Zentrum für Entwicklungsforschung (ZEF)
Centre for Development Research

MODELING FARM IRRIGATION DECISIONS UNDER RAINFALL RISK IN THE WHITE-VOLTA BASIN OF GHANA:

A tool for policy analysis at the farm-household level

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KURZFASSUNG

Eine unzureichende natürliche Ressourcenausstattung in Verbindung mit schwachen institutionellen Rahmenbedingungen hat in der Vergangenheit zu Armut im nördlichen Ghana geführt. Unsichere Niederschlagsmengen haben insbesondere die Verwendung verbesserter Technologien wie z.B. Dünger erschwert und die landwirtschaftliche Produktivität verringert. Dies gilt ebenso für landwirtschaftliche Haushalte im White-Volta Basin in der ghanaischen Upper East Region. Die Ausweitung von Bewässerungslandwirtschaft wurde lange Zeit als eine Entwicklungsstrategie zur Lösung der komplexen Probleme in der Region wahrgenommen. Dies führte zu erheblichen Investitionen des öffentlichen Sektors in die mittel- sowie kleinstrukturierte landwirtschaftliche Bewässerungsinfrastruktur. Allerdings begrenzte das bestehende stringende makroökonomische Regime in Ghana die Finanzierungskapazität des öffentlichen Sektors. Dennoch sorgte die zunehmende Lücke zwischen lokaler Getreideproduktion und –nachfrage, wie z.B. nach Reis, dafür, dass die Strategie einer Ausweitung der Bewässerungslandwirtschaft als eine zentrale Maßnahme in Ghana's ländlicher Entwicklungspolitik bis dato aufrecht erhalten wird. Durch die Nutzung primärer und sekundärer Datensätze analysiert die vorliegende Studie die Bestimmungsfaktoren für Bewässerung auf Haushaltsebene vor dem Hintegrund des neuen makroökonomischen Rahmens. Ebenso wird ein sog. Safety-First Risk Programming Modell zur Simulation des Einflusses verschiedener Politikmaßnahmen im Hinblick auf die Bewässerungsentscheidungen von auf Subsistenz und kommerzieller Landwirtschaft ausgerichteter Haushalte erstellt. Die Resultate dieser Studie legen nahe, dass die Vermögensausstattung eines Haushalts im allgemeinen und das vorhandene Arbeitsangebot im speziellen eine signifikante Rolle im Entscheidungsprozess des Haushalts spielen. Die ökonometrische Analysen sowie die Simulationsstudien zeigen, dass zwischen der Bewässerungsentscheidung des Haushalts und externer Beteiligung eine Komplementarität besteht. Diese korrespondiert mit der Beobachtung, dass in Ermangelung von Krediten Landwirte auf außerlandwirtschaftliche Finanzierungsquellen zurückgreifen um die Bewässerungstechnologie zu finanzieren. Eine signifikante Zunahme des Kreditangebotes für kommerzielle Farmer führt zu einem Anstieg der Nachfrage nach Arbeit welches profitabel durch die auf Subsistenz ausgerichteten Landwirte angeboten werden könnte. Schließlich legen die Ergebnisse dieser Studie nahe, dass die Ausweitung der Bewässerungslandwirtschaft zu einem Anstieg des Einsatzes von inorganischen Düngemitteln führt.

ABSTRACT

Poor natural resource base coupled with weak policies and institutional set ups made poverty in the semi-arid tropics of northern Ghana prevalent. Rainfall risk in particular is important in limiting the use of improved technologies such as fertilizer and in decreasing agricultural productivity. Farm households living in the White-Volta basin of the Upper East Region of Ghana share this episode. Expansion of irrigation agriculture was long perceived as a development strategy to solve the multifaceted problems in the study area. This perception led to an investment on both medium and small scale irrigation. However, the existing stringent macroeconomic regime in Ghana limited the public sector's capacity to finance irrigation. Nevertheless, the increasing gap between local production and demand for cereals like rice kept irrigation expansion as a core strategy in Ghana's rural development endeavor up to now. Using both primary and secondary datasets this study analyzed determinants of household irrigation decision in the white Volta basin of the Upper East Region of Ghana. The study also built a Safety-First Risk Programming Model to simulate the impact of different policy interventions on subsistence and commercial farm households' irrigation decisions. The findings of this study suggest that household asset endowments in general and labor endowment in particular play significant role in farm households' irrigation decision. Both econometric and simulation analyses showed a complementarity between household irrigation decision and off-farm participation. The complementarity confirms well with the observation that in the absence of credit services farmers resort to alternative sources of finance such as off-farm income to finance irrigation. A significant increase in agricultural finance to commercial farmers increases their demand for labor that could be profitability supplied by the subsistence farm group. Finally, the findings of this study suggest that expansion of irrigation promotes the use of mineral fertilizer.

DEDICATION

This work is dedicated to all who exert their at most effort to make poverty a history.

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List of Acronyms

AHM = Agricultural Household Models

CGE = Computable General Equilibrium

CRS = Constant Returns to Scale

DSS = Decision Support System

EA = Enumeration Areas

EU = expected utility

GIDA = Ghana Irrigation Development Authority

GLOWA = Global Change in the Hydrological Cycle

GLSS = Ghana Living Standards Survey

ICOUR = Irrigation Company of Upper Region

IFAD = International Fund for Agricultural Development

KMO = Kaiser-Meyer-Olkin

Kg = Kilogram,

LACOSREP = Land Conservation and Smallholder Rehabilitation Project

LPM = Lower partial moments

MAS = Multi-Agent Systems

MLE = Maximum Likelihood Estimate

MoFA = Ministry of Food and Agriculture

MOTAD = Minimization of Total Absolute Deviations

RDEU = Rank dependent expected utility model

SAP = Structural Adjustment Program

SF = Safety-first

SSA = sub-Saharan African

UER = Upper East Region

URADEP = Upper Region Agricultural Development Program

UWADEP = Upper West Agricultural Development Program

VaR = Value-at-Risk

1: Introduction

The performance of the agricultural sector in sub-Saharan African (SSA) is the worst among the developing world. The yield level of major crops has either declined or remained where it was decades ago and is unable to match the population growth rate. As a result of this mismatch there is an increase in the level of poverty in the region in general and the rural and semi-arid areas in particular (IFAD 2001). Rural farm households in the semi-arid tropics of Ghana, the focus area of this study, share this unfortunate episode. Both bio-physical and socio-economic factors play significant role in the poverty incidence. The biophysical environment is characterized by poor soil quality and erratic rainfall conditions. The erratic nature of the rainfall in particular plays a central role both in directly reducing crop yields and indirectly limiting the adoption of soil improvement technologies such as fertilizer and other yield enhancing technologies.

In recognition to the concentration of poverty in the rural part of the SSA, focusing development efforts to the rural parts has for long been recommended as a poverty alleviation strategy with wide range significance (Abdulai and Delgado 1995). In this rural based poverty alleviation strategy, the dependence of the agricultural sector on traditional technologies gives an entrance point. The Asian experience of the Green Revolution, which led to a doubling or tripling of yields for the major food grains in the 1960s and 1970s, reinforced the conviction that a technological change can be a powerful force in reducing poverty (de Janvry and Sadoulet 2002). Irrigation was particularly an important technology that enabled achieving food self-sufficiency in large parts of Asia, therefore it is also perceived as an appropriate development strategy particularly for the semi-arid tropics of SSA.

(Bhattarai and Narayanamoorthy 2004) reported that in India the marginal impact of irrigation on Total Factor Productivity (TFP) is positive and significant with an elasticity of 0.32 which is more than three times the elasticities of other factors such as fertilizer, high yielding varieties (HYV), and road infrastructure. It also had a strong inverse relationship with rural poverty in India. (Jimenez 1995 as quoted by (Sawada and Shinkai 2003) after summarizing various studies across 58 countries showed that irrigation contributed much more than any other rural infrastructure investment. In general, irrigation technology played a central role in increasing calorie availability per person and ultimately avoiding widespread famine (Carruthers et al. 1997; IFPRI 2002).

1.1 A Conceptual Framework of Irrigation-Food Security Linkage

Generally, agricultural technologies can have direct and/or indirect impacts on poverty (de Janvry and Sadoulet 2002). Agricultural technologies can have direct impacts on poverty levels through raising the welfare of poor farmers who adopt the technology in question. The farmers can derive potential benefits from increased production for home consumption, higher gross revenues from sales and lower production costs. On the other hand, the indirect impact on poverty can be on non-technology adopters through: the price of food for consumers; employment and wage effects in agriculture; employment, wage, and income effects in other sectors of economic activity through production, consumption, and savings linkages with agriculture, lower costs of agricultural raw materials, lower nominal wages for employers (as a consequence of lower food prices), and foreign exchange contribution of agriculture to overall economic growth (Haggblade et al. 1991).

As any other technology irrigation can also have both direct and/or indirect impacts on food security (Diagram 1). Irrigation can directly contribute to food security by reducing rainfall risk and therefore boosting the use of complementary technologies such as mineral fertilizers (Lamb 2001). This direct effect can be successfully realized if irrigation is used for the production of cereals that are already important in the community's consumption bundle, for example rice in Ghana. Alternatively, irrigation can directly contribute to food security through the creation of necessary conditions for the production of non-traditional food crops.

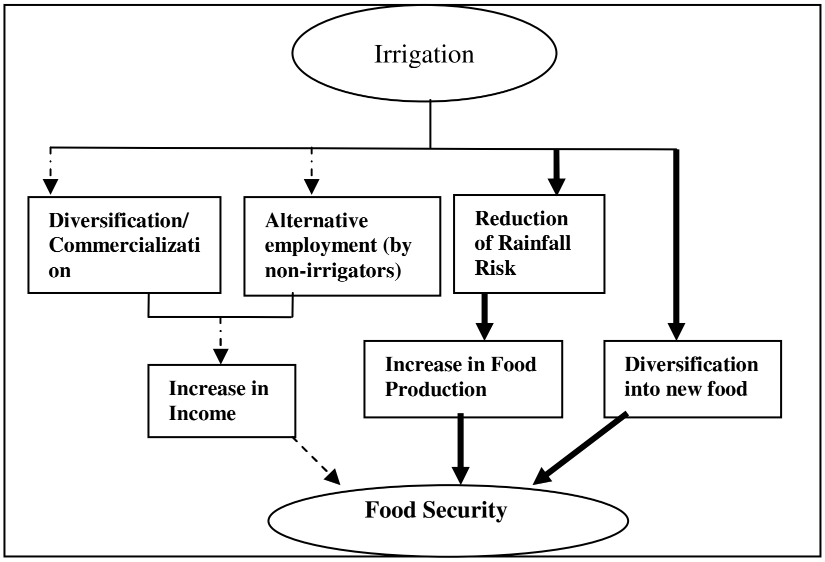


Diagram 1: Schematic Representation of Irrigation and Food Security Linkage

On the other hand, irrigation can indirectly contribute to food security by creating employment opportunities. The adoption of irrigation by large-scale farms could increase the demand for farm labor, which would create employment opportunities for non-irrigating farm households. For example, rice and horticultural productions demand large planting and harvesting labor inputs, therefore the expansion of these crops as a result of irrigation will increase demand for labor. The increase in employment income can increase household access to food. A very good example for this linkage is, the irrigation based export market of floriculture and horticulture in Kenya which has created employment opportunity around the irrigation areas (Mekuria Tafesse 2003). (von Braun 1994) also reported that commercialization of vegetable production in Guatemala led to a 45 % increase in employment while commercial rice production in the Gambia led to a 56 % increase in employment.

The other indirect contribution of irrigation to food security is its potential to create new opportunities such as commercial fishery production, which could increase household income and lead to increased food availability. (Kennedy 1994) reported that farmers who were part of a sugarcane out-growers program in southwestern Kenya got higher income and had higher level of consumption as compared to non-participants. The potential benefits from the indirect linkages of irrigation to food security, however, depend on the availability of both domestic markets and comparative advantages in international markets for crops/products of irrigation agriculture.

The whole sets of linkages between irrigation and food security show that irrigation policies need to consider whole set of factors so as to meet their intended goal of sustainable food security. Improvements in infrastructure, transport facilities, price and market policies, are vital to avoid the problems that made the first Green Revolution too expensive or inappropriate for much of Africa and efficiently materialize the benefit of irrigation technology (IFPRI 2002). Market policies designed to ensure stable and profitable input/output prices ratios for all farmers, by guaranteeing procurement of output and subsidized factor inputs as experienced elsewhere in Asia (Johnson et al. 2003) could help to sustain the benefit of irrigation.

Relevant information for policy advice on the above discussed irrigation food security linkages in the UER of Ghana is either scant or unavailable. This research work is part of the Federal Government of Germany's funded research on global hydrological cycle in the Volta basin of West Africa, called the GLOWA-Volta project. The GLOWA-Volta project is designed with the core objective of developing a scientifically sound Decision Support System (DSS) for the assessment, sustainable use and development of water resources in the Volta-Basin.

1.2 Research Questions, Hypothesis and Objectives of the Study

The expansion of irrigation into the northern regions of Ghana, regions which lie in the semi-arid agro-ecology, was long perceived as a policy strategy to break the evil marriage of unreliable rainfall conditions, low agricultural technology use and low agricultural productivity. In addition to that, irrigation's contribution towards poverty alleviation through the creation of local employment and limiting out-migration was also seen as a solution to the historical migration of the young and able bodied northerners to southern Ghana (Konings 1986).

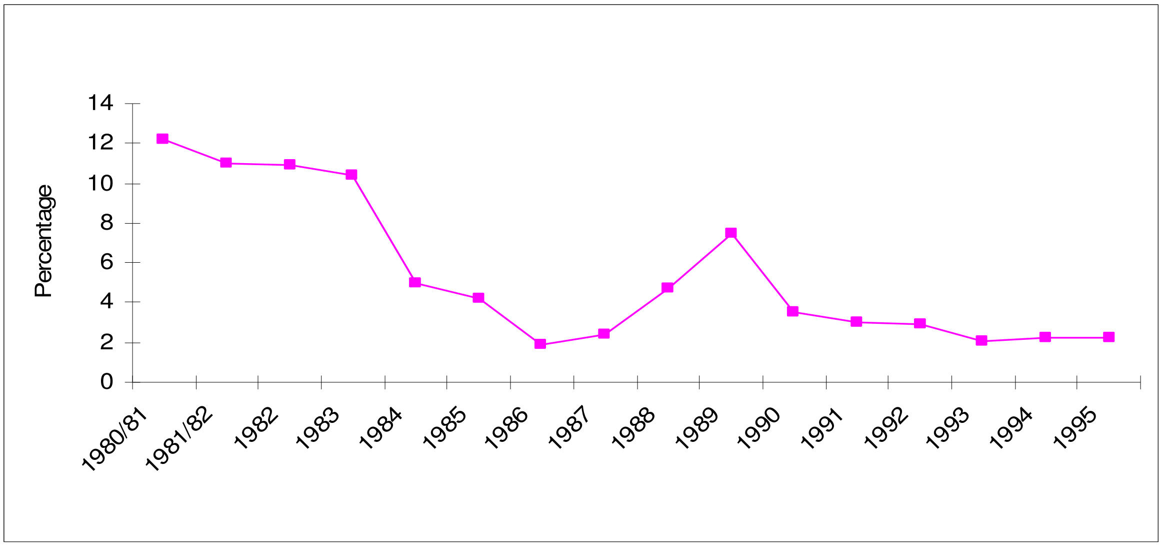
Even today, the increasing gap between local production and demand for cereals like rice keeps irrigation expansion as a core strategy in Ghana's rural development endeavors.

Ghana's poverty reduction strategy stressed that in order to meet the country's targets the total irrigation area need to be increased by 5000 ha per year to 100,000 ha by the year 2015 (GIDA/JICA 2004). For example, the 2002 budget statement of the Government of Ghana mentioned that the importation of rice should be reduced by 30% by 2004 and irrigation is supposed to play key role to growing all the rice and other cereals that the country currently imports (Mekuria Tafesse 2003). Irrigation becomes particularly important in the semi-arid parts of Ghana, where there is high concentration of poverty and the agricultural sector is constrained by erratic rainfall condition.

Therefore, given the growing gap between agricultural production and population size in the study area irrigation cannot be kept out of the food security equation. Therefore, there is immense interest both from policy and research to understand the economic drives behind farm household irrigation decisions. The increasing interest to expand irrigation services in Ghana is constrained by the existing macro-economic regime, which limits the public sector's capacity to finance irrigation. The introduction of the Structural Adjustment Program (SAP), which Ghana embarked on since the early 1980's has changed the paradigm of irrigation agriculture. The reform included a large nominal devaluation of the Cedi[1] and a fiscal contraction to achieve and sustain a real devaluation. Credit and monetary policies were also designed to reduce inflation and the current account deficit with the elimination of controls on deposits and lending interest rates (Corbo and Fischer 1995).

After the reform the budget share of agriculture shrank from 12 % prior the reform to only 2 % in the 1990s (Figure 1.1). This drop in budget share resulted in huge cuts in formal credit and input supply programs such as subsidies for fertilizer, and animal traction equipments (Reardon et al. 1994). In addition, the reforms led to increased gap between input and output prices. For example, the ratio[2] of fertilizer price to rice price dropped from its level of 0.2 in the late 1980s to a level of 0.8 in the 1990s (Gerken et al. 2001).

[1] Ghanaian National Currency which had an exchange rate of roughly 1€=10,000 Cedis during the field work for this study between November 2003 to January 2004.
[2] This ratio measures the Kg. of rice required to purchase one Kg. of fertilizer.



Source: (Nyanteng and Dapaah 1997)

Figure 1.1: Change in the budget share of the Agricultural sector

Credit for the purchase of inputs for small-holder farmers was also significantly affected by the reforms. According to a World Bank estimate in 1995 the effective demand for agricultural credit in Ghana was 196.7 billion Cedis (in 1988 prices) while the total loans available to agriculture, forestry and fisheries was only 42.12 billion Cedis (Seini 2002).

The macro economic reforms through their effect on agricultural budget also forced a reorientation of the Irrigation Company of Upper Region (ICOUR), a parastatal body managing two large irrigation schemes in the UER. ICOUR was reoriented to cover its running costs; as a result it has increased irrigation levy and stopped provision of subsidized inputs.

Internationally too, the financial constraint on irrigation development has become more and more binding as international funding institutions such as the World Bank decreased irrigation lending significantly (Rosegrant and Svendsen 1993). During the financial years, 1995-99, there were only 39 irrigation projects with an average annual lending of US$ 750 million as compared to the case in the 1970s where the Bank gave credit to over 250 projects at a total cost of US$ 1120 million (1991 prices) (Lipton et al. 2003).

All these factors do have significant implications on farm households' irrigation decisions, the contribution of irrigation agriculture to food security and poverty alleviation. Therefore, it is timely and relevant to analyze the irrigation decisions in the

UER of Ghana. To this end, the following research questions, hypothesis and objectives were addresses.

