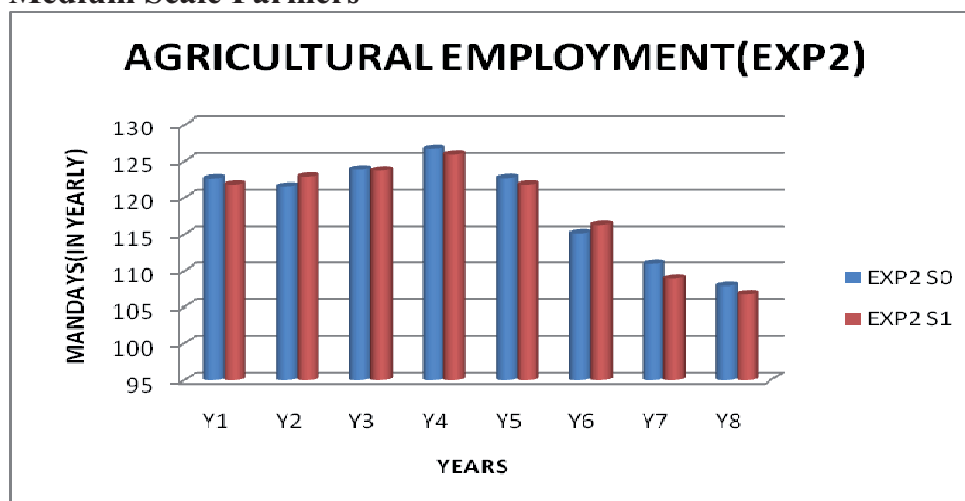
Source: own compilation

**Figure 8.33: Scenario for Increase Credit Availability for Large Scale Farmers**



Source: own compilation

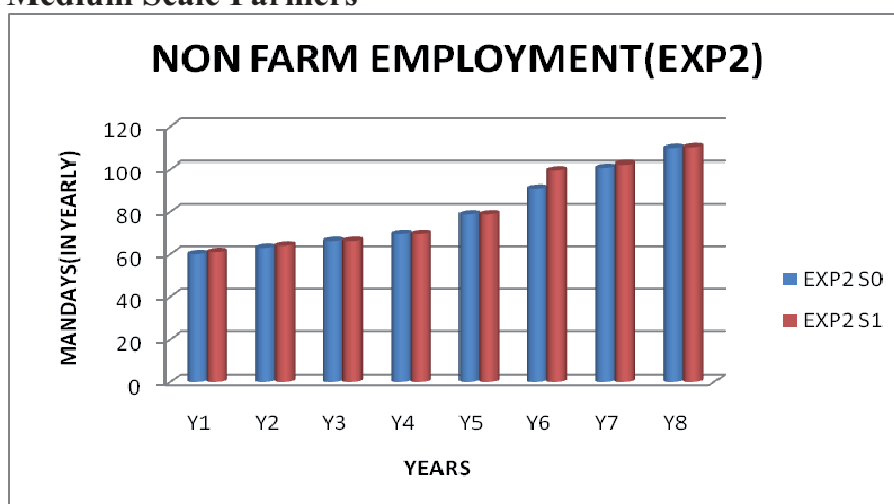
**Figure 8.34: Scenario for Increase Credit Availability for Medium Scale Farmers**



Source: own compilation

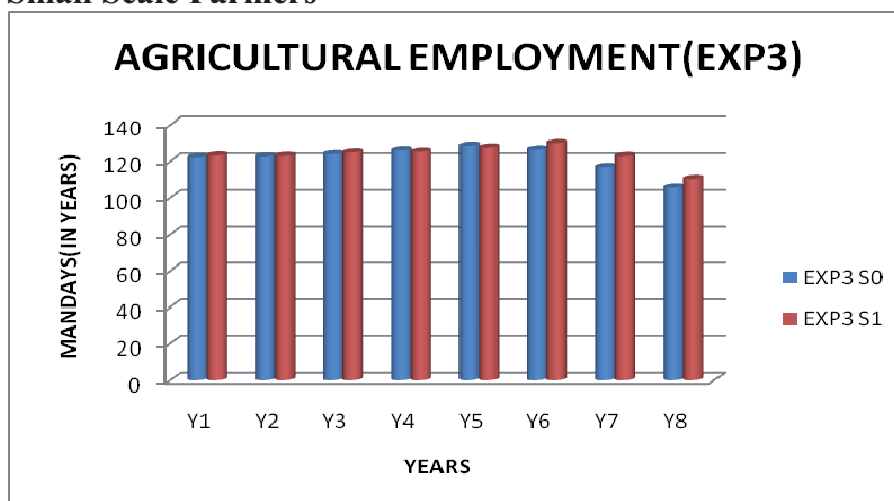


**Figure 8.35: Scenario for Increase Credit Availability for Medium Scale Farmers**



Source: own compilation

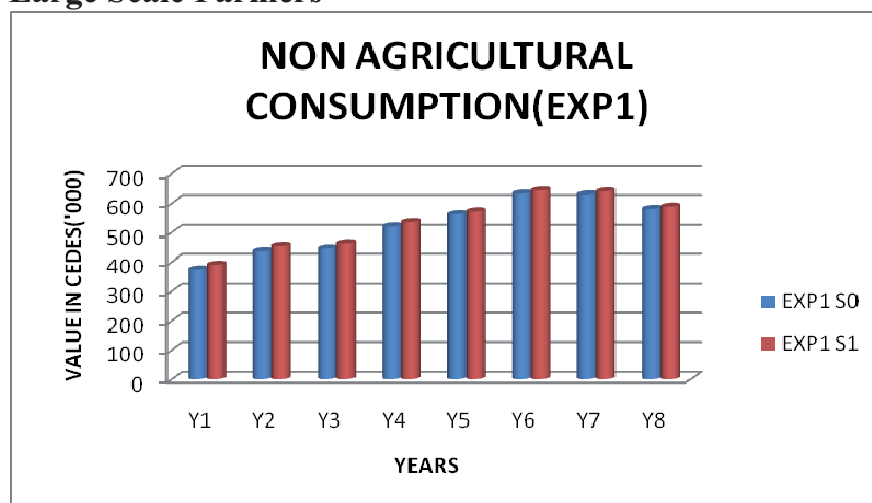
**Figure 8.36: Scenario for Increase Credit Availability for Small Scale Farmers**



Source: own compilation

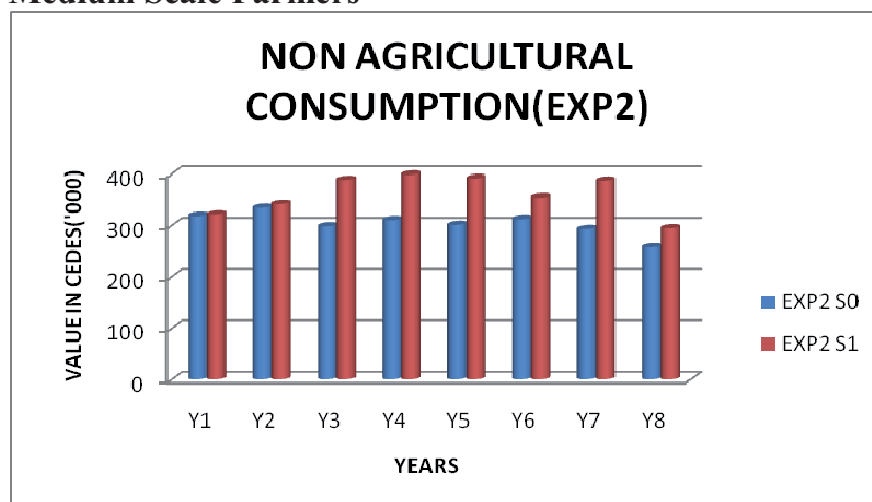
## Impact of credit Availability on Non Agricultural Consumption