1.2.1 Objectives of the research

1. To analyze the determinants of farm irrigation decision under a macro-economic reform,

2. To develop a modeling tool for analyzing policy and technology interventions, and

3. To analyze the effect of irrigation technology on household welfare.

1.2.2 Research Questions

1. What are the major determinants of farm irrigation decisions in the UER?

2. Which structural and price incentives induce subsistence farmers to engage in irrigation farming?

3. What are the impacts of irrigation participation on farmers' welfare?

1.2.3 Central Hypothesis

Given the need for a wider use of irrigation technology in the semi-arid of the White Volta Basin of Ghana and the existing constraint in the credit market, this study started by putting the following hypotheses:

1. Household labor endowment plays an important role in irrigation decision.

2. Off-farm income is an important source of agricultural finance.

3. Irrigation use by large farmers has a spillover effect on subsistence farmers.

1.3 Outline of the Dissertation

This dissertation is organized into 7 chapters including this introductory chapter. Chapter 2 gives socio-economic and bio-physical description of the UER. Therefore, by way of introducing the study area it tried to give the justification for the effort made to address the research questions.

Chapter 3 of this dissertation has three major focuses. First, it discusses the data collection methods followed and the different data used. Secondly, it discusses the characteristics of the sample households. It will give an overview of the socio-economic conditions of the sample households. Thirdly, it will discuss how the sample households were used to identify representative farm households. It discusses the result of factor and cluster analysis and also discusses the characteristics of the identified clusters.

Chapter 4 of this dissertation will discuss a theoretical model developed to capture irrigation decision under the assumption of credit market constraint and a working labor market. It empirically tests the hypotheses on determinants of irrigation decision. In addition to that, it discusses an empirical model on the impact of irrigation on mineral fertilizer use. The results of this particular chapter will serve as bases for the identification of policy instruments, which will later be used for scenario analysis.

Chapter 5 of this dissertation gives a full documentation of a mathematical programming model developed for policy and technology analysis for use in the Decision Support System of the GLOWA-Volta project. It discusses how a Lower Partial Moment based safety first risk constraint is incorporated into a linear programming framework.

Chapter 6 of the dissertation discusses simulation results of selected policy and technological interventions using the programming model discussed in Chapter 5. It discusses the impact of different interventions on different farm groups. Finally, Chapter 7 winds up the dissertation by summarizing and giving some conclusions and drawing some implications.

2: Background of the Study Area

2.1. Socio-Economic Features

2.1.1 Demography, Household structure and Labor Use

According to the 2000 census the UER of Ghana has a population of 917,253 and a total land area of 8,842 Km^2 (GSS 2000). The region is subdivided into six districts namely Kassena-Nakana, Bongo, Bolgatanga, Bawku-East, Bawku-West and Builsa. Two additional districts were created during the survey for this study. The population size in the region has increased, between the 1984 and 2000 census years at an annual rate of 1.1 percent, which is much less than the national average of about 3.1 percent (Wardell et al. 2003).

The UER is one of the most densely populated regions in Ghana. Successive studies on the demographic features of the region revealed a larger increase in the population density leading to an increase in the number of farm households and decrease in average farm size (Webber 1996). According to the 2000 census the population density of Bongo district is the highest with 204 persons/ km^2, followed by Bawku East 146 persons/ km^2, Kassena-Nankana 111 persons/ km^2 and Bolgatanga 105 persons/ km^2. All the four districts have a very large population density as compared to the national average of 75 persons/ km^2 (ICRA 2002). The population density of the UER is not only larger than the national average but it is also larger than the population densities in the other two neighboring regions of northern Ghana, namely Northern and Upper West Regions.

The migration of labor from the northern parts of Ghana to the southern parts is very prominent. The most important internal migration pattern is the seasonal migration of labor from the northern to the southern regions. Existing studies show that, migration in Ghana is motivated by three main factors, namely the differential vegetation zones of the forest and savanna with the predominance of cash crops especially cocoa in the former, existence of mineral resources in the forest areas, and the advent of European colonization which fostered concentration of development in Southern Ghana (Nabila 1985).

Farm households in the UER are organized in compounds, where more than one household, what we refer to here as micro-household, live under the spiritual authority of an eldest family male member. Under this system, newly married couples will build their hut in the compound and cultivate their own lands that will be allotted to them by the eldest member of the household. This implies that, the micro-households within the compound have some economic independence and autonomy in terms of farm decision making. Since the micro-household largely corresponds to the common definition of a household as the farm decision making unit it was taken as the sampling unit for this study. However, hereafter for the sake of simplicity the term household will be used in this study in reference to the micro-households in a compound.

The household head is responsible for allocating labor within the household. He can command the labor power of all the young males on the family farm. All adult males are traditionally charged with the responsibility of providing the household with grains and so they concentrate on farming whilst adult females are responsible for the household maintenance task. Where they do not have their own farms, adult females also actively participate in the household farms.

The compound head can also mobilize labor from relatives, friends within the community, sons-in-law, and relatives living in other villages for specific activities (such as weeding and harvesting of crops), and serve food and beverages. The host is not obliged to repay but it is moral for him/her to reciprocate if anyone (especially of the participants) makes a similar call. However, the rising costs of providing food and drinks for the participants of this form of communal labor is dwindling the ability of many households (especially the poor ones) to mobilize communal labor.

2.1.2 Land Holding and Tenure Arrangements

2.1.2.1 Land Size

On average households in the UER own land which is very small, fragmented. There is significant variation across districts with 2 hectare in Builsa and about half a hectare in Bawku West and Bongo districts. The three districts covered in this study namely Bolgatanga, Bongo and Kasena-Nakana on the average have holdings less than 2 ha.

Given that the average family size in the area is 8 persons per HH the average land size of 1.3 hectare implies that the per capita land size is only 0.16, which clearly shows the level of land scarcity in the region. According to a report by the region Ministry of Food and Agriculture (MoFA) more than 90 percent of the population in the region has land holding less than 2.1 ha (Table 2.1). The scale of land fragmentation limited agricultural mechanization and fallowing. Increasing population pressure and declining soil fertility have led to an increasing fragmentation of farms in the agricultural landscape in most parts of the region (Konings 1986).

Table 2.1: Distribution of Size of land holding in UER

Size (ha.)	Frequency	%	Cumulative %
0.1-0.6	72	17.4	17.4
0.6-1.1	87	21.2	38.6
1.1-1.6	126	30.7	69.3
1.6-2.1	100	24.2	93.5
>2.1	26	6.5	100
Total	411	100	

Source: LARCOSEP Phase II Report

In the study area there are two types of farms namely compound and bush farms. Compound farms are farms located immediately surrounding or in the vicinity of the homestead. Compound farms are small in size as a result fragmentation and are mainly used for the production of cereals such as millet and sorghum intercropped with cowpeas and other beans. Land use intensity is very high on the compound farms and no fallowing is practiced (Clottey and Kombiok 2000) but they are usually supplied with household refuse and livestock droppings. Farmers usually, tether livestock around their houses and keep changing the positions (dynamic kraal) so that their droppings can spread evenly around the compound (Clottey and Kombiok 2000).

Bush farms are farms usually located some kilometers away from homesteads; however as a result of population pressure, in the UER, bush farms are not very popular as is the case in the Northern and Upper West regions. The most commonly harvested crops on bush plots are groundnut, soybeans, bambara beans, rice, late millet, sorghum and maize and they are more marketed than harvest from compound lots. The bush farms are largely not manured, and are usually cropped in rotation with bush fallows. Population pressure and increasing land scarcity, however, are limiting the fallow length, and effectively reducing the ability of the system to naturally restore soil fertility.

2.1.2.2 Land Tenure

The Frafra and the Kasena, the two major ethnic groups in the survey districts, believe that the land is a goddess and belongs to the ancestors. The goddess of the Earth is represented by objects such as stones, rivers, streams, and trees (Konings 1986). These objects are called *tangwani* in Kasen. It is the duty of the *tegatu* (or *tindana* in Frafra), the landlord and priest of the Earth, to sacrifice to the *tangawani* so as to secure peace and prosperity for the community. The land priests are the descendents of the pioneer settlers and have the ultimate authority over land in their respective villages and towns. The land tenure system, therefore, stems from discovery, settlement and inheritance (Kasanga 1994).

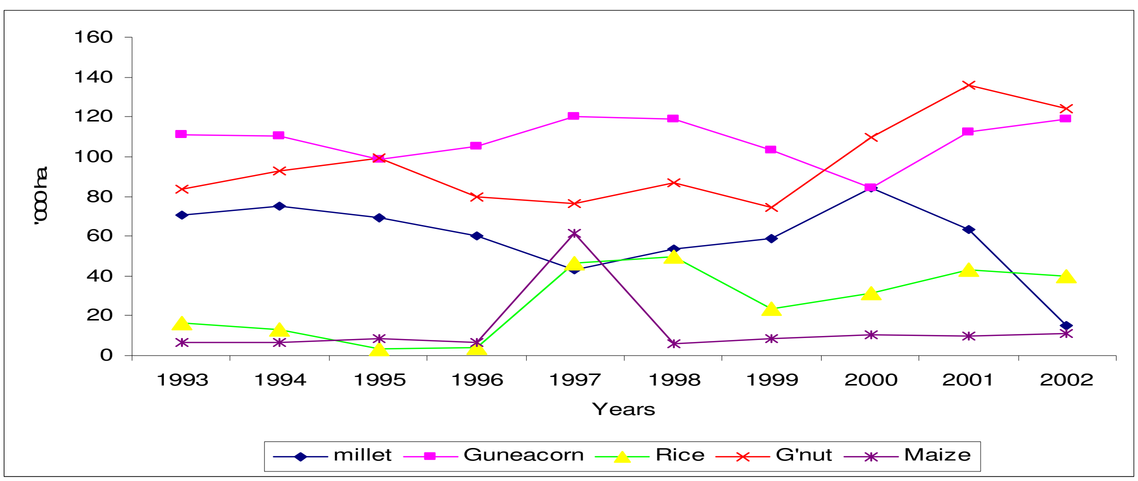
There is a relationship between absolute title to a land and sacrificing to the tangawani of the area. Therefore, by virtue of having the spiritual authority to sacrifice to the tangawani, the tindanas own the land on behalf of the community. Anyone who needs land has to get it from the tindanas and in both the Frafra and Kasena areas land is never sold and land borrowing is the most common form of land acquisition (Konings 1986). Borrowed land is not transferable to successors; the borrower enjoys usufructuary rights only as long as the landowner does not need the plot in question for himself.

2.1.3 Economic Activities

Agriculture is the major stay of the population in the UER. It contributes about 65 percent of household income (Ghana Statistical Service 2000b). Farmers in the area produce mainly for home consumption, while very small value of the total production is marketed. Only 12 percent of millet, 31 percent of Beans, 38.3 percent of groundnut and 46.9 percent of rice values are marketed in the rural savannah regions in general (Ghana Statistical Service 2000b).

2.1.3.1. Crop Production

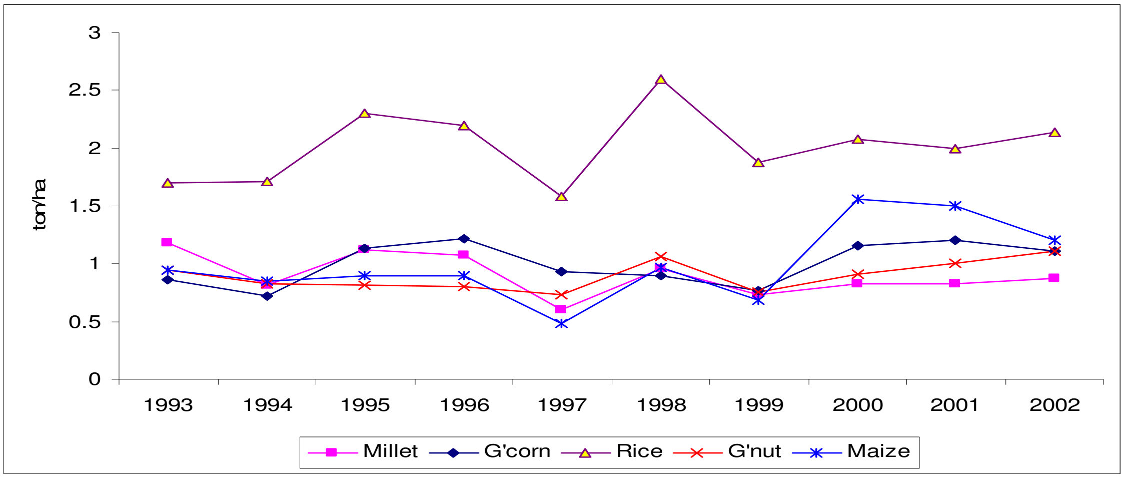
The common crops grown in the UER are early and late millet, sorghum/Guinea corn, rice and maize. Vegetables, such as onion, tomatoes, okro and other traditional leafy vegetables are also cultivated, especially, in the Bolgatanga, Bawku East and Kassena-Nankkana districts. Tomato, onions, and rice are cultivated both during rainy and dry seasons. Most crops are grown in mixed cropping systems, while rice and tomato are grown in mono cropping. A ten year average land allocation in the UER shows that guinea corn and groundnut account for 35 and 30 percent of the cropped land respectively. The importance of guinea corn is more vivid when one looks into district level data, where it occupies 45 percent and 40 percent of crop land in Bongo and Kassena-Nankani districts respectively. One possible explanation for the growing importance of guinea corn is the increasing demand from the local breweries to use it as additional input in malting and the government's support through credit provision (MoFA Personal Communication). The area allocated to different crops has changed through time (Figure 2.1).



Source: MoFA UER office

Figure 2.1: Trend in Area Coverage of Major Crops

Rice is cultivated in swampy areas during the rainy season and under irrigation during the dry season (for example, Vea and Tono irrigation schemes). Agricultural productivity in the region is very low and has shown little improvement (Figure 2.2). All crops but rice depend solely on traditional inputs and there is little use of mineral fertilizer in the study area, as a result on average rice yields better than other crops in the area. For most years between 1993 and 2002, the period for which data was available, the yield level of most crops was below one ton per hectare.

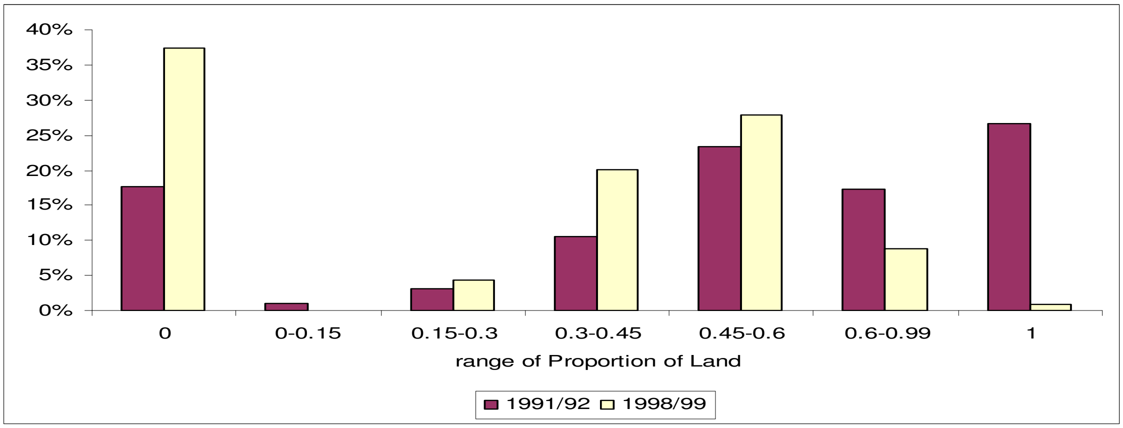


Source: MoFA UER office

Figure 2.2: Per Hectare Yield of Major Crops in the UER

2.1.3 1.1 Observed Land Use Trends

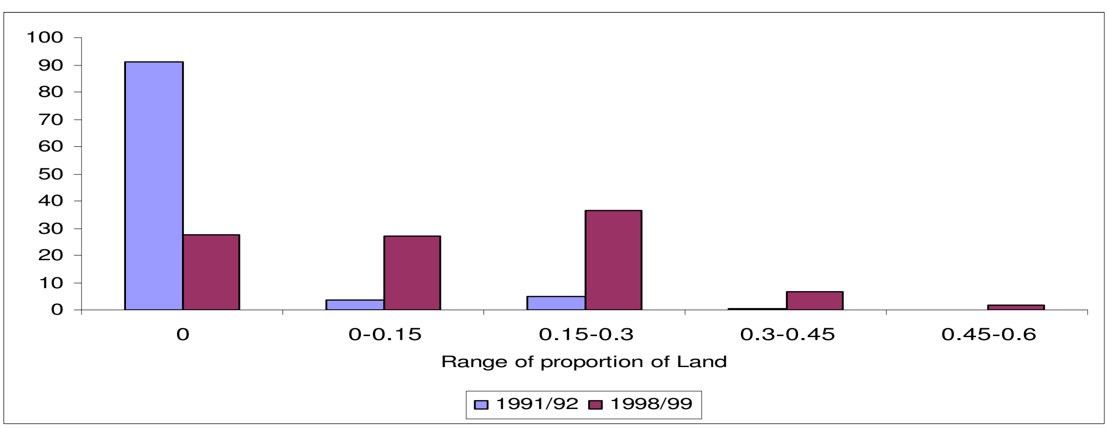
A comparison between the land use data in the 3rd (1991/92) and the 4th (1998/99) rounds of GLSS from the UER indicate a significant shift of land use from a mixed crop to a sole crop culture. In 1991/92 on average 56 percent of the land holding was allocated to a cereal- legume intercropping, while in 1998/99 the cereal-legume mix decreased by 45 percent to a level of only 31 percent of the total land use. On the other hand, in the 1991/92 cropping season only 1.5 percent of the total farm land was allocated to rice production with a maximum land allocated to rice of 0.13 ha. In 1998/99 the average area allocated to rice increased by about 800 percent to an average of 14 percent of the total farm land holdings with the maximum land allocated to rice increasing to 0.60 acres.



Source: GLSS 3 & 4

Figure 2.3: Proportion of Land Allocated to Cereal-Legume Mixed Cropping

In (Figure 2.3) it can be seen that there was a significant shift in the allocation of farm land. In 1991/92 there were only 17 percent of the farm households in the UER which did not allocate any land to the cereal-legume mix. This implies that the staple production pattern was an important component of the farming systems. However, in 1998/99 the proportion of households which have not allocated any land to the cereal-legume mix increased to 37.4 percent. On the other extreme, in 1991/92 about 25 percent of the farm households allocated all of their land to the cereal-legume mix while in 1998/99 this proportion dropped to only one percent. In conclusion, the change between the two time periods 1991/92 and 1998/99 showed that there is increasing interest in the production of rice (Figure 2.4).



Source: GLSS 3 & 4

Figure 2.4: Proportion of Land Allocated to Sole Rice between 1991/92 & 1998/99

Both changes in cropping patterns that is the increase in the average rice land and the decrease in the average cereal-legume mix land were statistically significant (Table 2.2).

Table 2.2: An ANOVA Table for the Change in Sole Rice & Cereal legume pattern

		Sum of Squares	Degrees of Freedom	Mean Square	F-stat.
Sole Rice	Between Groups	1.740	1	1.740	176.962***
	Within Groups	4.247	432	0.01	
	Total	5.987	433		
Cereal-Legume Intercrop	Between Groups	7.035	1	7.035	77.536***
	Within Groups	39.199	432	0.091	
	Total	46.234	433		

*** 1 % significance level

The above household level trend is in conformity with regional level observations where the area allocated to rice increased by more than 600 percent between 1987 and 1998 while that of millet decreased by about 20 percent (Table 2.3). There was also a significant increase in rice yield over the period 1987 and 1998.

Table 2.3: Change in Area & Yield of Major Crops in UER 1987/98

	% change in area	% change in yield
Millet	- 23.05	71.43
Sorghum	78.78	40.63
Rice	610.47	145.28
Groundnuts	84.13	- 7.83
Maize	42.45	29.33

Source: ICRA, 1999

2.1.3.1.2 Irrigation Technology

The history of irrigation and reservoir construction in the UER goes back to the pre-colonial times. During those times traditional irrigation systems, constructed with local technology, controlled and managed by local people in response to their felt needs, have been in practice in most parts of northern Ghana (Ayariga 1992). After independence expansion of irrigation schemes was proposed to facilitate the production of grain and cash crops to raise the standards of living of the people and to turn northern Ghana into one of the largest grain baskets of the nation (Konings 1986). The pace of irrigation development in Ghana was, raised in the 1970s and all irrigation related activities were institutionalized by the establishment of the Ghana Irrigation Development Authority (GIDA) in 1977 within the then Ministry of Agriculture. Irrigation schemes of varying sizes were developed to provide water for large livestock populations and for vegetable gardening in the dry season. The Ghanaian government, with the support of the World Bank and IFAD, instituted programs and projects including the Upper Region Agricultural Development Program (URADEP) in the past and recently the Upper East Land Conservation and Smallholder Rehabilitation Project (LACOSREP) which has and continue to make a significant contribution to irrigation development (Gyasi 2004).

In general, there are four types of irrigations systems in the area namely: (i) large scale irrigation systems (using large reservoirs and large networks of canals, laterals and sub-laterals); (ii) small-scale irrigation systems (using small reservoirs, consisting of small irrigable area served by canals from the reservoirs, and dugouts); (iii) small-scale pump systems (using motorized pumps to draw water from rivers and streams); and (iv) traditional "bucket and calabash" systems (using wells, streams, ponds, and other water bodies). The large and small-scale irrigation systems are the dominant systems in northern Ghana, with the small-scale (reservoir and dugout) being the most prominent. In fact, there is a growing trend towards the construction of small-scale farmer-managed systems due to the high costs of construction and management (including technical expertise required for the operation and maintenance) of large scale irrigation systems (Gyasi 2004).

The large scale irrigation schemes run by the ICOUR include the Tono and Vea irrigation schemes. The company administers a total irrigable area of 2490 ha at the Tono and 850 ha at the Vea irrigation projects, which in total benefit about 6000 small-scale farmers who have access to plots in the projects and they come from the village communities around the project (Tono 8 and Vea 8 villages) (ICOUR 1995). Each farmer is allocated a plot of land between 0.2-0.6 hectares through village irrigation committees, which liaison between ICOUR and the farmers. ICOUR charges a project levy for rainy season farming activities and an irrigation levy for irrigation farming during the dry season. The fees for the different services are usually fixed at the beginning of each season and are posted on the company's notice boards (see Annex 4 for the 2004 announcement). Both Tono and Vea are operating at half of their capacity mainly because of the lack of credit for irrigating farmers (ICOUR personal communication). Onion, tomatoes, millet, groundnut, sorghum and maize are the major crops grown in the uplands of the irrigation projects, while rice dominates the lowlands.

The dam-based irrigation systems are of the simple gravity type, based on surface flow of water from dams fitted with inlet and outlet valves. Reservoirs are designed and located to harvest water along water courses from defined catchments, and an irrigation area down stream of the reservoir located beyond the dam embankment. The irrigation area is watered through network of canals from service valves, controlling flows of water to the irrigation area. On the other hand, the traditional irrigation systems involve fencing out individual plots with either thorny bushes/shrubs or mud walls along valley bottoms, seasonal rivers and ponds. Shallow wells are constructed manually in dried river beds by farmers each year from which water is drawn either with motorized pumps or with buckets, gourds for vegetable gardening in the dry season. This form of irrigation is often more labor intensive than the formal irrigation systems. There is rapid growth of pump irrigation especially along the Red and While Volta, where motorized pumps are used to draw water from the rivers. There are challenges in the irrigation systems in the area, which include lack of efficient utilization of irrigation water and the lack of proper management of the water resources. In order to circumvent the management problem currently there is a move towards devolving of irrigation management powers, particularly in the small dams, to local water users associations (Gyasi 2004).

2.1.3.1.3 Gender and Irrigation

In general, women play a significant role in traditional agricultural production in African societies (Kumar 1987). The experience in the UER of Ghana shows that irrigation significantly contributed to empowerment of women. These contributions were significant because of at lease three factors. The first one is female farmers were given direct Access to Irrigated Plots That is, currently land allocation at the irrigation sites, mainly Tono scheme, is undertaken by water users group. These groups represent farmers and are allotted blocks of irrigation sites by ICOUR; the water users groups then distribute the blocks among their members. One of the conditions ICOUR puts on the farmers groups is that the groups need to have women members. The norm is 50 percent of the group members need to be women, and although the norm may not always be kept in practice, a significant number of women received plots on the irrigation sites. During the field work for this research, for example, it was observed that one of the farmers group in the *Korania* community had 13 female and 15 male members.

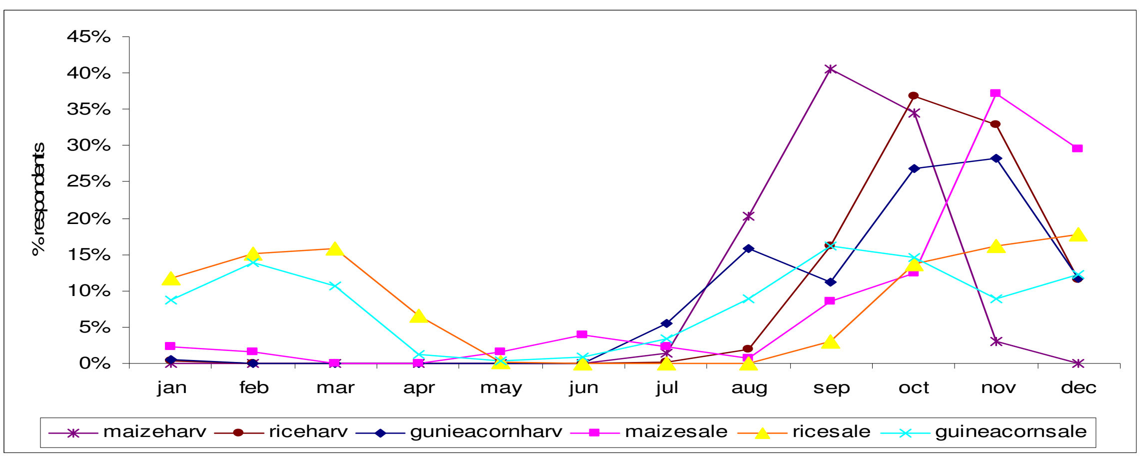
Secondly, the other important condition contributing to the positive effect of irrigation on women is the increased demand for their labor. Most of the agricultural activities in the irrigation areas depend on women labor. These activities include transplanting, harvesting and winnowing of rice and transplanting and harvesting of tomato. Irrigation therefore created demand for women labor, which increased women's bargaining power in the labor market, both in the terms of wage rate and forms of payment. During the survey it was observed that most farmers, who hired farm laborers particularly for rice, would prefer paying in cash but the majority of women laborers accept payments only in kind. Women laborers reported that the kind payment gives them the flexibility to use the payment directly for household consumption and sell it for cash. For example, for each 33 kg of paddy rice harvested and winnowed, women earn 2.4 kg of rice as a wage rate, which in monetary terms is equivalent to 6,000 Cedis. This increased bargaining power of women in the labor market would strengthen their social capital and is likely to increase their negotiation power also in other issues, like access to resources etc.

Finally, the comparison of irrigation in Cameroon and Ivory Coast with the irrigation in the UER showed that though women are involved in irrigated rice in all cases the benefits for women varied significantly (Kumar 1987). The major factors for these differences were the variation in the potential of irrigation in creating employment, the market orientation of irrigation products, the institutional setups that govern access to irrigation facilities and control over returns from irrigation activities.

2.1.3.1.4 Agricultural Marketing

The majority of the farmers sell their products in the local markets, which stand 2 to 3 times a week. Marketing agencies and co-operatives do not play significant roles in the marketing of crops except in one exception where ICOUR makes a deal with some irrigating farmers, who get fertilizer and other inputs on credit on the condition that they will repay in rice at fixed prices. Farmers on average travel 2 to 3 kilometers to reach the nearest market place. The predominant means of transportation of agricultural products is head portage and the majority of those using head portage are women. Farmers sell agricultural products and buy non agricultural products, such as kerosene, sugar, salt and also food items such as cereals and powders of Cassava (Gari) and Yam.

Between September and December most of the harvested products are sold on the market (Figure 2.5). The immediate supply of products after harvest is the result of a combination of factors such as lack of proper storage and cash demand to meet different obligation.



Source: (Ghana Statistical Service 2000a)

Figure 2.5: Harvest and Sell Calendar for Major Crops in the UER

Vegetables, particularly tomato, are mainly produced for the market. This is because, the supply of vegetable produced within the irrigation schemes in particular exceeds the local demand; therefore vegetables are usually marketed to urban centers such as Accra and Kumasi. Women traders, who are commonly called "Market Queens", are the major whole sellers who collect the vegetables from the farmers in the area. The "market

Queens" are more organized than the farmers and as a result they have disproportionately bigger bargaining power in the market. For example, the standard "crates", contain 52 kg but the traders bring their own crates, which are usually greater than 52 kg and force farmers to fill them but only pay the 52 kg price.

2.1.3.2 Livestock Production

Cattle, small ruminants (sheep, goats and pigs), donkeys and poultry including guinea fowls are the major species of livestock that are kept in the UER. As in most parts of Africa, farmers in the study area regard rearing and keeping of cattle as a store of wealth and measure of social status. Cattle are kept as insurance against unexpected need, calamity or hardships, and as draft animals.

Livestock herding in the area depends on the availability of water and season of a year. In cases where water sources are available within a reasonable distance, small boys herd cattle throughout the year, if not the animals are left to free range during the dry season (Bruce et al. 1999). However, bullocks are given more attention because of their important role in traction. Particularly during the ploughing season traction animals, be they oxen or donkey, are fed heads of millet. Sheep and goats are left to range in search of fodder and feed during the dry season while during the rainy season they are tethered on narrow patches of grass.

2.1.3.3 Crop Livestock Interactions

Crops and livestock interaction in most farming systems in the UER are observed through animal traction, soil fertility management and livestock feeding with crop residues. In most part of the UER hoe cultivation is increasingly giving way to animal traction (Bruce et al. 1999). Households that do not own traction animals often hire bullocks from other households for land preparation. On the other hand the interaction between crop and livestock via manure is important as most farmers in the area hardly use mineral fertilizers. For the most part, farmyard manures or animal droppings, as the case may be, are carried out of the household on head pans. The head pans are emptied in small piles and dotted all over the over the compound farms. Usually women do the carrying of manures from homestead to the farms. Finally, the feeding of livestock with crop residues is another important area of interaction between crops and livestock. Crop residues like groundnut, cowpea, soyabean vines and rice straws are important feeds for livestock during the dry season. In some areas these residues are gathered and stored on top of a shed at the homestead and fed in small quantities to cattle, sheep and goats throughout the dry season. Some rice-growing households also choose to leave the straw in the field rather than using extra labor to carry it home, so that livestock could graze on it.

2.1.3.4 Poverty

The UER is one of the poorest regions in Ghana. It is also a region where poverty is disproportionately a rural savannah phenomenon. The savannah agro-ecology has benefited very little from the poverty reduction programs in the country (Ghana Statistical Service 2000b). In the 1998-1999 at national level 40 percent of Ghanaians were classified as poor while the proportion of poor in the rural savannah agro-ecology was about 70 percent.

Table 2.4: Crop Production and Household needs in UER 1998 and 1999

Response	1998		1999	
	Frequency	%	Frequency	%
Production = Need	53	13	45	11
Production < Need	316	77	362	88
Non-response	42	10	4	1
Total	411	100	411	100

Source: LARCOSEP Report

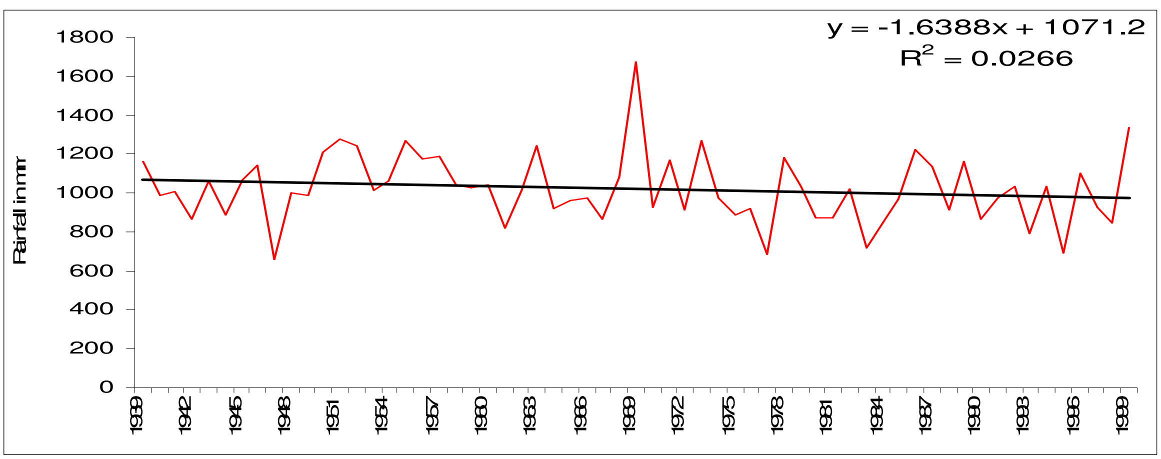
In a survey conducted by LACOSREP it was reported that in 1999 about 90 percent of the surveyed households reported that their agricultural production was not able to satisfy their needs (Table 2.4). The gap between household production and household needs shows the extent of food insecurity in the region and the need for interventions such as irrigation.

2.2 Bio-Physical Features

The UER has pronounced wet and dry seasons, which are due to the influence of two oscillating air masses namely the harmattan air mass and the monsoon air mass (Braimoh 2004). The harmattan is warm, dry and dusty while the monsoon wind is warm, humid and wet.

2.2.1. Rainfall

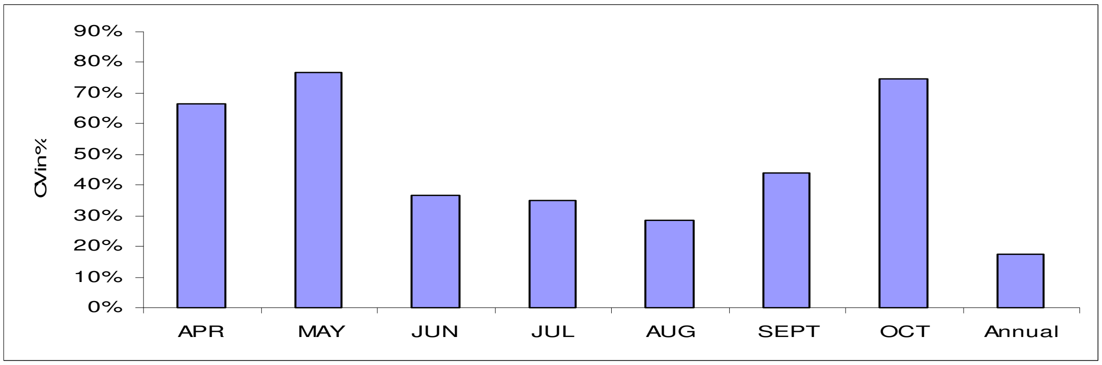
The UER has a uni-modal rainfall the major rainy season being between middle of April to October and the remaining months are dry. The long term average annual rainfall is 1044. The area also faces very irregular and frequent dry spells during the planting periods of June and July. The rainfall condition during the planting time is particularly important since it affects crop growth very much. The amount of soil moisture available for plants is considerably lowered by high runoff during the rainy season and by high evapo-transpiration especially during the harmattan wind.



Source of Data: (Obeng-Asiedu 2004)

Figure 2.6: Annual Rainfall in Navrongo, Upper East Region

As can be seen from (Figure 2.6) the fitted trend line explains only 2 percent of the total variation in rainfall across years. This means that there is no significant negative trend in average rainfall in the area (Hesse 1997). However, rainfall variability measured by the Coefficient of Variation (CV) shows that there is significant variation in rainfall during the on and off-set of rainfall (Figure 2.7). This indicates that the rainfall risk that farmers face can not be fully captured by only considering the total annual rainfall. One needs to consider the rainfall distribution in shorter intervals particularly during the critical periods of plant growth.



Source of Data: Volta River Authority, Engineering Department

Figure 2.7: Rainy Season CV of Rainfall for the period 1939-2000

2.2.2. Soil

The soils of the UER are known for their poor organic matter content. It emanates from high temperature, which causes rapid decomposition of organic matter, and the burning of the vegetative cover, which reduces the amount of available organic matter. Based on the FAO/UNESCO soil classification system, soils of UER fall into 3 basic classes (Anani-Sakyi et al. 1993). They are Class I, Class IV and Class VI, which account for 1%, 85% and 14% respectively. The Class I soils are soils suitable for intensive and continuous cultivation, while the Class IV soils are soils suitable for pastures, tree crops and for sustained annual crop cultivation, provided adequate measures are taken to maintain soil structure and fertility. The Class VI soils are soils which are shallow and rocky and unsuitable for arable farming. Agricultural productivity in the UER is very low and this is attributed mainly to the soils (Terbobri and Albert 1993)

Sustainable use of the soils of the area therefore requires the implementation of management practices that at least maintain if not increase the soil quality. The major technological approaches recommended by agronomists in the UER are application of organic and inorganic fertilizers plus the construction of soil and water conservation measures (Anani-Sakyi et al. 1993). Given that most of the soils are sandy, the use of organic fertilizer will not only increase the organic matter content but also stabilizes the soil in terms of higher yield response to inorganic fertilizers (Anani-Sakyi et al. 1993). The majority of the farmers use cow dung as a technique to maintain soil fertility on their plots around the compound, but its application is constrained with the increase in area of cultivation.