**Figure 8.37: Scenario for Increase Credit Availability for Large Scale Farmers**



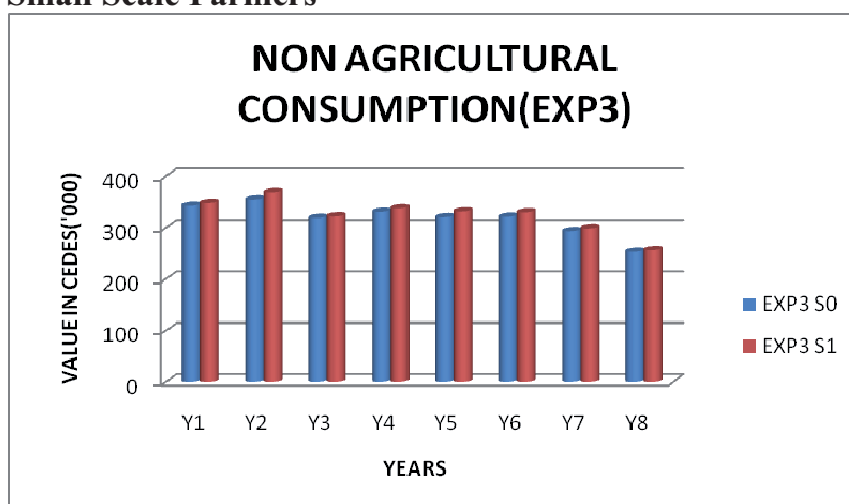
Source: own compilation

**Figure 8.38: Scenario for Increase Credit Availability for Medium Scale Farmers**



Source: own compilation

**Figure 8.39: Scenario for Increase Credit Availability for Small Scale Farmers**

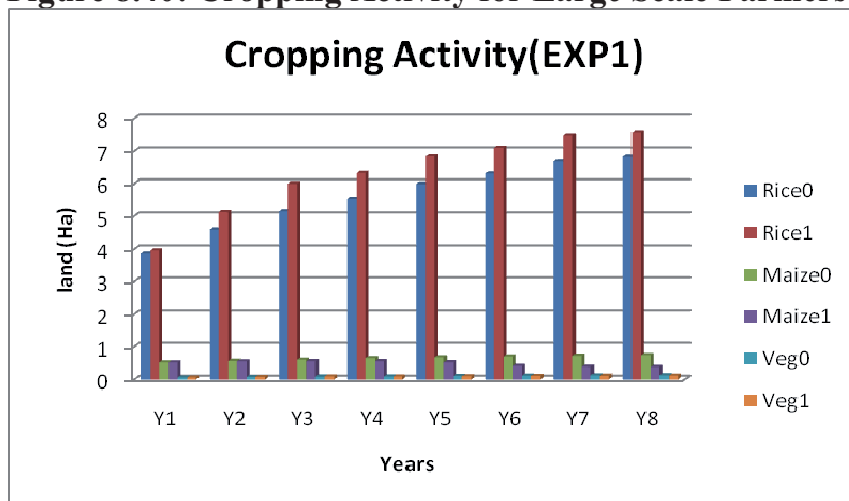


Source: own compilation

## Appendix 13: Price Expectations Scenario

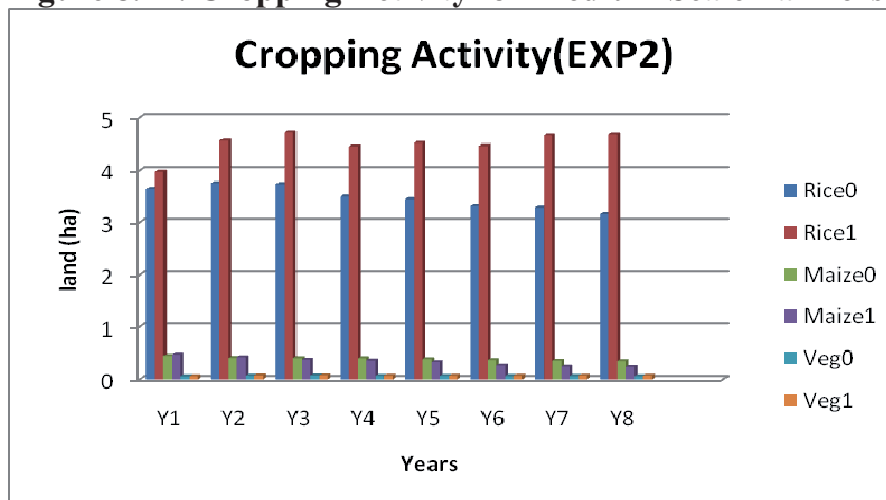
### *Impact on Cropping Activity*

**Figure 8.40: Cropping Activity for Large Scale Farmers**



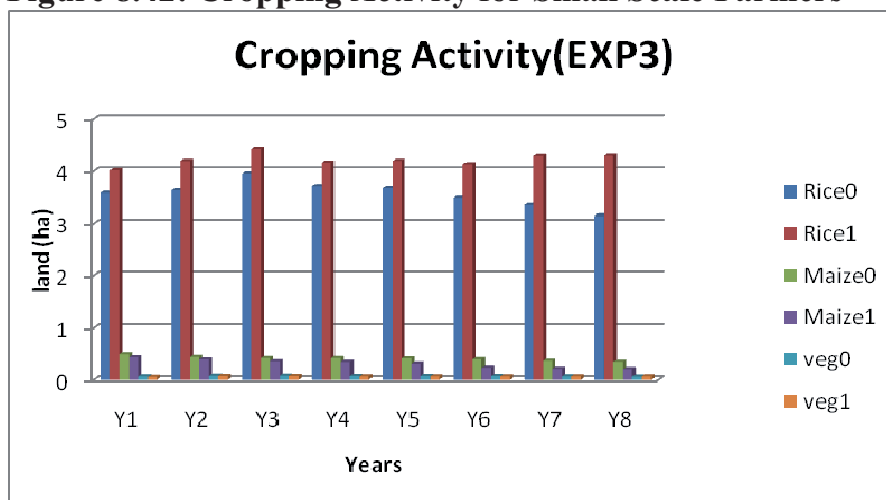
Source: Own Compilation