However, in spite of its important role in increasing soil fertility and improving the soil structure dependence on manure application has major limitations. The first one is the low nutrient concentration in manure. According to (Sanchez et al. 2002) animal manure contains from 1 % to 4 % N (on a dry-weight basis), while mineral fertilizer contains from 20 % to 46 % N and is already dry. This implies that to provide 100 kg of N generally needed to produce 4 t ha^{-1} maize grain crop, 20,000 kg of leaf biomass or manure (with 80 % moisture and 2.5 % N concentration) would have to be applied, in contrast to 217 kg of urea. In addition to that, organic inputs are poor sources of p because of their low concentrations.

Therefore, to meet the nutrient demand of the soils in the area one needs huge biomass. But arid and semi-arid agro-ecologies like the UER do not have the potential to produce large amount of biomass for organic fertilizer production. The cost of transporting bulky biomass to the plots is also another limitation, not mentioning the labor cost required to apply it on the plots. So any genuine effort to curb poverty requires abandoning the low-input low-output systems and a wider application of mineral fertilizers in combination of organic ones, for a maximum benefit (Sanchez et al. 2002).

In general, nutrition depletion in the semi-arid tropics of SSA exceeds replenishment by a factor of more than three times (Ryan and Spencer 2001). The literature suggests that traditional ways of dealing with the problem of soil nutrition losses will not suffice under current conditions in SSA to restore soil nutrients to levels needed to achieve steady increases in crop and animal production (Larson 1993). Few farmers use mineral fertilizers, largely because of the risks associated with rainfall variability (Hardaker et al. 1997).

2.2.3. Vegetation

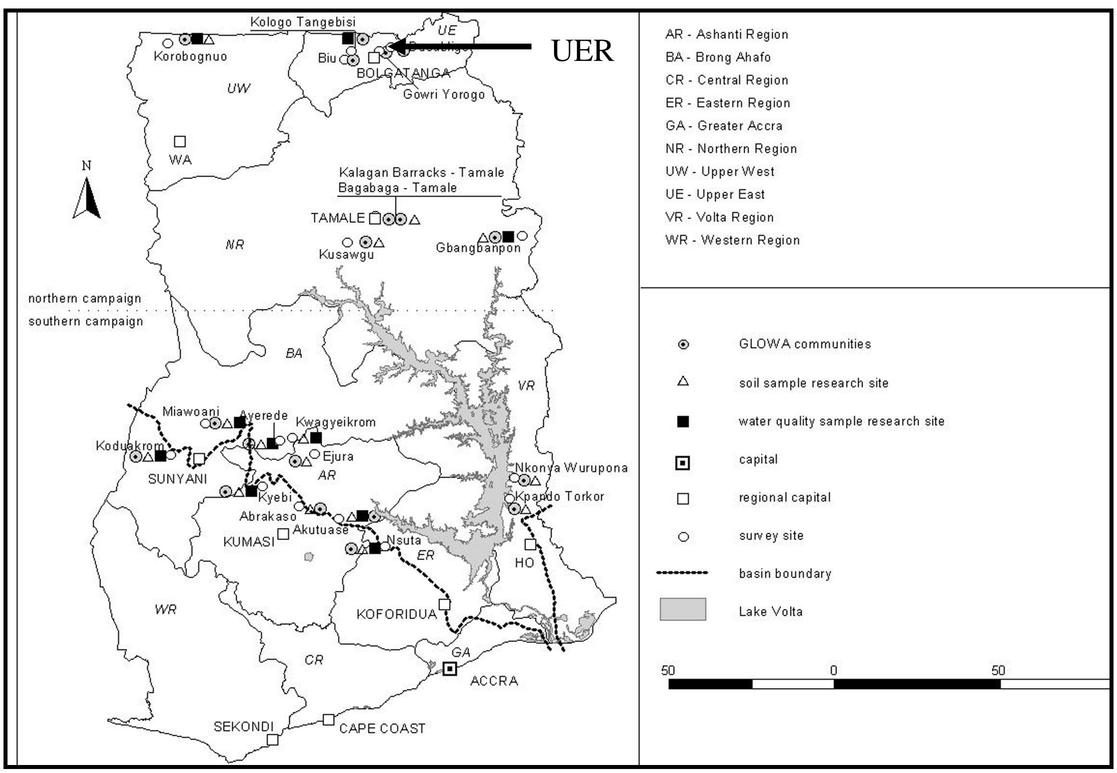
Most of the UER falls within the guinea savanna zone, with a small area north of Bawaku, which lies in the Sudan Savanna ecology. Natural vegetation is savanna woodland which consists of short, deciduous, widely spaced, fire resistant trees and shrubs which do not form a canopy, and grasses of various heights, liable to burning during the dry season (Anani-Sakyi et al. 1993). The predominant tree species of economic value that are commonly found growing on farmlands are Parkia filicoides (dawa-dawa), Butryospermum parkii (shea nut), and on some locations Faidhabia albida (Bruce et al. 1999). Grass species commonly found are Andropogon, Hyparrehnia and Heteropogon spp. On highly eroded soils Aristidia, Cymbopogon and Imperata spp. are also found (Dogbe 1998).

3: Farm Household Characterization and Classification for Policy Analysis

3.1 Characteristics of Sample Households

3.1.1 Sampling Procedure and Source of Data

The analysis for this dissertation was based on a follow up survey of the common sampling frame of the GLOWA-Volta community and household survey of 2001. The 2001 survey was constructed as a sub-sample of the Ghana Living Standards Survey of 1998/99 (GLSS IV) (Berger et al. 2002). The GLSS IV survey was a national survey conducted on a total of 300 Enumeration Areas (EAs). The GLOWA-Volta survey adopted the concept of common sampling frame, which takes into account the requirements of different sub-projects.



Source: GLOWA-Volta Project

Figure: 3.1 GLOWA-Volta 1st Household & Community survey sites

84 EAs, which satisfy the research requirements of the different sub-projects of the GLOWA-Volta Project, were selected out of 112 EAs of GLSS IV lying in the Volta basin. Using Principal Component Analysis, 8 factors that explain 70% of the variance in the 84 EAs were identified and used to classify the 84 EAs into 10 clusters. Finally 14 EAs closest to each cluster centroid were selected applying the "proportional to size" rule and additional 6 communities, out of the sampling frae were included (Figure 3.1). (Berger et al. 2002) documented the procedures and data used to identify the EAs for the first GLOWA-Volta household survey.

For this study, all the EAs of the GLOWA-Volta community and household survey in the UER were revisited and additional 6 communities were added to the list of communities. A standardized questionnaire was administered between November, 2003 and January, 2004 on the 10 communities, which all lie in the white-Volta sub-basin of Ghana (Table 3.1). A sample of 20 households from each community was interviewed. Most of the households interviewed were parts of the 2001 GLOWA-Volta community and household survey and they were located using their recorded Global Positioning System (GPS) and in the cases where the old households could not be located a farm household in the vicinity was used as a substitute.

Table 3.1: List of 2003/2004 Survey Communities in the UER of Ghana

District	Community	# of Households Surveyed
Bolgatanga		60
	1. Baare-Sakpare	20
	2. Benkute	20
	3. Dasabilgo	20
Kassana-Nakani		100
	1. Bawio	20
	2. Biu	20
	3. Blembisi	20
	4. Kolgo-Tangebisi	20
	5. Korania	20
Bongo		40
	1. Gowri-Yorgo	20
	2. Sambolgu-Amanga	20
Total		200

The interviews were conducted by 5 enumerators selected based on their knowledge of the study area and survey experience from similar research undertakings. They were provided two days training followed by a pre-test with some farmers around Bolgatanga. Because of the special interest on irrigation farming, more communities were sampled from Kassena—Nakani district, the district where the Tono irrigation scheme is located. As a result out of the 10 communities 3 are located in the vicinity of irrigation schemes.

In addition to the structured data from the household survey, the data collection included informal discussions with key informants like experts of the MoFA, commercial farmers, Tindans (land priest), chiefs and assembly men. The survey also benefited from farm records kept by some commercial farmers in the Biu community.

In addition to the primary data, the current study benefited from GLSS IV (Ghana Statistical Service 2000a). The GLSS IV survey contains disaggregated data among others on household income and expenditures. The expenditure records include cash expenditures (on food, services, housing, etc.) and data on household consumption of home produced goods and services, which are imputed expenditures. The data set covered a total of 260 households from the Upper East Region but only 197 households had all the specific variables of interest for the estimations at hand.

In summary, the primary data was used to describe households in the study area, to estimate irrigation decisions and for building the major components of the programming model. On the other hand, the data from GLSS IV was used to estimate consumption functions.

3.1.2 Demographic Characteristics

3.1.2.1 Family Size

The average family size for the sample households is 7.79 with an average of 3.57 male and 3.79 female members. About 55 percent of the households had family sizes ranging between 5 and 9, while 26 percent had more than 9 members (Table 3.2). The large proportion of young members of the household below the age of 15 indicates a higher level of dependency. That is, each economically active member of a household between the age of 15 and 50 supports 0.83 economically dependent members, both young and old.

Table 3.2: Family Size and Sex of sample households

	Mean	Stad. dev	Maximum
Total No. of Male	3.57	2.24	14
Total No. of Female	3.79	2.42	14
No. of Male < 15 Years	1.39	1.38	10
No. of Female < 15 Years	1.63	1.62	9
No. of Male b/n 15 & 50	2.02	1.64	9
No. of Female b/n 15 & 50	2.25	1.92	14
No. of Male older than 50	0.32	0.46	1
No. of Female older than 50	0.19	0.43	2

3.1.2.2 Education Level

The majority of households in the sample were headed by illiterate heads. More than 75 percent of the heads had no formal education and were not able to read and write. On the other hand, about 10 percent of the heads were secondary and junior secondary school completes. Though our survey did not data on school enrolment rates, informal discussions with farmers and some youngsters who are not attending school showed that school fees were important factors limiting school enrolment. About 85 percent of the sample households had reported that they made cash expenditures on schooling. The mean and median school expenditures are 488,896.6 and 150,000 Cedis, respectively. The opportunity of non-farm employment was also cited as another factor in low child enrolment or school drop out in communities like Bawio, which is located at the Burkina Faso border. In this community, children were employed by cross-country cattle herders, who pay boys attractive wages as a result many boys leave schools to take these jobs.

3.1.3 Asset Ownership

3.1.3.1 Farm Equipments

Farm tools such as hand hoes, catlars, and knives are the most important farm equipment assets in the study area. Only 7 percent of the sample households had oxen ploughs, as a result for the majority of farm households, expenditure on bullock and tractor hiring is an important component of household expenditure. More than 65 percent of the sample households had reported that they spent some money on renting bullocks or tractor. The average and median expenditures were 345,000 and 170,000 Cedis respectively.

3.1.3.2 Livestock Ownership

About 20 percent of the sample households owned chicken and 16 percent of households own guinea fowl. Goats and sheep were the next important types of livestock owned by 19 and 15 percents of the sample households respectively. Only 6.4 percent of the sample households had bullocks, which indicate their level of constraint in land preparation. In terms of their monetary value the mean and median of the total livestock assets were 6,836,106 and 2,360,000 Cedis respectively. About 25 percent of the sample households have livestock assets worth less than 725,000 Cedis.

3.1.4 Crop Production Activities

3.1.4.1 Major Crops

Farmers in the area undertake both rainy season and dry season farming. Rainy season farming is the major agricultural activity in the area. The major crops harvested by the sample households were groundnut, early millet, guinea-corn, bambara-bean[3], late millet and rice. All crops but groundnut and rice are in most of the cases planted in mixed form. The most commonly harvested crop mixes were early millet-late millet; early millet-guinea corn; guinea corn-early millet-late millet; late millet-early millet-means; early millet-guinea corn-late millet-beans; groundnut, bambara-beans and groundnut, beans-bambara-beans.

[3] Bambara-bean is a traditional legume

(Table 3.3) shows that millet and groundnut together account for about 70 percent of the operated land. Rice was cultivated under rain-fed, irrigated and supplementary irrigation, which is rain-fed rice on plots of land which have irrigation structures and can provide supplementary water in case of rainfall shortage. More than 90 percent of the sample households cultivate millet and groundnut, while only 25.5, 44 and 18.5 percent of the sample households had irrigated, rain-fed and supplemented rice plots respectively.

Table 3.3: Mean Area Coverage of Major Crops

Crop	Area (ha)	Std. dev	%
Millet	1.045	0.854	38.3
Groundnut	0.902	0.923	33.0
Irrigated Rice	0.207	0.514	7.7
Rain-fed Rice	0.190	0.315	6.9
Irrigation & Supplemented Rice	0.181	0.583	6.6
Guinea corn	0.039	0.181	1.4
Soybean	0.110	0.365	4
Maize	0.058	0.269	2.1
Total	2.732		100.0

3.1.4.2 Plot Location, Fragmentation and Size

The predominance of mixed-cropping culture and the increased fragmentation of land in the study area make the definition of a plot very difficult. Here we followed the definition that a plot, which is equivalent to saying a parcel, is a piece of land covered by a single cropping system. The cropping system could be both mono-cropping as well as mixed cropping. Most plots operated by the sample households are located around the homesteads and are referred to as compound farms. The compound farms account for about 60 percent of the plots followed by bushes, which account for about 20 percent of the plots. Even under the compound and bush plots farm households operate fragmented plots. 42 percent of the sample households operate more than 4 plots of land and 25 percent of households have exactly four plots (Table 3.4).

Table 3.4: Number of Operated Plots per Household

Number of Plots	No. of Observations	%
1	4	2
2	23	11.7
3	37	18.8
4	50	25.4
>4	83	42.1
Total	197	100

The average and median plot sizes were recorded to be 0.73 and 0.41 hectares respectively. About 25 percent of the plots are less than 0.3 hectare while 25 percent of the plots are greater than 0.8 hectare. In general the operated plots operated by the sample households were very small. That is, households in the area operate fragmented plots with the average number of plots operated per household being 4.36. At the aggregate level the total rain-fed and irrigated lands operated by the sample households are 3.1, 2.45 and 0.69 hectares respectively (Table 3.5).

Table 3.5: Size of Operated Land in ha

	Mean	Std. dev	Percentiles		
			25	50	75
Total Operated Land	3.14	3.71	1.42	2.23	3.45
Rainy season Land	2.45	1.86	1.22	2.03	2.85
Irrigated Land	0.69	2.66	0.00	0.00	0.40

Though the mean of the total operated land looks relatively large for the study area the associated standard deviation indicates the significant variation in operated land among the sample households. The majority of the households only operate plots obtained from the head of the compound. Cash based renting of agricultural land is not practiced in the area. The three most important forms of access to agricultural lands among the sample households are family assignments accounting for 79.7 percent of the cases, followed by water users associations and irrigation projects which accounts for about 11 percent of the cases, and finally relatives and friends, which account for 6.2 percents respectively.

3.1.4.3 Input Use

Agricultural labor is the most important agricultural input used by the majority of the sample households. The use of external inputs such as mineral fertilizers and agrochemicals is limited (Table 3.6). As explained above, plots close to the compound receive more organic matter than plots located in bush farms. More than 70 percent of the sample households reported that they used organic manure and only 32 percent used mineral fertilizers. The majority of those farmers, who used mineral fertilizer, were farmers who were engaged in irrigation agriculture. Even those farmers who applied inorganic fertilizer used much less than the recommended levels. The majority of the farmers, who have used fertilizer, have used it on their irrigated plots.

Table 3.6: Use of Improved Inputs on Rain-fed plots

Inputs	Have you used the input?	
	No. of Users	%
Manure	145	73.5
Fertilizer	64	32.5
Insecticide	41	20.8
Herbicides	34	17.3
Fungicides	7	3.6
Sample Size	197	

From the sample households 66 percent did not engage in irrigation farming. Out of this non-irrigating group more than 85 percent did not use mineral fertilizer. On the other hand, out of the 66 sample households, who irrigated, about 75 percent of them used mineral fertilizer. This implies a strong correlation between irrigation and fertilizer use, which can be explained by the risks of fertilizer use in rain-fed cropping systems.

3.1.5 off-Farm Activities

In the study area in general income from off-farm activities is an important supplement to the income from agriculture. The most common non-farm activities are petty trade, artisanship, food stuff trading and fishing. Within the sample households women are the major participants in the off-farm market. About 70 percent of the sample households reported that at least one member of the household participated in off-farm activities. With respect to gender specific participation, in about 20 percent of the cases only male members participated in off-farm while in about 25 percent of the cases only female members participated in off-farm markets. In the remaining cases both male and female members participated in off-farm markets. Farm households use income generated from off-farm activities both for consumption and for the purchase of agricultural inputs.

3.1.6 Agricultural Decision under Rainfall Risk

Rainfall variability and the associated production risks are important parameters in farm household decision-making in the semi-arid tropics of northern Ghana. The onset of rain fall is unpredictable, and the first rains are usually torrential with only a small amount percolating into the soils. As described in chapter 2, rainfall patterns are usually uncertain, while unexpected droughts usually lead to crop failure (Braimoh 2004). Farmers follow different strategies to ensure food security and generate enough income to meet immediate cash demands. Seasonal and temporary migration is one of the strategies among residents of both the Frafra and Kasen, the two major ethnic groups in the UER (Konings 1986). Diagram 2 gives an overview into the decision environment of a small holder farmer in the White Volta basin of Ghana.

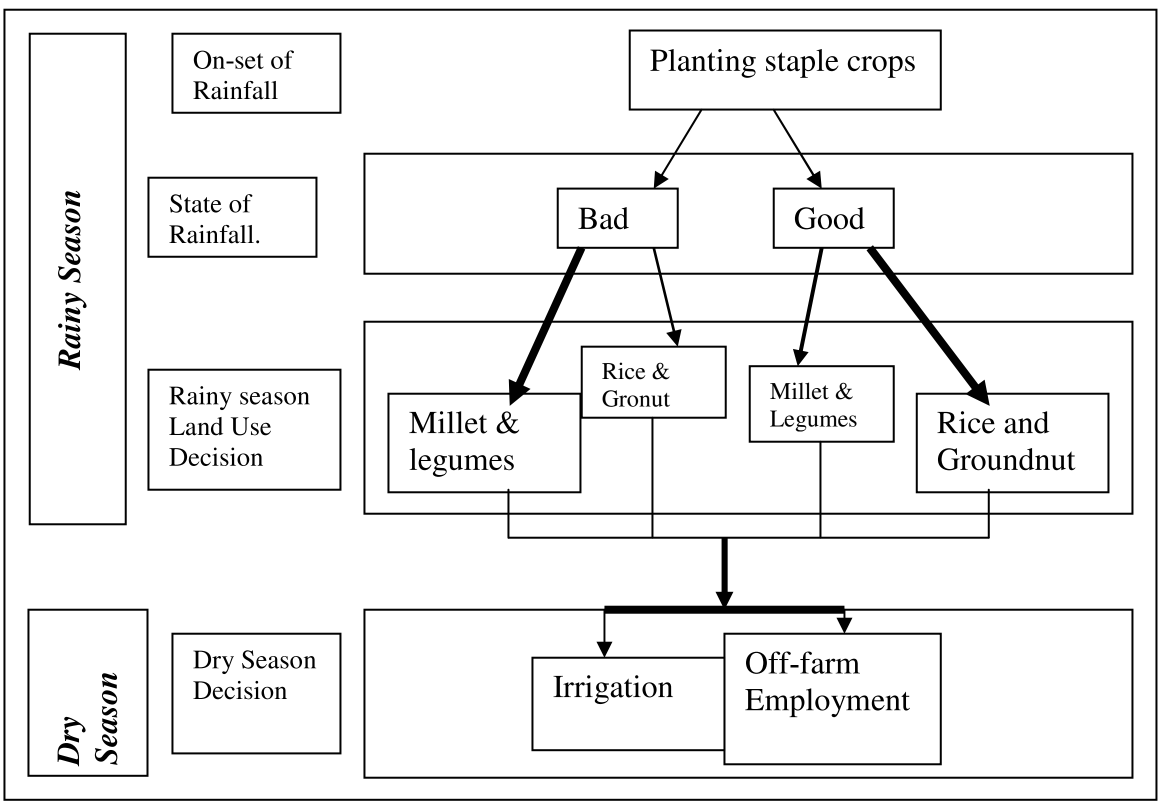


Diagram 2: Conceptual Framework of Decision under Rainfall Risk

Under environmental risks such as delays in rainfall onset and unreliable amounts of rainfall, the major driver of farm households' decision-making is attaining acceptable levels of household food security. This can include ensuring subsistence level of consumption and generating enough cash income to meet immediate obligations (such as school fees, repayment of credit, etc). The decision process can be conceptualized as a sequential process in which activities directly related to subsistence requirements have precedence over market-oriented activities. This implies allocating resources for land preparation and planting of the staple crops millet (early and late millet simultaneously or in relay) plus legumes (cowpea, beans) immediately or at the early stage of the rainy season (middle may to early June). These priority activities are usually undertaken on the compound plots. During the rainy season, the compound plots, therefore, have priority over bush farms (Tripp 1982). Depending on the actual rainfall conditions, further labor and capital resources are then allocated to the remaining plots in the bush and valley bottoms.

In (Diagram 2) the box sizes and the arrows thicknesses indicate the importance of the different land use strategies under different rainfall conditions. For simplicity, the states of rainfall were grouped into two, namely good and bad. When the rainfall condition is good farmers cultivate the compound plots and then will start working on the bushes and valley bottoms to cultivate secondary crops, which are crops are crops produced both for home consumption and the market, such as groundnut and rice. The implication is that, under a good rainfall condition there will be a possibility of planting more marketable crops since the plots planted with the staples will be able to supply the minimum household requirements for the first few months during and after the rainy season.

But if the state of rainfall is bad then farmers would not be able to meet the subsistence requirements from staples grown on compound plots alone and will therefore try to fill the gap by expanding the land allocated to the staples or in the worst case by replanting some of the plots during the next rainfall cycle (Atokple 1993). As a result, less labor and capital resources will be available for planting the secondary crops and less land will be allocated to them.

Whatever the state of rainfall is farmers in the study area hardly meet their annual consumption and cash requirements from rainy season agriculture. Dry season activities, such as irrigation farming and/or off-farm employment, play crucial roles in generating additional income to smoothen consumption. Farmers in the study area commonly engage in at least one of these activities. However, unlike the rain-fed farming irrigated agriculture during the dry season is a labor and cash intensive activity.

3.1.6.1 Risk Perception

Identifying rainfall variability as the major source of risk is only an initial step in understanding the process of household decision making. The other important element is finding out how farmers internalize the rainfall risk in their decision making. This can be done by analyzing their risk perceptions. Risk perceptions reflect the decision maker's interpretation of the likelihood of risk exposure and its assessment of the risk associated with a particular situation (Hardaker et al. 1997). In a semi-arid agro-ecology like the one in the study area, intuitively one would expect the quantity of rainfall to serve as a direct measure of farmers' evaluation of rainfall risks. If this is the case, one can identify thresholds of rainfall amounts and elicit the probability that the observed rainfall falls within a given range (Maleka 1993).

In semi-arid agro-ecologies, however, the quantity of rainfall measured by meteorological stations tells only part of farmers' overall evaluation of the rainfall condition. Other rainfall features such as its lateness, shortness, and the condition of dry spells, which are rather related to quality than quantity of rainfall, are important features. Unfortunately, rainfall data with these qualitative features from the study area was not available. The alternative approach is, therefore, to find out how farmers subjectively evaluate the rainfall in their locality with respect to these features. (Table 3.7) presents the subjective rainfall evaluation of sample households in the UER.

The farmers' responses in (Table 3.7) are somewhat counterintuitive but only as long as high amounts of rainfall are considered as good quality rainfall. On the average less than 5 % of the respondents refer to lower quantity of rainfall as an attribute of a bad rainfall condition; on the other hand about 46 % of the respondents referred to high quantity of rainfall as an attribute of a bad rainfall conditions. These responses look counter intuitive for an agro-ecology with poor rainfall condition. However, the recorded responses are in line with a study by (Mensah-Bonsu 2004), who stressed that the association of high rainfall with bad rainfall conditions is mainly because of torrential rainfall events causing floods which damage crops and increase soil erosions.

Table 3.7: Farmers Evaluation of Rainfall Features

Community	Features of a Bad Rainfall condition				
	Lateness	Shortness	Dry spell in between	Low Amount	High Amount
Kolgo-Tangebisi	15 %	20 %	5 %	0%	60 %
Bawio	35 %	10 %	0%	10 %	45 %
Blembisi	10.5 %	5.3 %	15.8 %	10.5 %	57.9 %
Baare-Sakpare	5 %	25 %	40 %		30 %
Benkute	25 %	20 %	20 %	5 %	30 %
Dusabilgo	35 %	15 %	10 %	5 %	35 %
Samboligo-Amanga	5 %	10 %	15 %	5 %	65 %
Biu	5 %	10 %	15 %	0%	65 %
Gowri-Yorgo	20 %	10 %	40 %	0%	30 %
Korania	5 %	35 %	10 %	5 %	45 %
Mean	16.05 %	16.03 %	17.08 %	4.05 %	46.29 %

Source: Household Survey 2003/04

The above record of farmers' perceptions does also confirm the findings of previous empirical studies in the area, which reported that annual rainfall amounts are adequate for agriculture without a negative trend over recent years (Hesse 1997). Rather it is the reduction in both the number of days with rainfall and the amount of rainfall per rainfall event, particularly during the critical flowering periods, that have a marked effect on the yield of most cereals (Kasei and Sallah 1993). Therefore, it is safe to say that for farmers in the study region it is the seasonal distribution of rainfall that matters most than the mere volume of rainfall in a given season (Kasei and Sallah 1993).

Against this background, using rainfall data from meteorological records without accounting for some of the quality measures of rainfall is inappropriate for understanding farm households' decision-making in the study area. To fill this gap subjective probabilities, that is the probability levels determined by farmers after internalizing both the quantity and quality of rainfall, were generated using the techniques described in the following section.

3.1.6.2 Eliciting Subjective Probabilities

Farmers' perceptions of rainfall risks, reflected in their evaluation of rainfall conditions in the area were used as a reference to elicit their subjective probabilities. The most important consideration in eliciting subjective probabilities is to organize the questions so as to help the respondents to make judgments that are consistent with their real feelings of uncertainty and as well as with the rules of probability (Hardaker et al. 1997). In our survey farmers were asked to evaluate the rainfall conditions of their community for the period from 1990 to 2000 as good, normal or bad (See Annex 14). Some of the questions employed in the elicitation exercise were: "Following your characterization of the rainfall conditions in this locality, how many of the years between 1990 and 2000 had good, normal and bad rainfall?" (Here the responses were interactively adjusted until they sum up to 10). In addition to the iterative adjustment, farmers were asked to name a representative year for each rainfall condition between 1990 and 2000 so as to help them have a good focus on the past rainfall events. (Figure 3.2) presents the result of the elicitation process, where on average good, normal and bad rainfall conditions have a probability of 0.36, 0.33 and 0.31 respectively.

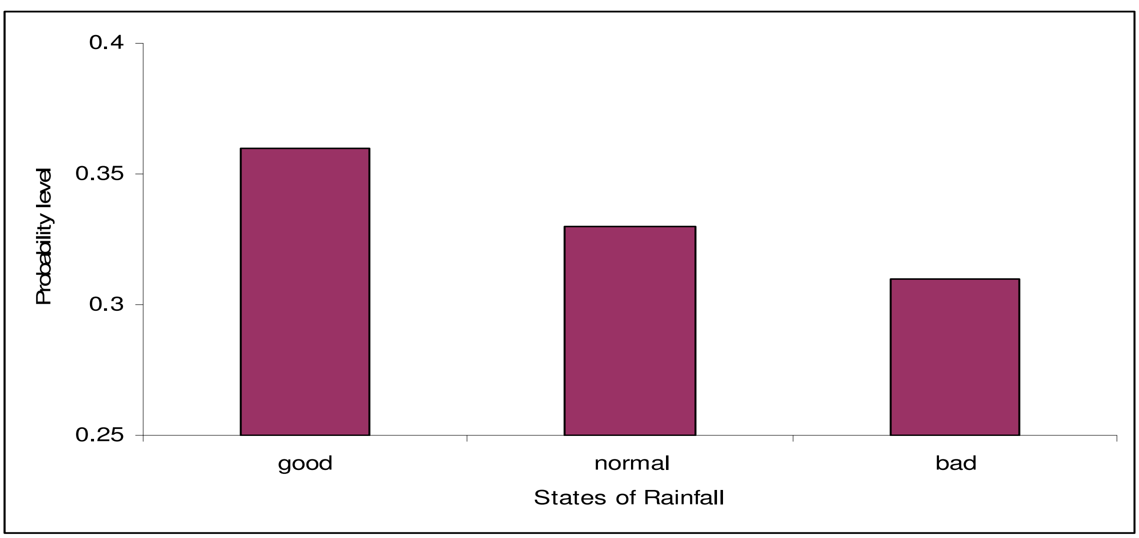


Figure 3.2: Frequency Distribution of States of Rainfall

Given the importance of rainfall in this semi-arid agro-ecology, one would expect the distribution of the rainfall condition to show high frequency of bad states of rainfall. However, the subjective probabilities of the rainfall conditions were rather a little bit positively skewed. This subjective evaluation need to be evaluated from two perspectives. The first one is, when farmers say a given rainfall condition is good it is only in reference to the long term local rainfall condition. It does not take into account the amount of rainfall required for an optimum agronomic performance of plant growth, because farmers have no knowledge of this. The other perspective is the absence of long term rainfall trend in the area, which affects farmers' subjective evaluations of the states of rainfall (Hesse 1997).

3.2 Farm Household Classification for Policy analysis

The preceding discussion on farm household characterization indicated that there are marked differences among farm households in the study area. This has significant implications on building quantitative models that represent the agricultural decision-making process. There are two ways of modeling farm households for the analysis of policy and technology responses. The first one is to aggregate all households into a mega household as was applied by (Okumu 2000). This approach ignores the heterogeneity among farm households that is prevalent even within a very small watershed. The second approach accounts for this limitation and assumes that farm households' land use and technology choice decisions are governed by their objectives and constraints, which include available resources, production possibilities and external economic and bio-physical constraints (Berger 2001; Woelcke 2003). The modeling of separate representative farm household groups too has its own limitations, one of which is it ignores the interaction among farm household groups. The recent advances in computation have made it possible to account for modeling interactions among agents in a Multi-Agent framework (Berger 2001). At the latter stage this work will also serve as an input to one such model.

The identification of representative farm households requires the definition of what a homogenous farm group is. A group's homogeneity is a relative term; for example, a group that is homogeneous in the level of income may be heterogeneous in the use of a given technology or a given agricultural practice. Therefore, grouping farm households for policy analysis requires setting criteria for grouping and identifying indicator variables, which measure the stated criteria. The identification of these distinct groups could be done through grouping farm households into groups like quartiles of one important variable, for example size of land holding. However, in cases where one variable is not enough to fully distinguish groups of households Factor Analysis can be of help in incorporating different variables into the grouping process.

3.2.1 Selecting Clustering Variables using Factor Analysis

Determining the variables for clustering precedes the clustering technique. Unlike other multivariate techniques cluster analysis does not determine the grouping criteria empirically; rather the researcher must decide which variables to take (Hair et al. 1998). The selection of variables depends on the purpose of clustering. In our case the main purpose of clustering is to identify groups of farm households to analyze the impact of policies and technologies on household welfare and land use. Theoretical and empirical evidence show that farmers' resource endowment, social and political environments determine their resource allocation decisions and thereby their response to policy and technological interventions (Bouman et al. 2000). However, the list of variables that determine the decision environment could be very long and some variables may be interrelated. Factor Analysis was used to reduce the number of variables into manageable and a meaningful size (Woelcke 2003).

Factor analysis is a multivariate statistical method which addresses the problem of analyzing the structure of the interrelationships (correlations) among large number of variables by defining a set of common underlying dimensions known as factors (Hair et al. 1998). In our case a total of 10 variables representing households technology use, access to infrastructure and resource endowments were used for a factor analysis.

Table 3.8: Descriptive Statistics of Variables Used in the factor analysis

Variables	Mean	Std. dev
Farm Equipment value (Cedis)	288074.5	679845.9
Operated Land (Ha.)	2.9	2.45
Value of Livestock Asset (Million Cedis)	5.94	11.67
Family Labor (MD)	5.39	3.10
Irrigation Use (Yes=1, No=0)	0.335	0.47
Located Near Irrigation Village (Yes=1, No=0)	0.29	0.46
No. of Male Working Off-farm	0.44	0.63
No. of Female Working Off-farm	0.599	0.79
Distance to Road (Km)	1.694	2.07
Credit Obtained (‘000 Cedis)	111.5	481.93
No. of Observations	197	

Both the Kaiser-Meyer-Olkin (KMO)[4] measure of sampling adequacy and Bartlett’s test of sphercity (Hair et al. 1998) indicated that all the variables included for the factor analysis were relevant. Four factors which cumulatively explain about 65 percent of the total variance of the ten variables were identified. (Table 3.9) presents the factor loadings of the different variables. The factor analysis involved Principal Component Analysis as extraction method and the orthogonal rotation method of Variance Maximizing (Varimax) with Kaiser Normalization for the rotation method was used.

The numbers in (Table 3.9) except the ones under the summary rows indicate the factor loadings of each variable on each of the factors. The Sum of Squared factor loadings (Eigenvalues) indicates the relative importance of each factor in accounting for the variance associated with the set of variables being analyzed. The first factor with a value of 2.022 is more important than the second factor with a value of 1.831 in explaining the variation in the 10 variables. The total of the Eigenvalues, which is 6.45, represents the total amount of variance extracted by the four factors.

[4] Kaiser-Meyer-Olkin (KMO) is a statistics 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 .60 or higher to proceed with factor analysis. If it is not, the lowest individual KMO statistic values will be adopted, until KMO overall rises above .60.

Table 3.9: Rotated Component Analysis Factor Matrix

	Components				
	1	2	3	4	Total
Farm equipment value	0.714	0.246	0.126	0.025	
Total land operated in hectare	0.681	0.177	0.329	-0.086	
Value of livestock assets in Cedis	0.789	0.044	0.085	0.013	
Total family labor	0.267	-0.198	0.716	0.064	
Irrigation	0.313	0.791	0.033	0.126	
Dummy for irrigation project village	0.229	0.840	-0.161	0.063	
Number of male working off farm	-0.192	-0.065	0.224	0.732	
Number of female working off farm	0.196	0.085	0.728	0.027	
Distance to the nearest all weather road in km	-0.148	-0.158	0.148	-0.701	
Total credit obtained	-0.328	0.574	0.486	-0.163	
Summary					
Sum of Squares (Eigenvalue)	2.022	1.831	1.510	1.087	6.45
Percentage of trace	20.222	18.311	15.100	10.872	64.5

Trace is equal to 10 (sum of Eigenvalues).

The last row indicates the percentage contribution of the factors individually and in groups as a percentage of the trace of the factor matrix. The trace is the total variance to be explained and is equal to the sum of the Eigenvalues of the variable set where each variable has a possible Eigenvalue of 1.0 (Hair et al. 1998). The total percentage of trace indicates that the four factors extract 64.5 percent of the total variance in the 10 variables considered for the factor analysis.

The variables farm equipment, total operated land and value of livestock asset had the largest factor loading on the first factor. Since these variables measure household asset status the factor was referred to as *Asset Endowment*. On the other hand, the second factor has more factor loadings from the variables measuring household irrigation practice and from the variable measuring the location of the household in reference to irrigation projects; therefore it is referred to here as *Access to Irrigation*. The third factor has the largest loadings from total family labor and number of female working in the off-farm, as a result was referred to as *Labor Endowment*. The last factor had the largest loadings from the variable measuring distance to the nearest all weather road and number of male working off-farm. Since male off-farm participation is negatively correlated to access to road, the factor was referred to as *Access to Road*, a name which accounts for both the off-farm participation and road access.

3.2.2 Identifying Representative Farm Households

Cluster analysis is the name for a group of multivariate techniques whose primary purpose is to group objects based on the characteristics they possess (Hair et al. 1998). It classifies objects so that each object is very similar to others in the cluster with respect to some predetermined selection criteria, in other words the grouped objects will have high internal homogeneity and high external heterogeneity. There are different clustering techniques here we used a combination of a Ward hierarchical method in combination with a non-hierarchical technique (See (Hair et al. 1998) for more on clustering). The Ward method is one of the hierarchical methods in which the distance between two clusters is the sum of squares between the two clusters summed over all variables. At each stage in the clustering procedure the within-cluster sum of squares is minimized over all partitions obtainable by combining two clusters from the previous stage. The combined use of hierarchical and non-hierarchical methods is the recommended approach. In that case, first a hierarchical technique can be used to establish the number of clusters, profile the cluster centers and identify any obvious outliers. After outliers are eliminated the remaining observations can then be clustered by a nonhierarchical method with the cluster centers from the hierarchical results as the initial seed points. In this way the advantages of the hierarchical methods are complemented by the ability of the nonhierarchical methods to "fine-tune" the results by allowing the switching of cluster membership.

The observation level factor scores for the four factors generated in the factor analysis were used to cluster the sample observations. Since the four factors were extracted using the Variance Maximizing (VARIMAX) technique, where each consecutive factor is defined to maximize the variability that is not captured by the preceding factor, consecutive factors are independent of each other. That is, the four factors are uncorrelated or orthogonal to each other. Finally, the 197 households in the data set were grouped into four clusters with a size of 14, 28, 52 and 102.