**Figure 8.41: Cropping Activity for Medium Scale Farmers**



**Source: Own Compilation**

**Figure 8.42: Cropping Activity for Small Scale Farmers**

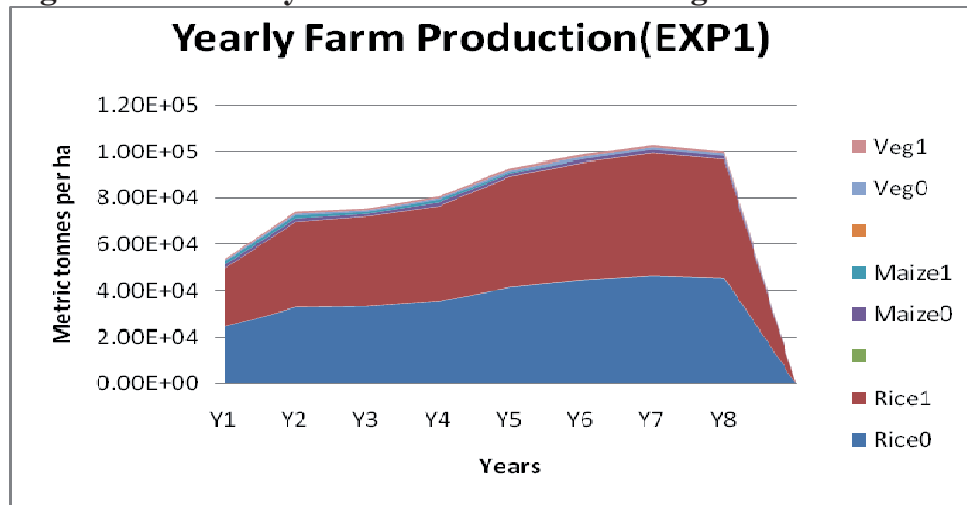


**Source: Own Compilation**



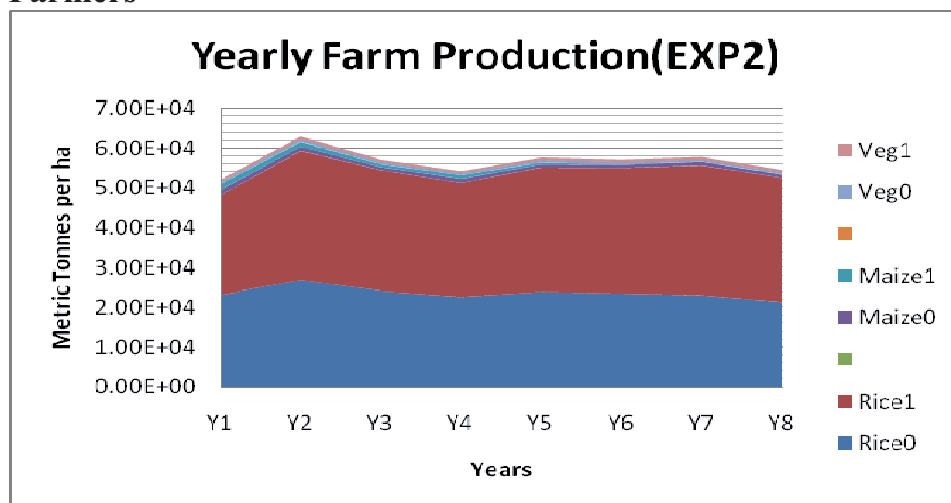
## Impact on Yearly Agricultural Production

**Figure 8.43: Yearly Farm Production for Large Scale Farmers**



Source: Own Compilation

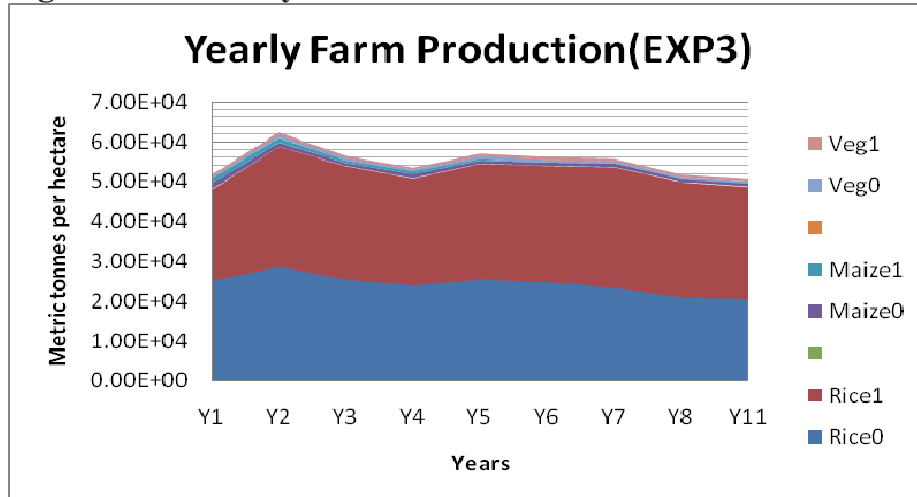
**Figure 8.44: Yearly Farm Production for Medium Scale Farmers**



Source: Own Compilation



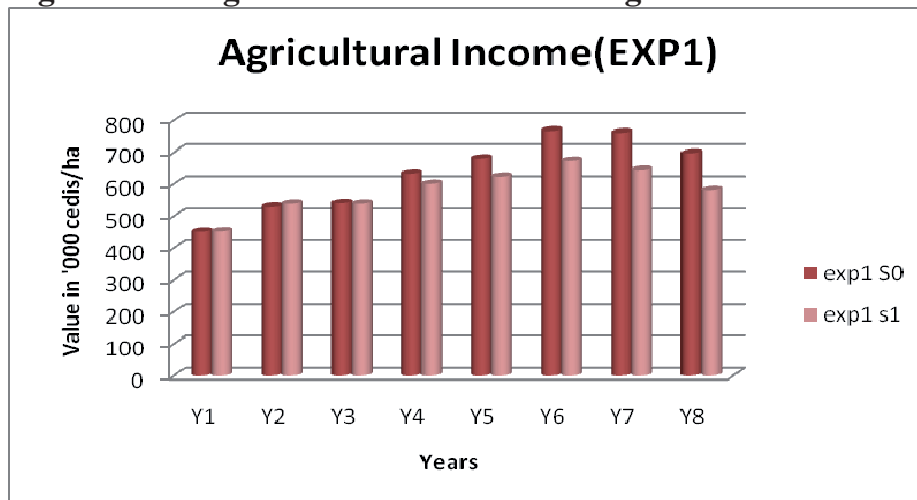
**Figure 8.45: Yearly Farm Production for Small Scale Farmers**



**Source: Own Compilation**

### *Impact on Farm Income*

**Figure 8.46: Agricultural Income for Large Scale Farmers**



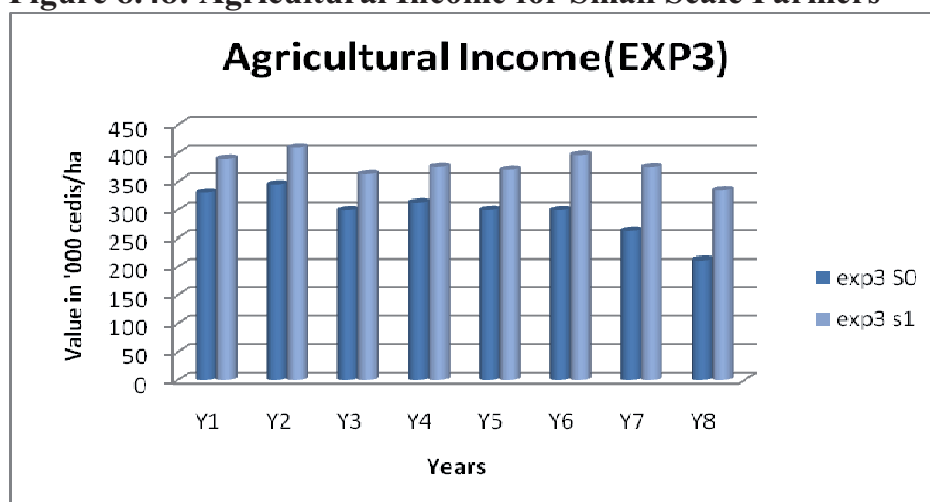
**Source: Own Compilation**

**Figure 8.47: Agricultural Income for Medium Scale Farmers**



**Source: Own Compilation**

**Figure 8.48: Agricultural Income for Small Scale Farmers**

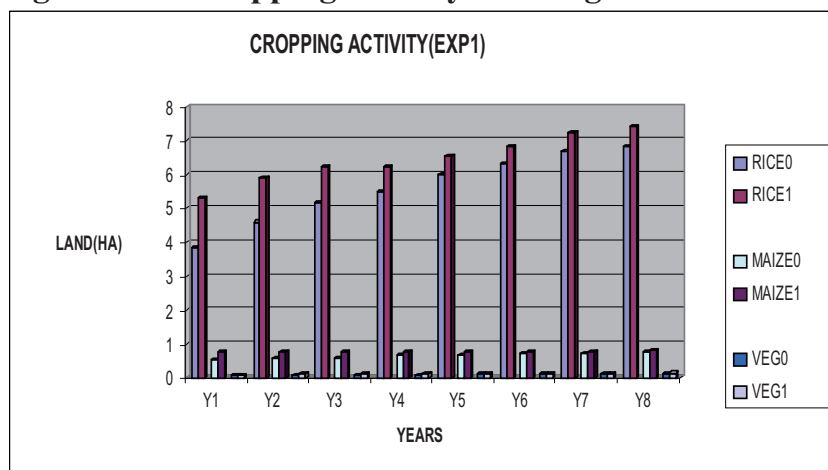


**Source: Own Compilation**

## Appendix 14: Land Reform Policy Scenario

### *Impact on Cropping Activity*

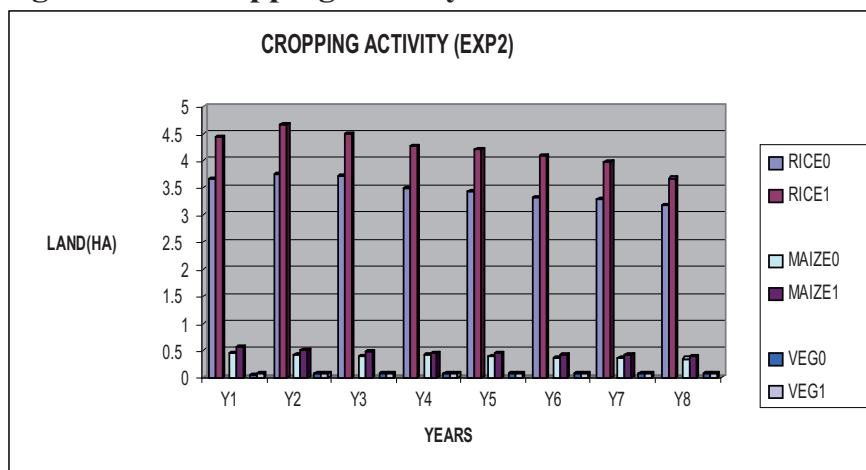
**Figure 8.49: Cropping Activity for Large Scale Farmers**



**Source: Own Compilation, 2010**

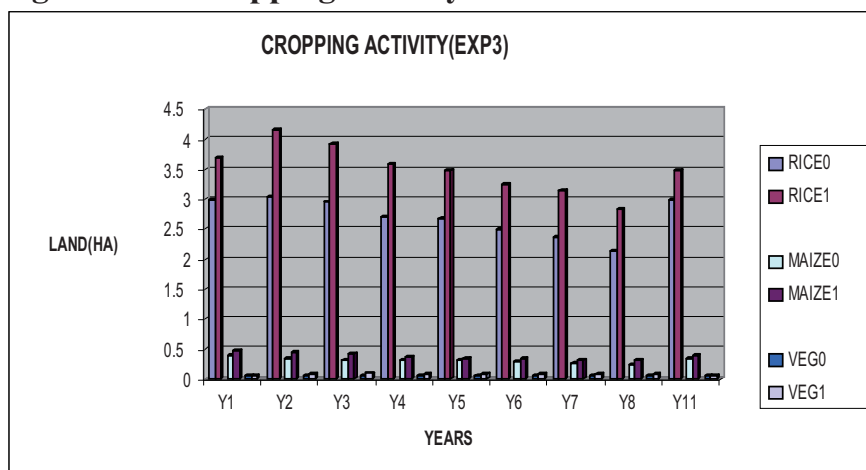


**Figure 8.50: Cropping Activity for Medium Scale Farmers**



**Source: Own Compilation, 2010**

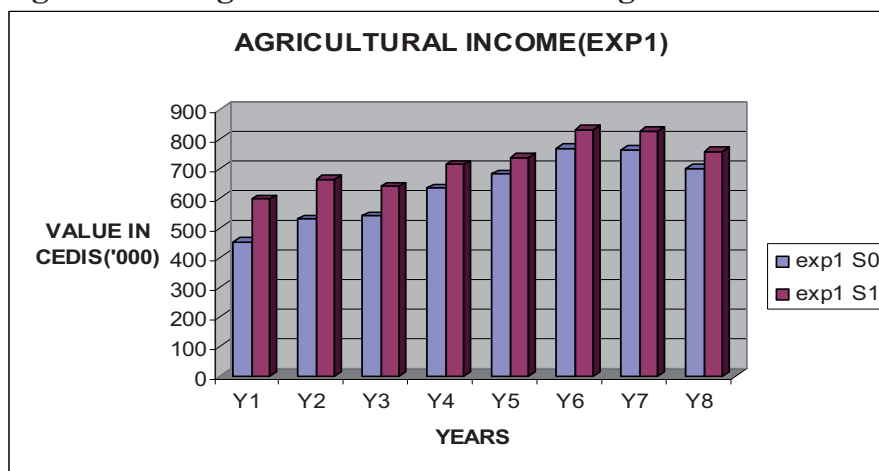
**Figure 8.51: Cropping Activity for Small Scale Farmers**