3.2.3 Characteristics of the Identified Clusters

The four clusters showed significant differences in total land holding and family size. Cluster 1 had the largest land holding while clusters 2 and 3 have almost equal land sizes. On the other hand cluster 2 had the largest family size followed by cluster 3, while clusters 1 and 4 had almost equal family sizes. The other important difference among the four clusters was their difference in equipment and livestock asset ownership (Figure 3.3). It can be seen that Cluster 1 had more livestock and farm equipment assets than the other clusters.

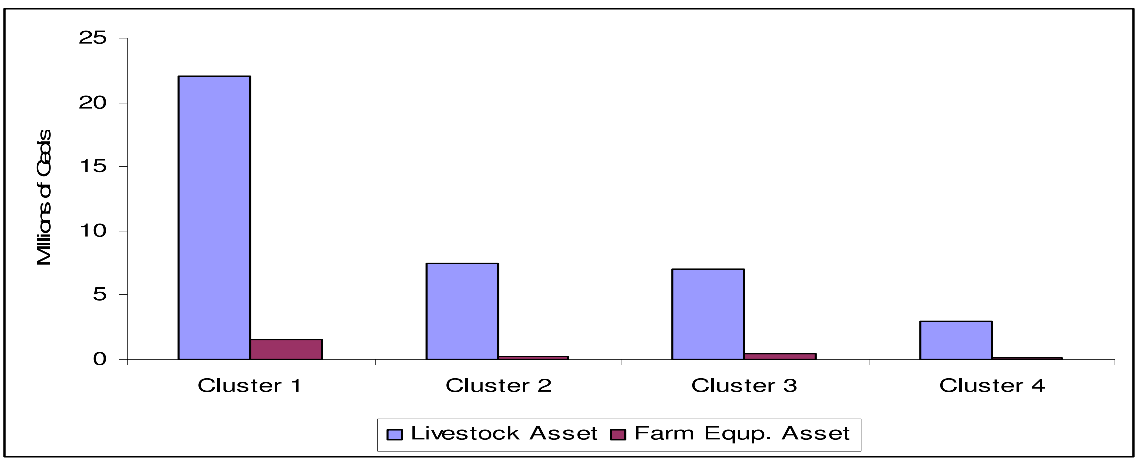


Figure 3.3: Asset Ownership across Clusters

In addition to its asset ownership cluster 1 received more agricultural credit followed by cluster 3. Their asset and credit access positions had enabled households in clusters 1 and 3 to be the only clusters that were practicing irrigation agriculture. Another important feature that significantly discriminated among the four clusters was off-farm labor market participation (Figure 3.4). In conformity with other studies in Africa, the off-farm participation was correlated to household wealth (Barrett, et al., 2001); those households who had higher wealth status were also the ones engaged in off-farm activities. Some off-farm activities such as trading between regions require large initial investments, which are beyond the reach of subsistence farmers. Therefore, the poor are constrained from venturing into some of the off-farm activities.

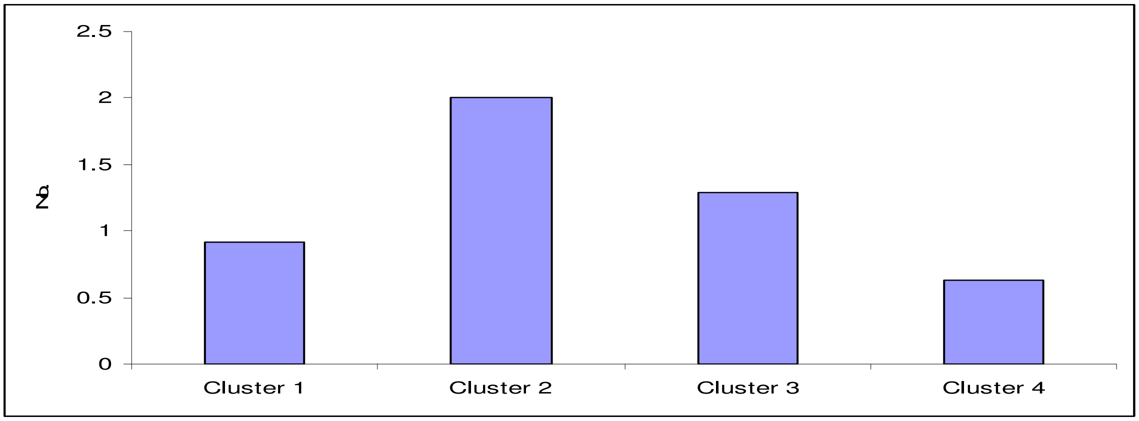


Figure 3.4: Off-farm Market Participation

The four clusters also differ in their degree of market participation. For example, both households in clusters 1 and 3 sold more than 80 percent of their rice harvest on the market (Table 3.10). In terms of total output produced, households in cluster 1 produce more output than those in the other clusters.

Table 3.10: Production and Disposal of Major Crops across Clusters in '00 Kgs

	Cluster 1		Cluster 2		Cluster 3		Cluster 4	
	Mean	St. dev	Mean	St. dev	Mean	St. dev	Mean	St. dev
Rice								
Harvest	89.65	53	4.14	4.78	27.3	40.46	2.61	6.07
% cons.	15%		60%		19%		45%	
% market	85%		40%		81%		55%	
Millet								
Harvest	10	9.22	8.52	4.21	6.81	6.68	5.04	3.92
% cons.	53%		76%		75%		80%	
% market	47%		24%		25%		20%	
Ground nut								
Harvest	11.54	7.5	7.56	5.83	7.64	10.06	4	4.69
% cons.	24%		54%		38%		51%	
% market	76%		46%		61%		49%	
Legumes[2]								
Harvest	3.62	4.6	1.7	1.58	2.59	4.44	1.71	2.41
% cons.	35%		65%		66%		61%	
% market	65%		35%		34%		39%	

1. Includes early and late millet and guinea corn. 2 Includes beans and bambara beans

Depending on the above discussed features and detailed data presented in (Appendices 1 &2) the four clusters can be named as Commercial Farm Households, Non-Irrigating Labor Selling Farm Households, Small Irrigator Farm Households, and Non-Irrigating Subsistence Farm Households, respectively.

4: Household Irrigation Decision

4.1 Introduction

About 70 % of the water drawn from rivers, lakes and aquifers is used in agricultural production implying that irrigation agriculture is the leading human use of water (Wallace and Batchelor 1997). The enormous potential of irrigation technology to curb food insecurity and to release millions from chronic poverty is well documented (Rosegrant and Cai 2001). The simple fact that irrigation agriculture accounts for only 17 percent of all crop land but produces about one-third of the global harvest is a witness (Wallace and Batchelor 1997). However, the successes of irrigation agriculture can not be indefinitely tapped because of increasing opportunity costs of water and decreasing supplies of fresh water (Brown 2001). (Shortle and Griffin 2001) summarized the major research questions associated with irrigation water use as issues of non-point pollution, salinity and water allocation.

Therefore, agricultural economics research on irrigation agriculture has long changed its course from the analysis of mere economic profitability of irrigation technology to the analysis of environmental impacts of irrigation (Shortle and Griffin 2001). In SSA in general and the study area in particular, however, the classical research questions of determinants of irrigation decisions and analysis of the impacts of irrigation adoption on household welfare are still important. As was discussed on the introductory part of this work the paradigm of irrigation agriculture in Ghana has shifted from state sponsored and subsidized system to a cost recovery one. This change of paradigm gave birth to development policy questions such as the place of the poor in irrigation agriculture under the new macroeconomic regime and the identification of policy relevant factors that determine irrigation participation.

4.2 Conceptual Framework and Theoretical Specification of Irrigation Decisions

4.2.1 Conceptual Framework

In the study area, irrigation agriculture is labor and cash intensive as compared to the rain-fed agriculture. Therefore, factors composed of both labor and capital will have important implications on the wider use of irrigation agriculture in the area. Existing literature shows that farmers in Africa access off-farm income/remittances, which are in the range of 10 to 13 percent of urban incomes (Rempel and Lobdell (1974) quoted in (Williamson 1995). These incomes are used to increase households' farm productivity by mitigating risk and promoting farm investment (Abdoulaye and Sanders 2003; Evans and Ngau 1991; Reardon et al. 1994; Schrieder and Knerr 2000). They also serve as collaterals where existing credit markets require a guaranteed income (Hoffman and Heidhues 1993). In Senegal, for example, farm households finance irrigation facilities through remittances from family members who are specially sent out for this purpose ((Dia 1992) as quoted by (Konseiga 2004)). Similarly, the level of fertilizer demand in the semi-arid tropics of India is positively related to the depth of the village labor market (Lamb 2001).

In the study area both seasonal and permanent migration are prominent among residents of both the Frafra and Kasen, the two major ethnic groups in the UER, who commonly engage in wage labor for varying periods of time, mostly in Southern Ghana (Konings 1986). One of the peculiar features of inland migration in Ghana is the little attachment migrants have with their destination communities and their high affinity to their origins, which is reflected through remittances and frequent visits (Daniel 2004)

This shows that there is complementarity between on and off-farm employments, a relationship that can increase pressure on household labor pool in cases where a household depends on income generated from off-farm employment to finance agricultural activities, which also take place during the same season and are also labor intensive. This can have multiple implications including inducing increase in household size in the extreme case (Williamson 1995). Children provide investment returns since they can work on the family farm or in the family businesses and may eventually contribute to the support of parents (Birdsall 1995; Dasgupta 1993).

4.4.2 Theoretical Model

Following (Basu and Van 1998) the effects of lack of credit market and the possibility of financing agriculture from income generated in the off-farm labor market on irrigation decision was theoretically analyzed as follows. Basu and Van's model has an appealing feature for modeling technology adoption in the absence of credit markets. Their major assumptions, with some modifications to meet the research problem at hand, were: the assumption that preferences are such that a family with small size will prefer to remain small and work off-farm during the dry season and supplement its consumption through purchases from the market. The household will opt for larger family only if the income from existing adult off-farm labor can not meet minimum household consumption requirement *S*; the second assumption was technology is such that adult and child labor are substitutes; finally, since agricultural productivity in developing countries is less tied to human capital than is the case in rich countries (Dasgupta 1993), children are capable of providing net economic benefits to the family. In addition to the above three assumptions the following additional assumptions were made:

- There is no credit market or it is very thin,
- Farmers have the possibility of both hiring in and selling out labor, that is, there is aperfect labor market. There are off-farm employment possibilities both on other farmers' irrigation farms and through seasonal migration to southern Ghana,
- Agricultural productivity during the rainy season is very low, as a result farmers in the area can not satisfy their annual consumption demand from their rainy season production; they depend on local purchase for the consumption gap.

If a household participates in the labor market it can earn a wage income of wL_0, where w is wage rate and L_o is amount of labor supplied to the off-farm market. Let X_m be the amount of market goods purchased at a price of P_m.

Let a household's irrigation decision be represented by $I \in \{0,1\}$, 1 if the household irrigates and 0 otherwise. Let us also assume that there is a household preference ordering over pairs of consumption C_m and irrigation participation I. Under this preference ordering the household decides to irrigate only if consumption would fall below some exogenously determined consumption level, S, in the absence of irrigation participation. The household preferences can be defined over pairs (C_m, I) for $C_m \geq 0$ and $I \in \{0,1\}$; and ordered as follows:

$$\left.\begin{array}{l} (C_m + \Phi, I) > (C_m, I) \\ \\ (C_m, 1) > (C_m, 0) \text{ if } C_m < S \\ \\ (C_m, 1) < (C_m, 0) \text{ if } C_m \geq S \end{array}\right\} \quad (4.1)$$

For a constant $\Phi \geq 0$, $S > 0$, Preferences are such that higher consumption is preferred to lower consumption.

Let us elaborate a little bit on the rationale of the stated assumptions and their applicability in the study area. Observations in the study area indicate that traditional labor exchanges particularly during the dry season are very limited. This means that demand for additional labor has to be met from own labor endowment or from the labor market. For a household with limited own labor like our case household a decision to irrigate means to depend on hired labor. This dependence means an induced demand for agricultural finance to pay for hired labor.

In the absence of credit market and/or household endowments to finance irrigation one possibility for our case household is to consider increasing family size as an investment decision so as to generate enough labor endowment to undertake both irrigation farming and off-farm employment. However, enlarging own labor is a decision taking more than one period. To accommodate the time lapse between the birth of a child and its readiness to join the labor force the whole decision horizon was divided into two periods. The household has to give birth in period 1 in order to irrigation in period 2 and consumption and labor participation decisions are made in both periods *1* and *2*. A decision to increase family size in period 1 has additional consumption requirement, C, which is equal to the consumption requirement of the additional family member or a child. Capitalizing on the productivity of children at early age in developing countries (Dasgupta 1993) we assume that in period 2 the additional child labor force will be able to produce sufficient output from irrigation that can satisfy the household consumption. Finally, irrigation will have an additional financial cost denoted by K. The lapse between period 1 and period 2 is arbitrary but was assumed to be reasonably short. In summary:

Period 1:

- Income from off-farm: wL_o (4.2)

- Consumption Expenditure = $\left\{\begin{array}{ll} X_m(P_m+\alpha) & \text{if } I=0 \\ (X_m+C)(P_m+\alpha) & \text{if } I=1 \end{array}\right\}$ (4.3)

Period 2:

- Discounted off-farm income: $=\delta wL_o$ (4.4)

- Discounted Consumption Expenditure= $\left\{\begin{array}{ll} \delta(P_m+\alpha)X_m & \text{if } I=0, \\ 0 & \text{if } I=1. \end{array}\right\}$ (4.5)

- Cost of Irrigation= δK (4.6)

Where α is transaction cost in the output market.

In aggregation:

Budget constraint: $\left\{\begin{array}{ll} wL_o+\delta wL_o=(P_m+\alpha)X_m+\delta(P_m+\alpha)X_m & \text{if } I=0 \\ wL_o+\delta wL_o=(P_m+\alpha)(X_m+C)+\delta K & \text{if } I=1 \end{array}\right\}$ (4.7)

Where δ is discount operator.

The levels of X_m conditional on the state of irrigation decision will be:

$$X_m = \begin{cases} \dfrac{wL_o}{(P_m+\alpha)} & if \quad I=0, \\ \dfrac{wL_o + \left[\delta(wL_o - K) - C(P_m+\alpha)\right]}{(p_m+\alpha)} & if \quad I=1 \end{cases} \tag{4.8}$$

The superiority of irrigation over the non-irrigation decision in (Eqn.4 8) depends on the value in the parentheses of the equation under irrigation. That is,

$$\text{If} \begin{cases} \delta(wL_0 - K) - C(P_m+\alpha) = 0 & then \quad U_1 = U_0 \\ \delta(wL_0 - K) - C(P_m+\alpha) > 0 & \text{then} \quad U_1 > U_0 \\ \delta(wL_0 - K) - C(P_m+\alpha) < 0 & \text{then} \quad U_1 < U_0 \end{cases} \tag{4.9}$$

Where, U_1 and U_o are preferences under irrigation and without irrigation respectively.

The relationship in (Eqn.4.9) indicates that the household will be indifferent between irrigating and not when the discounted off-farm income net of irrigation cash expenditure is equal to consumption expenditure on the additional family member in period 1. On the other hand the household will be better off if it irrigates when the discounted off-farm income net of irrigation cash expenditure is greater than expenditure on the consumption of the additional family member in period 1. In general, the conditions in equation 9 indicate that household irrigation decision depends on the cost of irrigation, the level of income from off-farm employment, output price and transaction cost in the output market. The relationship between irrigation decision and off-farm income is particularly of interest to the empirical question at hand, where farm households make irrigation decisions in the absence of credit markets and resort to alternative sources of finance such as off-farm income.

The empirical analysis below tried to investigate the irrigation decisions of farm households in the White Volta basin of Ghana. Though the preceding discussion of the theoretical model is based on a multi period decision, lack of panel data limited the full specification of the empirical analysis. As a result the empirical analysis was based on only a cross sectional data but with the hope that it will be able to shade light on the multi period implication of the observed decisions.

4.3 Empirical Specification

Following the preceding theoretical model a farm household's irrigation decision is a discrete problem. It can be argued that behind the discrete decision there is a latent variable that measures the farm level profitability of irrigation. Let us call this latent variable Y* and specify the underlying data generating process as:

$$Y^* = \beta' X + U \qquad (4.10)$$

Where X_i's are variables determining irrigation decision and the major variables considered with their signs corresponding to the core hypothesis are as follows:

SEXHEAD: Sex of the head of household: (1=male, 0= female) (+/-),

AGEHEAD: Age of the head of household (in years) (+/-),

AGESQU: The square of the age of household head (-),

EDUDUMY: Education dummy (1= read and write, 0 otherwise) (+/-),

PROPOFF: Proportion of household members participating in off-farm work (both the off farm labor and total household labor are measured in Man Equivalent (ME)) (+),

FAMLAB: Size of family members in ME (+),

IRRIVILA: Whether the household lives in the irrigation project village or not (1=in irrigation village, 0=otherwise) (+),

DISTMKT: Distance of the household from the nearest big market (in Km.) (-), DISTROAD: Distance of the household from the nearest all-weather road (in Km.) (-),

LNFARMEQ: The logarithm of farm equipment asset owned by the household (+),

CREDIT: Credit (in '000 Cedis) available for the household during the cropping season (+),

U is the error term while β' is a vector of parameters to be estimated.

This model has the usual OLS-type assumptions; particularly that U is distributed according to some distribution. Since Y* is a latent variable we only observe its realization in the following form:

$$\left.\begin{aligned} Y_i &= 1 \quad if \quad Y^* > 0 \\ Y_i &= 0 \quad if \quad Y^* \leq 0 \end{aligned}\right\} \tag{4.11}$$

In probability terms we can write:

$$\left.\begin{aligned} \Pr(Y_i = 1) &= \Pr(Y_i^* > 0), \\ &= \Pr(\beta' X + U > 0), \\ &= \Pr(U > -\beta' X), \\ &= \Pr(U \leq \beta' X) \end{aligned}\right\} \tag{4.12}$$

The relationship in Equation (4.12) implies that the household will irrigate (Y=1) if the "random part" (U) is less than or equal to the "systematic part" ($\beta' X$). If we assume that U follows some distribution, we could integrate over that distribution to get an idea of the probability that U fell above some point (eg. $\beta' X$). Normal and logistical distributions, which will give the probit and logit models respectively are the two commonly assumed distributions (Greene 2003). The two do not have marked differences in their parameters, except the parameters from logistic distribution are about 1.8 times bigger because of the thickness of the logistic distribution on its tail (Amemiya 1981). However, the logistic model is easier to use as $\beta' X$ can be written as the odds ratio. So, here the logistic distribution was assumed, which gives:

$$\Pr(Y=1) \equiv \Lambda(\beta' X) = \frac{\exp(\beta' X)}{1+\exp(\beta' X)} \qquad (4.13)$$

To get a probability statement for every observation *i* in our data, that is probability of being either irrigating (1) or not-irrigating (0) given the values of the covariates and the parameters, we have to calculate the likelihood of a given observation *i* as:

$$L_i = \left(\frac{\exp(\beta' X)}{1+\exp(\beta' X)}\right)^{Y_i}\left(1-\frac{\exp(\beta' X)}{1+\exp(\beta' X)}\right)^{1-Y_i} \qquad (4.14)$$

That is, observations with Y=1 contribute $\Pr(Y_i=1/X_i)$ to the likelihood, while those for which Y=0 contribute $\Pr(Y_i=0/X_i)$. Assuming independent observations, we can take the product over the N observations in our data to get the overall likelihood:

$$L_i = \prod_{i=1}^{N} \left(\frac{\exp(\beta' X)}{1+\exp(\beta' X)}\right)^{Y_i}\left(1-\frac{\exp(\beta' X)}{1+\exp(\beta' X)}\right)^{1-Y_i} \qquad (4.15)$$

Taking the natural logarithm of (Eqn 4.15) yields the log likelihood function:

$$\ln L = \sum_{i=1}^{n} Y_i \ln\left(\frac{\exp(\beta' X)}{1+\exp(\beta' X)}\right) + (1-Y_i)\ln\left(1-\frac{\exp(\beta' X)}{1+\exp(\beta' X)}\right) \qquad (4.16)$$

Maximizing the log-likelihood function with respect to the $\beta' s$ will give us the MLEs of (Eqn4.10).