**Source: Own Compilation**

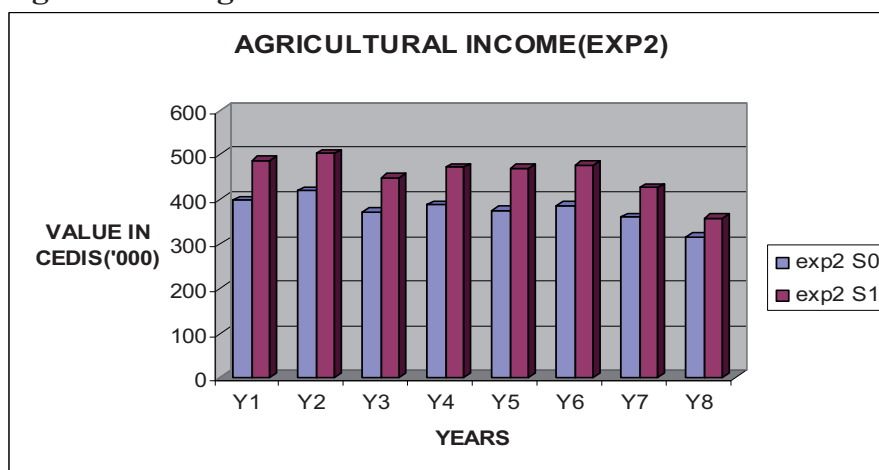
## Impact On Agricultural Income

**Figure 8.52: Agricultural Income for Large Scale Farmers**



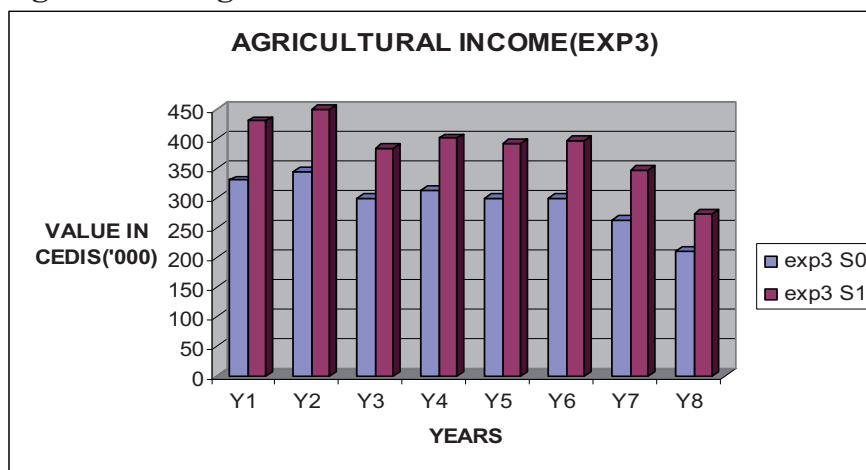
Source: Own Compilation, 2010

**Figure 8.53: Agricultural Income for Medium Scale Farmers**



Source: Own Compilation, 2010

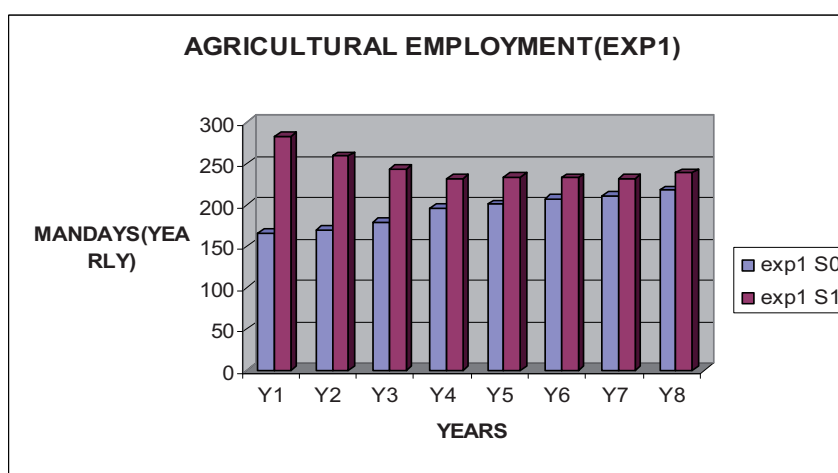
**Figure 8.54: Agricultural Income for Small Scale Farmers**



Source: Own Compilation, 2010

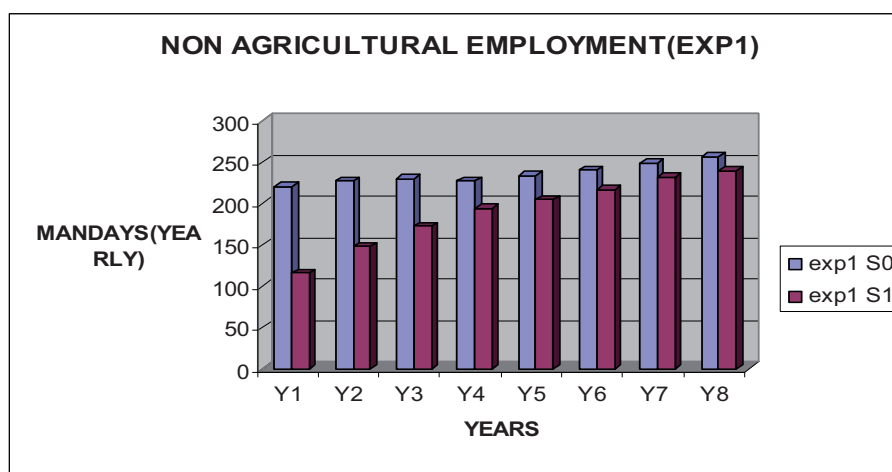
### *Impact On Employment and Non Farm Employment*

**Figure 8.55: Agricultural Employment for Large Scale Farmers**



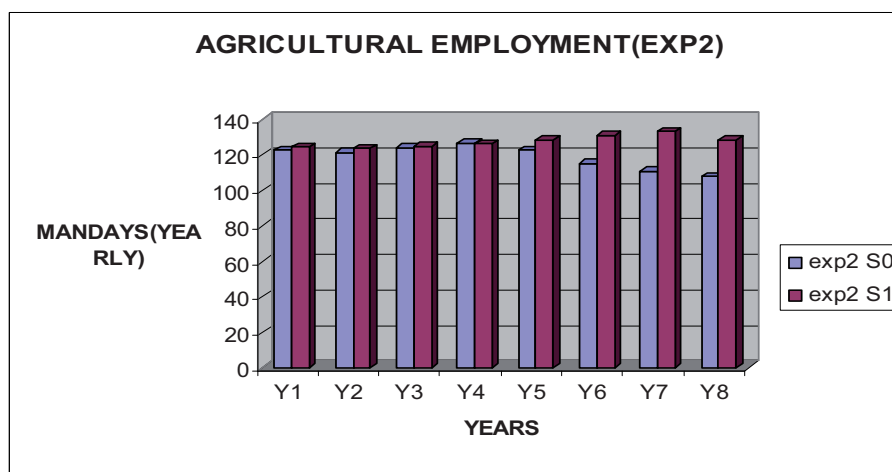
Source: Own Compilation, 2010

**Figure 8.56: Non Agricultural Employment for Large Scale Farmers**



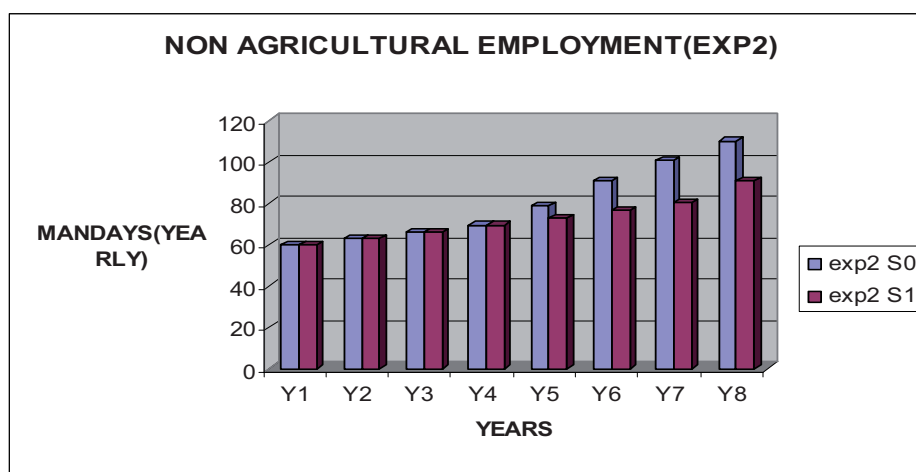
Source: Own Compilation, 2010

**Figure 8.57: Agricultural Employment for Medium Scale Farmers**



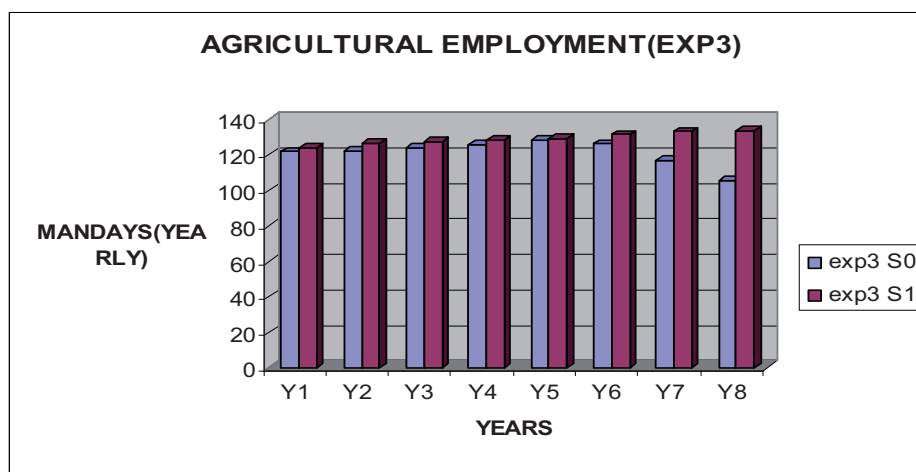
Source: Own Compilation, 2010

**Figure 8.58: Non Agricultural Employment for Medium Scale Farmers**



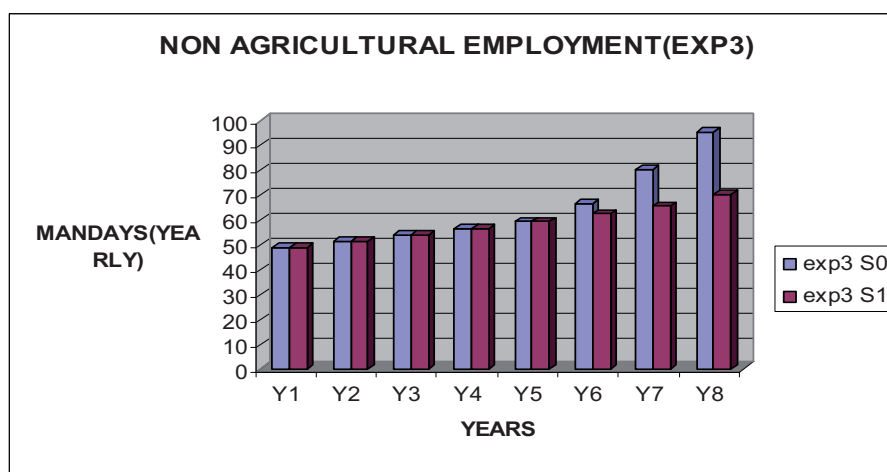
Source: Own Compilation, 2010

**Figure 8.59: Agricultural Employment for Small Scale Farmers**



Source: Own Compilation, 2010

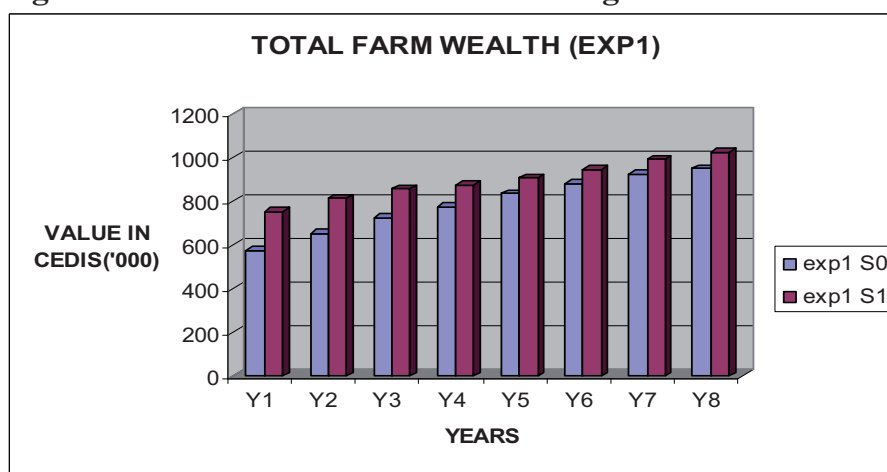
**Figure 8.60: Non Agricultural Employment for Small Scale Farmers**