4.4 Characteristics of Irrigating Households

(Table 4.1) presents some descriptive statistic of both irrigating and non-irrigating households. It can be seen that irrigating households obtained more credit, have higher proportion of their members in the off-farm market and also have higher levels of both equipment and livestock assets. The differences are not only big but all except family size and the proportion of male members in the off-farm market are statistically significant. In terms of product market participation, (Table 3.10) of the preceding section showed that, irrigating households, which constitute clusters 1 and 3 sell more of their products, particularly rice than the non-irrigating households.

The significant difference in the amount of fertilizer use between the two groups in particular indicates the potential of irrigation to break the problem of low use of mineral fertilizer among farm households in the study area. In similar agro-ecologies combining technologies that increase soil moisture and crop nutrients have been shown to raise yields by 50 to 100 percent (Sanders et al. 1996). The implication is that in most of the semiarid regions the two constraints need to be addressed simultaneously.

Table 4.1: Selected Summary Statistics for Survey Farmers

Variables	Mean	
	Irrigators	Non-Irrigators
Total Family Labor (ME)	5.6	5.3
Credit (Cedi)	246136	44000
Prop. Male off-farm	0.09	0.09
Prop. Female off-farm	0.14	0.09
Prop. Family Labor	0.23	0.17
Rainy Season Fertilizer (kg)	227	13.6
Total Fertilizer (Kg)	592	13.6
Equipment Asset (Cedis)	624333	119035
Livestock Asset (Cedis)	9987629	3846681
Operated Land	3.9	2.4
Number of Observations	66	130

4.5 Determinants of Irrigation Decision

The χ^2, McFadden R^2 and the proportion of observations correctly predicted show that the model fits the data very well. The McFadden R^2 of 50 percent indicates that the variables considered in the model explain 50 percent of the irrigation decision. In addition, the model correctly predicted about 85 percent of the observations.

Table 4.2: Maximum Likelihood Estimates of Irrigation Decision Model

Variables	Standard Logit		Robust Estimator	
	Coefficients	Marginal Effects	Coefficients	Marginal Effects
CONSTANT	-9.05***	-1.77***	-9.05***	-1.77***
SEXHEAD	-0.92	-0.20	-0.92	-0.20
AGEHEAD	0.08	0.015	0.08	0.016
AGESQU	-0.001	-0.0002	-0.001	-0.0002
EDUDUMY	-0.76	-0.13	-0.76	-0.133
PROPOFF	**2.54****	**0.497****	**2.54****	**0.497****
FAMLAB	**0.17****	**0.034****	**0.174****	**0.034****
IRRIVILA	**4.46*******	**0.805*******	**4.46*******	**0.81*******
DISTMKT	**-0.16****	**-0.03****	**-0.16****	**-0.03****
DISTROAD	-0.14	-0.03	-0.15	-0.028
LNFARMEQ	**0.55*****	**0.11*****	**0.55*****	**0.11*****
CREDIT	0.016	0.003	0.016	0.003
Log Likelihood	-62.79		-62.79	
Correctly predicted Obser	86.7 %		86.7 %	
McFadden R^2	0.498		0.498	
$\chi 2$	124.8****		124.84****	

*** 1 %, ** 5 % and * 10 % levels of significance

The following sections discuss the determinants of irrigation decision by grouping the explanatory variables into household head characteristics, household resource endowment and market and infrastructural access.

4.5.1 Household Head Characteristics and Irrigation Decision

The household head characteristics variables, such as sex, age and educational level were not statistically significant but their signs confirmed expectations. Based on the observed signs there is higher probability of irrigation in female headed households than male headed ones. The fact that in Ghana, women play significant role in irrigation activities could be one reason for the high probability of irrigation by female headed households.

Especially in rice production, women are the major sources of transplanting, harvesting and winnowing labors. Another important factor could be that in the studied irrigation projects, farmers form groups in order to get irrigation plots from ICOUR and each group was required to include female members.

Education is an attribute which can create the opportunity for individual's exit from the rural economy as well as individuals' adoption of improved technologies like irrigation by increasing entrepreneur quality (Huffman 2000). Therefore, a sign attributed to the impact of education on the probability of irrigation indicates the role played by education in the socio-economic setting under investigation. In our case the sign was negative, which could suggest that education played more as an exit means from agricultural than increasing use of irrigation technology in agriculture. This confirms to Addo's finding on the impact of education on migration decision in Ghana (Addo 1974). Migration requires gathering information and acting upon the available information for which educated heads are more equipped in this regard than their non-educated counterparts. As a result, during the dry season the more educated farmers decide to migrate or engage in other off-farm activities than irrigation. To the contrary, (Tutu 1995) reported that the majority of the migrants were illiterate and most of them get employment in the agriculture and he attributes this to the fact that farming did not need much schooling or formal skills. However, the lack of statistical significance in our estimation does not allow us to make any strong statement with respect to the effect of household characteristics in general and the unsettled role of education in particular on household irrigation decision.

4.5.2 Household Resource Endowments and Irrigation Decision

Irrigation is a labor and liquidity intensive activity, that is, it saves land and capitalizes on other factors of production mainly cash and labor. Three variables describing household resource endowment were considered, namely, household labor endowment FAMLAB, household farm equipment endowment LNFARMEQ, and the proportion of household labor engaged in off-farm activities PROPOFF. All the three variables conformed to the expected signs that are a positive impact on household irrigation decisions. In addition, FAMLAB and PROPOFF were significant at 5 percent level while the farm equipment variable was significant at 1 percent level. Therefore, there is a strong suggestion that household endowments matter a lot in the irrigation decision in the study area.

The farm equipment variable, LNFARMEQ was used to measure both the household's ability to operate its land and as a proxy to household wealth status. As a household's equipment endowment increases its dependence on the market for renting decreases. Renting of farm equipment for irrigation activities is an important feature in the study area. As a proxy to a household wealth status it showed the advantage of the well-to-do households over the poor. This has an important implication on the poverty alleviation role of irrigation facilities in the most poverty stricken part of Ghana.

The variable PROPOFF measures the role of household labor as a source of liquidity. The statistical significance and its positive sign confirm its role in liquidity generation. It also confirmed the theoretical expectation. The positive sign plus the statistical significance of the off-farm participation variable imply that irrigation farming and off-farm participation are complimentary activities. Other works like (Evans and Ngau (1991) & Reardon et al. (1994)) also found a complimentary relationship between off-farm income generation and agricultural productivity. But in most empirical works agriculture and off-farm activities are assumed to be undertaken in two different seasons. When they were undertaken during two seasons, usually agriculture during the rainy season and off-farm activities during the dry season; the overall decision is mainly that of a diversification strategy. In that case the pressure on the household labor will not be very intense as compared to a case where both are undertaken during the same season.

The joint implication of the variables FAMLAB and PROPOFF is particularly worth noting. The positive effect of both variables on the probability of irrigation implies that there is a huge dependence on household labor pool both as a source of farm labor and liquidity. As is argued in the theoretical model the absence of a credit market could be one factor which adds the burden of financing irrigation farming on households' capacity to generate income from off-farm sources. In turn, this capacity, among other factors depends on the households' family size, which should be large enough to carry both the labor and liquidity demands. The overall implication is in conformity with the theoretical model. That is, if there is liquidity intensive technology within a thin credit market, alternative liquidity sources play important role. In our case the alternative source was household labor based resource; as a result dependence on household labor can lead to an induced demand for larger family size. This relationship is particularly important if the technology under investigation is proved important in the farming system, for example irrigation technology is a pertinent technology in an arid environment.

4.5.3 Infrastructural Access and Irrigation Decision

The third group contains variables which measure households' access to irrigation, IRRIVILA, access to markets DISTMKT, access to road DISTROAD and finally access to credit, CREDIT. In terms of sign all the arguments under this category were consistent with expectation. In addition IRRIVILA and DISTMKT variables were statistically significant at 1 and 5 percent levels respectively. These access variables measure the effect of cost of irrigation on irrigation decision. For example, if a household does not belong to the communities where the irrigation facilities are located there will be high transaction cost on top of the direct costs of irrigation which will decrease its probability of irrigation. During our field work it was observed that the major factor limiting irrigation by farmers living in localities far away from irrigation sites was the associated cost. The fact that the irrigation facilities are operating at their half capacity also shows that there is potential to expand the existing irrigated land if there is effective demand for irrigation. The IRRIVILA has the largest coefficient of all the variables; therefore the most important factor to irrigate is the physical access to the facilities.

Most irrigation activities are market oriented as a result access to the market, DISTMKT, is an important and significant variable in determining household irrigation decision. The distance to the market determines the direct and transaction costs associated to inputs and outputs. The positive effect of market access on irrigation also shows the complementarity between different infrastructural developments. The credit variable, which was meant to directly measure the effect of credit was not significant, though had a positive sign. The main reason for the statistical insignificance was the lack of variability in credit access among the sample households.

4.6 The Impact of Irrigation on Fertilizer Use

4.6.1 Introduction

As discussed in Chapter 2 soils of the UER in general are not suitable for sustainable crop production. This is a similar feature of the arid and semi-arid parts of Africa, which have the coupled problem of low soil moisture and poor soil quality. Rainfall variability is a critical factor in efficiency of fertilizer and in determining risk aversion strategies of farmers in SSA (Yanggen et al. 1998). The realization of the full potential of irrigation or any form of agricultural water supply such as water harvesting, however, depends on improvements in plant husbandry such as weed control, fertility management, and "opportunism" with respect to the timing of planting (Critchley et al. 1992). Fertility management in particular is most important because soil fertility is often the most limiting factor to crop growth after moisture (Anderson 2001b). The issue of low soil moisture has been addressed partly by small and medium size irrigation projects. However, providing water when nutrient levels in the soil are low generally results in a small yield response (Sanders et al. 1990). Combined technologies to increase soil moisture and crop nutrients have been shown to raise crop yields by 50 to 100 percent (Sanders et al. 1996). Therefore, in most of the semi-arid regions the two constraints need to be addressed simultaneously. The following section presents an empirical model which measures the impact of In this section we will to model the effect of irrigation technology on the demand for inorganic fertilizer in the White Volta basin of UER.

4.6.2 Empirical Model Specification

A model depicting fertilizer use decision by a farm household in the study area can be represented by:

$$f_i = f(Irri, Z) \tag{4.17}$$

More generally, we can write the fertilizer use equation as;

$$f_i = \beta' X + \varepsilon, \qquad \varepsilon \sim N\left[0, \sigma_\varepsilon^2\right] \tag{4.18}$$

Where f_i is Kg. of fertilizer per hectare of cultivated land, X represents a vector of explanatory variables including irrigation, which determine fertilizer application decision, β' is a vector of parameters to be estimated and ε_i is the disturbance term. Among the sample households about 70 percent of them reported that they have not used any fertilizer during the cropping season under study, which is zero level of fertilizer. Under such conditions, the conventional OLS regression methods of fail to account for the qualitative differences between zero observations and continuous observations (Greene 2003). Restricting the analysis only to equation (18), that is to those households, who applied fertilizer, will yield a biased and inconsistent parameter estimates since the process generating the observed fertilizer use is not taken into account (Maddala 1983).

The Tobit and Heckit regression models are the most commonly used approaches in cases when the empirical observation includes both continuous and zero dependent variable. Confusion reigns, however, about the proper use of these models and the appropriate interpretation of findings from them. Theoretically the standard Tobit model is applicable only if the underlying dependent variable contains negative values that have been censored to zero in the empirical realization of the variables (Maddala 1992). The Heckit model has emerged as the de facto default alternative to Tobit when values are clustered at zero due to selection bias rather than censoring (Sigelman and Zeng 1999). Practicaly sparking there can not be a negative level of fertilizer use; therefore the clustering at zero can only be because of selection bias. Therefore, fertilizer decision model with zero observations can better be captured by the Heckit model than the Tobit model. A Heckit specification of the fertilizer use decision will be:

$$Z_i^* = \gamma' w + \mu \qquad (4.19)$$

$$f_i = \beta' X + \varepsilon \qquad \text{Observed only if} \qquad Z_i^* > 0 \qquad (4.18')$$

Where the error terms μ_i ε_i are assumed to follow a bivariate normal distribution with means 0, variances $\sigma_\mu = 1$ and σ_ε, and correlation coefficient ρ.

Given the joint distribution, the likelihood of the observed f_i can be derived and maximum-likelihood estimation can be carried out. However, because maximum-likelihood estimation is computationally cumbersome and sometimes fails to converge for this model, two-step estimator is usually employed instead (Heckman 1979). The estimator is based on the conditional expectation of the observed f:

$$E(f/z^* > 0) = \beta' X + \rho\sigma_\varepsilon\lambda(-\gamma' w) \quad (4.20)$$

Where $\lambda(-\gamma' w) = (\phi(-\gamma' w))/(1-\Phi(-\gamma' w))$ is the inverse Mills ratio. Equation (4.20) implies that the conditional expectation of f is $\beta' X$ only if the errors of Equations (4.19) and (4.18') are uncorrelated; otherwise it is affected by variables in the selection equation as well. Equation (4.20) also suggests that consistent estimates of β can be obtained via OLS regression of the observed f on **X** and λ(.); the unknown coefficients in λ(.), γ, can be obtained from a probit estimation of **z** on **w**, where **z**=1 if $z^* > 0$ and 0 otherwise. The probit specification of the fertilization decision model was specified as:

$$z_i = \gamma_0 + \sum \gamma_{ij} w_j + \mu_i \quad (4.19')$$

Where W_j's are variables determining fertilization decision and the major variables considered including irrigation variable are as follows:

SEXHEAD: Sex of the head of household: (1=male, 0=female)

AGEHEAD: Age of the head of household (in years)

FAMLAB: Size of family members (in ME)

MAOFFR: a dummy measuring a male household member's off-farm participation (1=yes and 0 otherwise),

FEOFFR: a dummy measuring a female household member's off-farm participation (1=yes and 0 otherwise)

FAMOFFR: a dummy measuring whether both male and female household members participate in off-farm (1=yes and 0 otherwise)

LNLANDOP: logarithm of total land operated during the season,

LNFARMEQ: The logarithm of farm equipment asset owned by the household,

MANURE: a dummy measuring a household's manure use (1=yes and 0 otherwise),

IRRIVILA: Whether the household lives in the irrigation project village or not (1=in irrigation village, 0 otherwise),

LNDISMKT: logarithm of distance of the household from the nearest big market (in Km.),

CREDIT: Credit available for the household during the cropping season (in Cedis),

μ_i is the error term while γ's are parameters to be estimated.

A fertilizer use function incorporating the computed inverse Mills ratio, λ, as an instrument variable from the probit model was estimated as:

$$f_i = \alpha_0 + \sum \alpha_{ij} X_j + \theta_i \lambda_i + \varepsilon_i \tag{4.18'}$$

Where: X_j's are factors determining per hectare fertilizer use. They include:

SEXHEAD: Sex of the head of household: (1=male, 0=female),

AGEHEAD: Age of the head of household (in years),

NUFEOFF: Number of female working off-farm,

NUMALAD: Number of male adult available in the household,

LNFEMLB: Logarithm of household female labor,

EDUDUMY: Education dummy (1=read and write, 0=otherwise), IRRIVILA: Whether the household lives in the irrigation project village or not (1=in irrigation village, 0 otherwise),

LNFARMEQ: The logarithm of farm equipment asset owned by the household,

CREDIT: Credit available for the household during the cropping season (in Cedis),

DISTMKT: Distance of the household from the nearest big market (in Km.),

ε_i is the error term while α's are parameters to be estimated, and

θ_i: is the parameter associated with the inverse Mills ratio.

It is important to note that only the non-zero observations on f_i are used in the second-stage estimation in order to estimate the conditional parameters. The marginal effect of the k^th^ element of **X** on conditional expectation of *f* will be:

$$\frac{\partial E(f/z^* > 0, X)}{\partial X_k} = \beta_k - \gamma_k \rho \sigma_\varepsilon \delta(-\gamma' w) \qquad (4.21)$$

Where the function δ[5] is as defined by (Sigelman and Zeng 1999). Equation (4.21) shows that the impact of X is a compound of its impact on the selection and the outcome equations. When the errors in the selection and the *f* regression equations are correlated ($\rho \neq 0$), it is incorrect to interpret β_k as the marginal effect of X_k on *f*, unless X_k does not enter the selection equation (in which case $\gamma_k = 0$).

4.6.3 Determinants of Fertilizer Use

Both the McFadden R^2 and the measure of observations correctly predicted indicate that the model is a good representation of the empirical observation and can be used for further analysis (Table 4.3). A growing number of works on fertilizer adoption emphasize the importance of price factors, risk, access to market, farm and farm characteristics and

[5] $\delta(\alpha) = \lambda(\alpha)(\lambda(\alpha) - \alpha)$ and $\lambda(\alpha) = \phi(\alpha)/(1 - \Phi(\alpha))$ and $\alpha = -(\gamma' \omega)$

liquidity/credit as important determinants of fertilizer use (Abdoulaye and Sanders 2003). Here we gave particular emphasis to the contribution of irrigation in reducing rainfall risk and promoting fertilizer use among the sample households in the White Volta basin of the UER of Ghana.

4.6.3.1 Irrigation Access and Fertilizer use

In semi arid agro-ecologies in general rainfall variability is a source of risk and limits return from investment on fertilizer. The variable IRRIVILA, which measures whether a household is located in or very close to the communities with irrigation facilities, was used to measure the effect of irrigation technology on fertilizer use. This variable was selected to measure the impact of irrigation on fertilizer use because the variable which directly measures individual household's irrigation use was highly correlated with most of the explanatory variables.