Source: Own Compilation, 2010

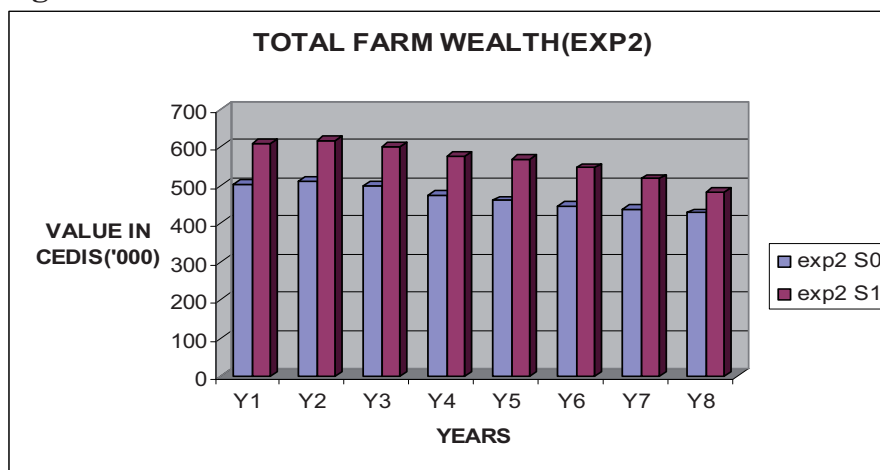
### *Impact on Total Wealth*

**Figure 8.61: Total Farm Wealth for Large Scale Farmers**



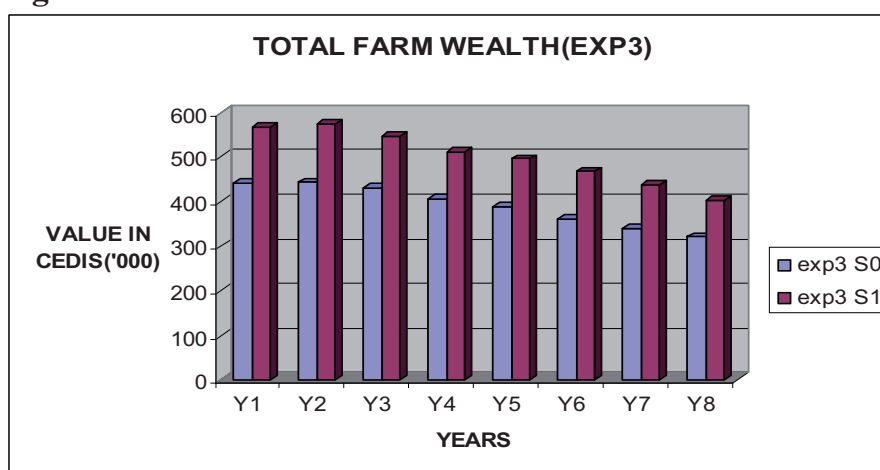
Source: Own Compilation, 2010

**Figure 8.62: Total Farm Wealth for Medium Scale Farmers**



Source: Own Compilation, 2010

**Figure 8.63: Total Farm Wealth for Small Scale Farmers**

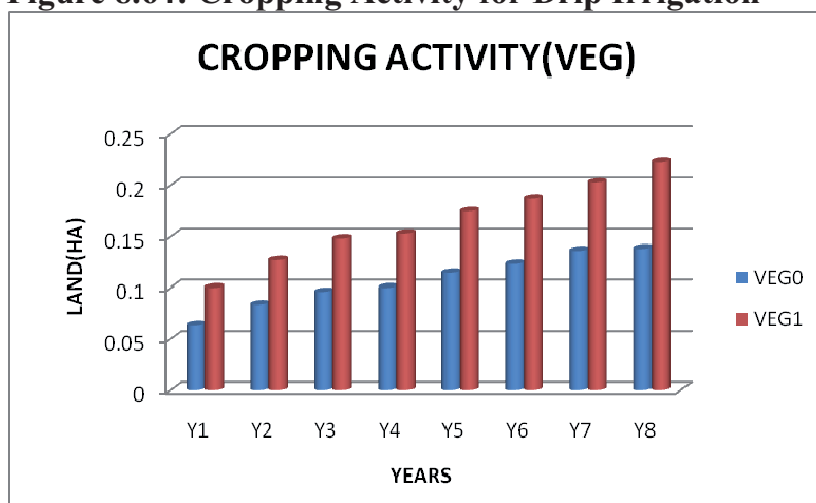


Source: Own Compilation, 2010

## Appendix 15: Change in Technology Scenario

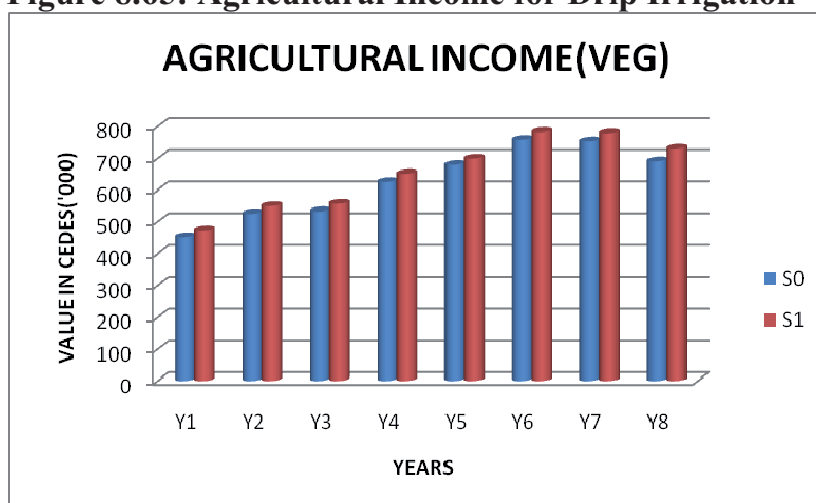
### *Impact on Cropping Activity*

**Figure 8.64: Cropping Activity for Drip Irrigation**



Source: Own Compilation, 2010

**Figure 8.65: Agricultural Income for Drip Irrigation**



Source: Own Compilation, 2010

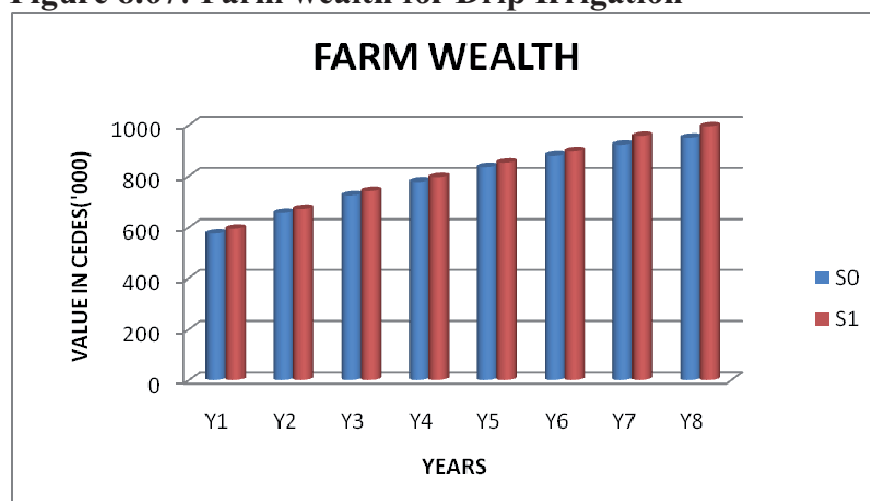


**Figure 8.66: Agricultural Employment for Drip Irrigation**



Source: Own Compilation, 2010

**Figure 8.67: Farm wealth for Drip Irrigation**



Source: Own Compilation, 2010



## **QUESTIONNAIRE FOR FOCUS GROUP DISCUSSIONS**

**Kindly note, that in a focus group discussion you will be asking one question to all participants to elicit their responses. Your recorded responses are therefore a summary of the views on a specific question posed.**

### **HOUSEHOLD ROSTER**

**1. REGION**

**2. DISTRICT**

**3. TOWN**

**4. ECOLOGICAL ZONE**

**5. NAME/ NAME OF COMMUNITY**

**6. AGE RANGE**

**7. MAJOR OCCUPATION IN COMMUNITY**

**8. AVERAGE FAMILY SIZE OF COMMUNITY**

### **AGRICULTURAL ACTIVITIES IN THE AREA**

**9. WHAT IS THE MAJOR MEANS OF LAND ACQUISITION**

**10. WHAT REFORMS IN THE LAND TENURE /LAND OWNERSHIP WOULD YOU ENVISAGE FOR INCREASED PRODUCTIVITY IN YOUR COMMUNITY?**

**11. WHAT IS THE AVERAGE NUMBER OF PLOTS / FARMS PER HOUSEHOLD**



**12. WHAT IS THE LABOUR TIME OF THE MAJOR CROPS GROWN IN THIS AREA?**

**CROP BUDGET/CALENDER**

	<b>DAYS OF LABOUR/ HA</b>	<b>PERIOD</b>	<b>NOTES</b>	<b>TYPE OF CROP</b>
<b>CLEARING OF LAND</b>	<b>1</b>	<b>MAI</b>		
<b>MANURE</b>	<b>1</b>	<b>MAI</b>		
<b>FERTILIZERS</b>	<b>1</b>	<b>MID JUNE</b>		
<b>FERTILIZERS</b>	<b>1</b>	<b>MID JULY</b>		
<b>HERBICIDE APPLICATION</b>	<b>1</b>			
<b>PLOUGH</b>	<b>4</b>			
<b>PLANT BAD</b>	<b>5</b>			
<b>PLANT GOOD</b>	<b>3</b>			
<b>WEEDING 1</b>	<b>10</b>	<b>MID JUNE</b>		
<b>WEEDING 2</b>	<b>8</b>	<b>END JULY</b>		
<b>WEEDING 3</b>	<b>6</b>	<b>MID AUGUST</b>		
<b>HARVEST</b>	<b>18</b>	<b>EARLY</b>		



<b>BAD</b>		<b>OCTOBER</b>		
<b>HARVEST</b>	<b>22</b>	<b>EARLY</b>		
<b>GOOD</b>		<b>OCTOBER</b>		

**13. WHAT ARE THE MAJOR CROPS YOU GROW IN YOUR VARIOUS FARMS IN THE AREA**

**14. WHAT ARE YOUR OUTPUT /YIELD PER ACRE IN THE LAST SEASON FOR YOUR ABOVE MENTIONED MAJOR CROPS? DRY AND RAINY SEASON.**

**15. DO YOU OWN ANY LIVESTOCK OR ENGAGED IN FISHING ACTIVITIES. MENTION AND COST THEM.**

#### **CHEMICAL USAGE/PRODUCTION**

**16. DO YOU USE FERTILISER OR MANURE?**

**17. WHAT TYPE OF CROPS NEED THE APPLICATION OF FERTILISERS?**

**18. WHAT KIND OF FERTILISERS DO YOU USE IN THIS AREA**

**19. WHAT IS THE AVERAGE QUANTITY IN BAGS APPLIED PER ACRE FOR ALL THE SPECIFIC CROPS?**

**20. WHAT OTHER INPUTS DO YOU USE ON YOUR FARM( MENTION THEM)**

**21. CAN YOU COST OR VALUE ALL THE INPUTS YOU USE?**



**22. WHAT IS YOUR AVERAGE COST OF PRODUCTION PER CROP TYPE OR PER ACRE IN A PERIOD?**

**23. DID YOU MAKE ANY LOSSES IN YOUR LAST SEASON? IF YES WHAT WERE THE REASONS THAT CONTRIBUTED TO YOUR LOSS**

**LABOUR (FARM AND NON-FARM ACTIVITIES)**

**24. DO YOU USE MECHANISED OR LABOUR I.E BULLOCK,TRACTION OR TRACTOR USAGE**

**25. HOW MANY HOURS DO YOU AND YOUR FAMILY MEMBERS WORK ON THE FARM IN A DAY DURING THE RAINY SEASON AND THE DRY SEASON**

**26. DURING NON- FARMING SEASON WHAT OTHER ACTIVITIES DO YOU ENGAGE YOURSELF IN.?**

**IRRIGATION ACTIVITIES**

**27. DO YOU USE IRRIGATED OR RAINFED IN FARMING**

**28. DO YOU HAVE ANY IRRIGATION FACILITY**

**29. IF YOU HAVE, IS IT A GROUP OWNED OR INDIVIDUAL OWNED**

**30. WHICH TYPE OF IRRIGATION FACILITY IS IT.(MENTION)**



**31. HOW MANY ACRES OF LAND DID YOU GIVE FOR THE IRRIGATION FACILITY?**

**32. WHAT DO YOU THINK ABOUT IRRIGATION, IS IT A GOOD PRACTISE OR DOES IT WASTES WATER OR TIME**

**33. WOULD IT BE PROFITABLE IF INVESTED INTO IRRIGATION**

**34. HOW WOULD IT AFFECT YOUR INCOME IF INVESTED INTO IRRIGATION?**

**35. WHAT WOULD YOU IF THERE IS NO SUFFICIENT WATER IN THE RESERVOIR**

**36. WHAT HAPPENS IF THERE IS FLOODING**

**37. WHAT ARE SOME OF THE CONSTRAINTS YOU FACE IF YOU WANT TO USE IRRIGATION FOR YOUR FARMING ACTIVITIES**

**38. IF IRRIGATION PRODUCTION FAILS WHAT WOULD YOU DO ARE THERE ANY ALTERNATIVE OR WAYS TO MAKE UP FOR THE LOSS**

**39. IN YOUR OPINION DOES IRRIGATION DEMAND WASTE WATER**

**40. COMPARING IRRIGATION DEMAND FOR WATER AND OTHER USES OF WATER WHICH WOULD YOU SAY DEMANDS FAR MORE WATER. E.G INDUSTRIAL**



**OR DOMESTIC USE OR LIVESTOCK OR HYDROPOWER  
(RANK THEM IN ASCENDING ORDER)**

**41. WHAT IS THE COST OF IRRIGATION**

**42. IN WHAT AREA WOULD YOU NEED HELP TO  
INCREASE YOUR PRODUCE AND INCOME**

**FINANCIAL ACTIVITIES**

**43. HOW EASY IS IT FOR YOU AGRICULTURE  
WORKERS TO ACCESS CREDIT TO INCREASE YOUR  
PRODUCTION SIZE?**

**44. WHAT ARE SOME OF THE CONSTRAINTS YOU  
FACE IN CREDIT ACQUISITION FOR YOUR FARMS?**

**45. APART FROM THE BANKS WHICH OTHER PLACES  
DO YOU GET CREDITS FOR YOUR AGRICULTURAL  
ACTIVITIES?**

**INSURANCE AND FORECAST**

**46. IF GIVEN THE CHANCE WOULD YOU LIKE TO  
TAKE INSURANCE ON YOUR FARM?**

**47. HOW MUCH MONEY OR IN BAGS OF PRODUCE  
WOULD YOU LIKE PAY IF YOU WERE GIVEN THE  
OPPORTUNITY.**



**48. HAS WEATHER FORCAST BEING HELPFUL OVER THE YEARS IF YES IN WHAT WAYS. (IF NOT FORMAL TRADITIONAL)**

**WATER USAGE**

**49. CAN YOU GIVE ME AN ESTIMATION OF HOW MUCH WATER THE MAJOR CROPS GROWN IN THIS AREA TAKE TO GROW?**

**50. IN YOUR VARIOUS HOUSE HOW MANY BUCKETS OF WATER DO YOU USE IN A DAY OR WHAT IS YOUR AVERAGE PER CAPITA HOUSEHOLD WATER CONSUMPTION.**

**51. WOULD YOU SAY THAT WATER IS VERY WELL ALLOCATED AMONG THE VARIOUS USES; I.E FOR AGRIC, DOMESTIC USE, HYDROPOWER AND FOR ENVIROMENTAL FLOW.**

**52. IN YOUR OPIONION DO YOU THINK SOME SECTORS ARE BEING FAVOURED AGAINST OTHERS AND WHY IN TERMS OF WATER DISTRIBUTION?**

**53. WHAT DO YOU THINK SHOULD BE DONE TO REDUCE WATER WASTAGE IN THE AGRICULTURE SECTOR**





**54. HOW MUCH ARE YOU WILLING TO PAY FOR AN  
IRRIGATION FACILITY/WATER**

**SOILS AND CONCLUSION**

**55. WHAT KINDS OF SOIL DO YOU HAVE IN YOUR  
FARM**

**56. DOES EROSION HAVE ANY INFLUENCE ON YOUR  
CROPS, IF YES WHAT DO YOU DO TO REDUCE IT.?**

**57. WHAT WOULD BE YOUR REMEDY FOR  
ALLEVIATING POVERTY WITHIN YOUR FARMING  
COMMUNITY?**

**CLIMATIC CHANGES**

**58. WHAT HAS CHANGED IN FARMING SINCE YOU  
WERE BORN**

**59. HAS THERE BEEN ANY CHANGE IN THE CLIMATIC  
CONDITION OVER THE PERIOD, MENTION THEM.  
HAS IT BEEN DRIER, WETTER OR BOTH EXTREMES?**

**60. HAS THERE BEEN ANY CHANGE IN YIELDS OF  
RAIN FED PRODUCTION OVER THE YEARS? IN WHAT  
DIRECTION**

**A) IF YES WHAT CHANGED THE YIELDS  
(RANKING)**



- MORE FERTILIZER USE
- LAND DEGRADATION

**B) HAVE YOU CHANGE SOMETHING IN YOUR FARMING SYSTEM OVER THE YEARS?**

- NEW VARIETIES
- MORE FERTILIZERS
- TRACTOR
- MORE MAIZE

**C) ARE THERE ANY NEW AGRICULTURAL STRATEGIES YOU ARE PRACTISING AS A RESULT OF CLIMATE CHANGE VARIABILITY**

**NON IRRIGATION**

**D) HOW MUCH WOULD YOU LIKE TO PAY FOR AN IRRIGATION FACILITY IF YOU WERE GIVEN THE CHANCE**

**E) WHAT ACRE/HECTARE OF LAND WOULD YOU LIKE TO GIVE UP FOR AN IRRIGATION FACILITY**