The variable IRRIVILA was the most significant variable both in the fertilization decision (Table 4.4) and intensity of fertilizer use models (Table 4.3). This implies that the risk associated with rainfall variability was important determinant of fertilizer use. The impact of other factors conditional on the irrigation condition also shows the significance of irrigation on fertilizer use. The conditional probabilities were computed from a logit model, calculated by multiplying all the probit coefficients of (Table 4.3) by a factor of 1.8 to get a logit model, which is easier to manually calculate the probabilities than the probit model. The index numbers (*x'β*) in a logit model for the probability of fertilizer use conditional on irrigation access can be calculated as:

$$\text{IRRIVILA} = 1: \beta'\chi = \begin{bmatrix} -4.82 - 0.78SEXHEAD - 0.043AGEHEAD + 0.11FAMLAB + \\ 0.976MAOFFR + 1.08FEOFFR - 0.569FAMOFFR + \\ 0.34LNFARMEQ + 1.24MANURE + 3.82IRRIVILA - 0.20LNDISMKT + \\ 0.279E - 06CREDICED \end{bmatrix}$$

$$IRRIVILA = 0: \beta'\chi = \begin{pmatrix} -4.82 - 0.78SEXHEAD - 0.043AGEHEAD + 0.11FAMLAB + \\ 0.976MAOFFR + 1.08FEOFFR - 0.569FAMOFFR + 0.34LNFARMEQ + \\ 1.24MANURE - 0.20LNDISMKT + 0.279E - 06CREDICED \end{pmatrix}$$

The conditional probabilities were evaluated at the mean value of AGEHEAD, FAMLAB, LNDISMKT and CREDICED and at the mood values of SEXHEAD, MAOFFR, FEOFFR and FAMOFFR. Then the predicted probabilities as a function of farm equipment asset and family labor as is the case in Figures 4.1 and 4.2 respectively conditioned on access to irrigation were calculated as:

$$\Pr(Fer_i = 1) = \frac{\exp(\beta' \chi)}{1 + \exp(\beta' \chi)} \qquad (4.23)$$

(Figure 4.1) shows the effect of household asset, proxied by farm equipment, on the probability of fertilization heavily depends on access to irrigation. The mean levels of the conditional probability of fertilizer use increases from a mere 0.13 in a non-irrigation village to a probability of 0.86 in an irrigation village. This indicates that secured supply of soil moisture is one important factor determining the use of inorganic fertilizer, which is a crucial input to a semi-arid system, where the soil is naturally deficient of major soil nutrients. Therefore, irrigation as a risk minimizing technology will encourage the use of technologies like fertilizer.

Likewise one can vividly see from (Figure 4.2) the effect of irrigation on the predicted probability of fertilizer use as a function of household labor endowment. That is, for the same level of family labor the probability of fertilization varies significantly based on whether the household is living in irrigation areas or not. Most households living in or in the vicinity of the irrigation schemes use fertilizer even with a smaller family labor. Those households outside the irrigation areas start fertilizing only at higher level of family labor endowments. This could indicate that larger household size gives the privilege to send part of the labor endowment to off farm market to generate cash, which will be used to finance fertilizer and other essential farm inputs.

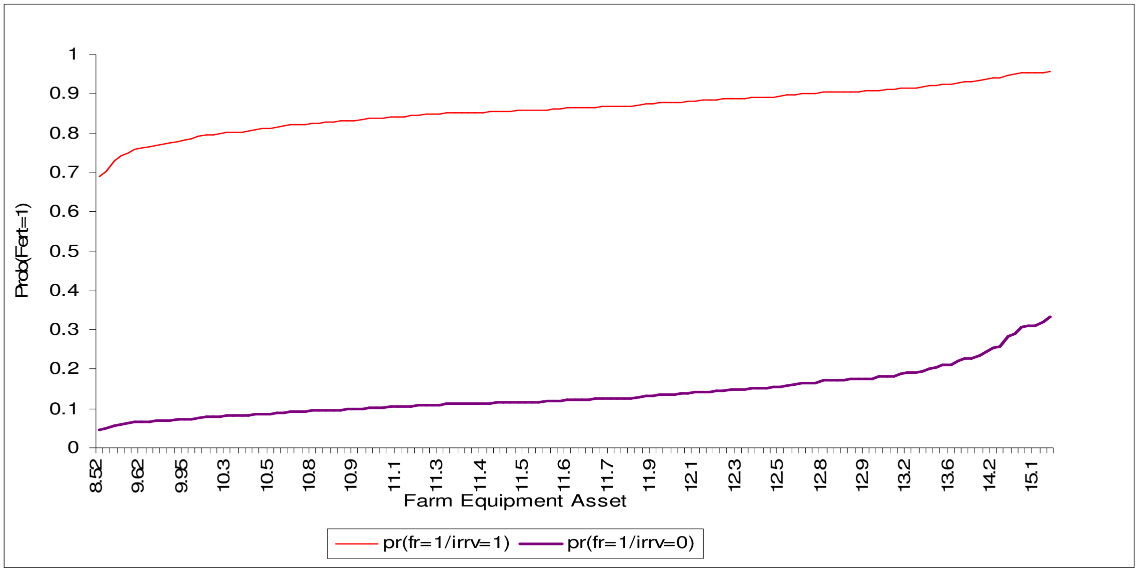


Figure 4.1: The conditional effect of farm equipment asset on fertilizer use

4.6.3.2 Household Resources & Head Characteristics and Fertilizer use

All of the household variables in the model showed the expected signs and they were also statistically significant. The age of the household, AGEHEAD, indicated that there is a negative relationship between the demand for inorganic fertilizer and age of the head of the household. This implies that, younger heads are more likely to adopt fertilizer than older ones. Though not statistically significant the model estimate showed that female heads are more likely to use fertilizer than their male counter parts.

The household livestock endowment, which is proxied by MANURE use positively determined household fertilizer use and was also significant at 5 %. In addition to its implication on the importance of household resource endowment on fertilizer use the significance of this particular variable shows the complementarity between organic and inorganic fertilizers. However, unlike research recommendations to use organic and inorganic fertilizers in combination their complementarity does not show that farmers are following the recommendations. Farmers in the research area mostly use organic fertilizers on their staple crops such as millet and beans, crops which they grow around their homesteads. On the other hand inorganic fertilizers are applied on high value crops such as rice, which are mainly supplied for the market.

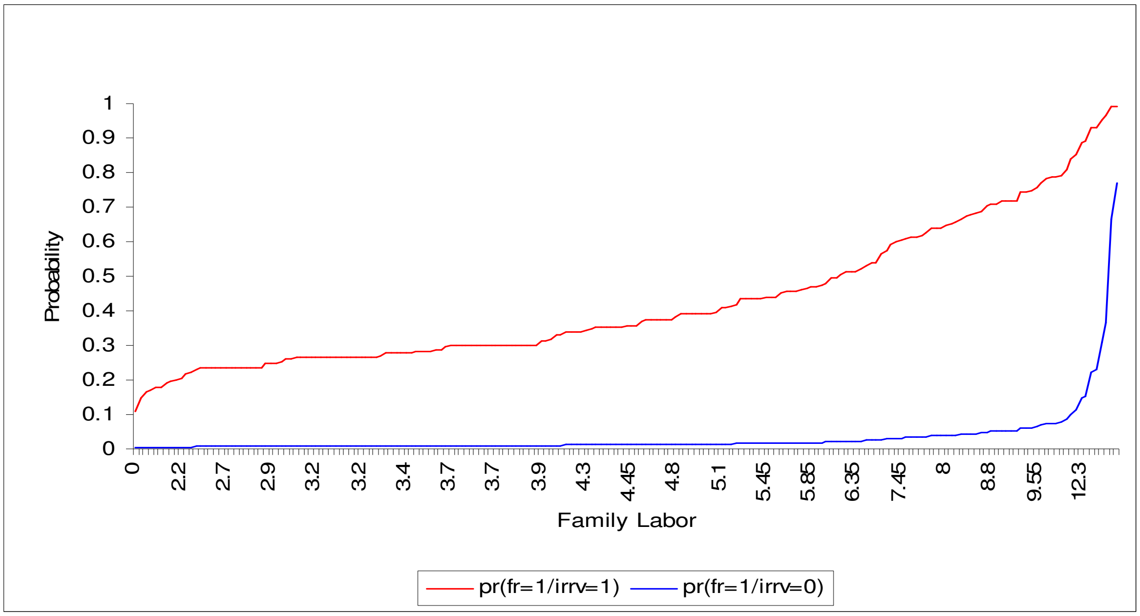


Figure 4.2: The conditional effect of family labor on fertilizer use

Another important household resource variable is the farm equipment, which positively and significantly determined fertilizer use. The variable, LNFARMEQ, measured the logarithm of the monetary value of the equipment assets. The importance of this variable showed the role of wealth as well as households capacity to prepare land. The household labor endowment, FAMLAB, was another important variable that determined the decision both positively and significantly. This implies that households with larger family size are more likely to use fertilizer than households with smaller family size. This has an import implication particularly when one looks at it in combination with the role of the household liquidity position.

4.6.3.3 Household Liquidity and Fertilizer use Decision

The household liquidity status is another important determinant of inorganic fertilizer use. Most farmers in the semi-arid tropics of West Africa are very poor to finance inputs such as inorganic fertilizer (Abdoulaye and Sanders 2003). About 75 percent of the sample households did not obtain credit in the cropping season 2002/2003. As a result the variable CREDICED had a positive but non-significant effect on fertilizer use.

Therefore, in the adoption of liquidity intensive activities the absence of the formal credit market indicates the importance of alternative sources of finance. In the study area income from off-farm activities are generated both from temporary migration to the southern part of Ghana, where there are more employment possibilities, and from employment on other farmers fields in the same locality. In order to explicitly account the importance of off-farm income three variables representing household off farm activities were considered. The variables are FEOFFR and MAOFFR, variables indicating if any female or male member of the household respectively was engaged in off farm and FAMOFFR, which indicates the case where both male and female members of the household are engaged in an off farm activity.

Table 4.3: A Selection Model of Fertilizer Use in the UER of Ghana

	Model 1	Model 2
Variables	**Coefficients**	**Coefficients**
CONSTANT	1.281 (1.906)	1.308 (1.782)
SEXHEAD	-1.169**** (0.447)	-1.174**** (0.445)
AGEHEAD	-0.004 (0.012)	-0.003 (0.141)
NUFEOFF	0.516 ****(0.129)	0.518**** (0.134)
NUMALAD	0.102** (0.059)	0.103** (0.059)
LNFEMLB		-0.027 (0.406)
EDUDUMY	0.578*** (0.272)	0.577*** (0.271)
IRRIVILA	3.327**** (0.800)	3.316**** (0.820)
LNFARMEQ	0.061 (0.113)	0.061 (0.113)
CREDICED	0.187E-06 (0.143E-06)	0.188E-06 (0.146E-06)
DISTMKT	-0.043 (0.032)	-0.043 (0.032)
Inverse Mills	1.147* (0.718)	1.140* (0.738)
N	80	80
Adjusted R^2	0.48	0.47
F-test	8.36****	7.49****

Dependent Variable: logarithm of fertilizer use per hectare. Model 2 the same model but with one additional variable to test the model's robustness. Values in Bracket are standard errors. Level of Significance: **** 1%, *** 5 % and ** 10 %.

Table 4.4: Maximum Likelihood Estimates of Fertilizer Use Decision Models

Variables	Model 1		Model 2	
	Coefficients	Marginal Effects	Coefficients	Marginal Effects
CONSTANT	-2.678*** (1.167)	-1.040*** (0.454)	-0.659 (0.557)	-0.255 (0.213)
SEXHEAD	-0.432 (0.318)	-0.168 (0.123)	-0.779*** (0.346)	-0.301*** (0.134)
AGEHEAD	-0.024**** (0.009)	-0.009**** (0.0036)	-0.023**** (0.009)	-0.009**** (0.004)
FAMLAB	0.059* (0.040)	0.023* (0.016)	0.041 (0.041)	0.016 (0.016)
MAOFFR	0.542** (0.337)	0.211** (0.130)	0.579** (0.347)	0.223** (0.133)
FEOFFR	0.602*** (0.318)	0.233*** (0.123)	0.571** (0.329)	0.221** (0.127)
FAMOFFR	-0.316 (0.471)	-0.123 (0.183)	-0.408 (0.488)	-0.158 (0.188)
LNLANDOP			0.754****(0.229)	0.292**** (0.089)
LNFARMEQ	0.189** (0.107)	0.073** (0.042)		
MANURE	0.691**** (0.292)	0.268**** (0.113)	0.660*** (0.295)	0.255*** (0.114)
IRRIVILA	2.122**** (0.320)	0.824**** (0.129)	2.297**** (0.340)	0.889**** (0.138)
LNDISMKT	-0.112 (0.186)	-0.043 (0.072)	-0.236 (0.195)	-0.091 (0.076)
CREDICED	0.155 E-06 (0.420E-06)	0.604E-07 (0.163E-06)	0.480E-07 (0.383E-07)	0.186E-07 (0.148E-06)
Log Likelihood	-80.00764		-75.5665	
Percent Correctly Predicted	80 %		83.2 %	
McFadden R^2	0.40		0.43	
χ^2	106.0940****		114.976****	

Model 1: A Probit Model with Farm Equipments as a measure of asset and Model 2: A Probit Model with Operated Land as a measure of assets

Level of Significance: * 15 % and less than 15 %, ** 10 % and less than 10 %, *** 5 % and less than 5 %& **** 1% and less than 1

Both the male and female variables positively and significantly determined fertilizer use decision. The female off-farm variable was significant at 5 % as compared to the 10 % significance of the male and was also slightly larger in magnitude. This implies that women contributed more from their off-farm income to the household's technology acquisition than male. Another implication of this result was, when only part of the family member was engaged in off farm activities to generated liquidity others were engaged in farming. Therefore, households with larger household size have more advantage than those with smaller household size. The negative sign of the family off-farm variable, FAMOFFR, supports this argument. That is, when a household engages both its male and female members it means it is giving more emphasis to the off farm activity and is not fully engaged in own farming and this leads to less demand for fertilizer.

5: Farm Household Models for the White Volta Basin of Ghana

5.1 The Concept of Agricultural Household Models

The theoretical motivation for modeling household irrigation decision in the northern Ghana can best be captured using the concept of Agricultural Household Models (AHM). The AHM is a model of a household that is jointly engaged in production, consumption and labor supply (Singh et al. 1986).The concepts of a household subjective equilibrium and of the shadow price of family labor was derived from Chayanov's (1925) analysis of peasant households' time allocation between production and leisure. Through the 1950's and 1960's, this analysis of household behavior under market failures has been revisited, formalized, and expanded notably by Nakajima (1970), to culminate in Singh, Squire, and Strauss edited book (Singh et al. 1986).

In its most general conceivable form, the household's objective is to maximize a discounted future stream of expected utility from a list of consumption goods including home-produced goods, purchased goods, and leisure, subject to what may be a large set of constraints. Most empirical analyses, because of research focus, analytical tractability, and availability of data, employ simplified forms of the objective function and the constraints. Most agricultural household models are also static and assume that households are risk neutral. Constraints typically include cash income, family time and endowments of fixed productive assets, and production technologies, (all of which may be combined into a single "full-income" constraint; see (Singh et al. 1986)), and prices of inputs, outputs, and non-produced consumption goods. Price-related constraints either fix prices exogenously (the case of household tradables with perfect markets) or, in the case of missing markets, specify an internal "shadow price" determination condition, i.e., that the household's demand for a good equals its output (the case of household non-tradables with missing markets(de Janvry et al. 1991)).

A key motivation for agricultural-household analysis is for policy analysis for cases in which households make production, consumption and labor supply decisions. Analytically, agricultural household models resolve the apparent paradox of a positive own-price elasticity of demand for food in farm households, as well as the puzzle of sluggish marketed-surplus responses to food-price changes (Taylor and Adelman 2003). In short, the added value of estimating a household model lies on the profit effect that it accounts. The fundamental difference between an agricultural household model and a pure consumer model is that, in the latter, the household budget is generally assumed to be fixed, whereas in household-farm models it is endogenous and depends on production decisions that contribute to income through farm profits. Thus, to the standard Slutsky effects of the consumer model, agricultural household models add an additional, “farm profit” effect, which may be positive (e.g., if the price of the home-produced staple increases) or negative (as when the market wage increases, squeezing profits). In a consumer model, when the price of a normal good (say, food) increases, its demand unambiguously decreases: a negative “real income” effect reinforces a negative “substitution” effect, as illustrated in the most basic indifference-curve analysis. However, the household-farm is both a consumer and producer of food. As a consumer, it is adversely affected by a higher food price, but as producer, its profit from food production increases. This adds a positive “farm profit” effect to the negative Slutsky effects on food demand, pushing the budget constraint outward. If this profit effect outweighs the Slutsky effects, the household’s demand for food increases with the food price.

The structure of markets in which the household is embedded is critical in shaping the response to exogenous policy and other shocks. A key assumption of most agricultural household models is that the household can obtain perfect substitutes for family labor in local labor markets—and conversely, that it can sell its own labor at a given market wage. This permits the household to decouple production from leisure: in response to a policy or market change, it can increase production (and demand more labor) while at the same time consuming more leisure, by hiring workers to fill the resulting excess demand for labor.

Before embarking into the application of the household model for the problem at hand it is important to describe some of the milestones of AHM. The first one is the issue of separability between consumption and production decisions. That is, whether households make the two decisions simultaneously or in a recursive manner. Recursivity of household decisions requires the existence of markets at least for some factors of production. Under recursive decision the household first makes production decision with the objective of maximizing profit. On the second stage it maximizes its utility depending on its income from its production decision and other non-farm incomes. In this case we are implying that there is separability between the two decisions and they can be handled without any bias in empirical estimation (Bardhan and Udry 1999). Under separability, for example a production decision made on any plot depends only on factor and output prices and the characteristics of the plot that is whether it is fertile, near to irrigation source etc, but not on household endowment and preferences. The fulfillment of separability property, which is even robust to the non-existence of some markets, will greatly simplify empirical analysis (Bardhan and Udry 1999).

The other milestone in the AHM is the issue of unitary and collective decision making. The unitary AHM considers the household as a single entity having the same objective and having equal access to household resources. This assumption ignores the neoclassical assertion that individuals in a household need to be treated by their own preferences. The alternative to the unitary approach is the treatment of household members as independent economic units and it is called a collective model. The collective model is subdivided into cooperative and non-cooperative models. The collective model is appealing particularly in handling complex decision process in settings like rural part of Africa. However, its demand on data makes it less attractive for empirical analysis.

5.2 Modeling Agricultural Decision under Risk

Agricultural producers, most of whom are risk averse (Antle 1987; Binswagner 1981), are faced with a variety of yield, price, and resource risks, which make incomes unstable. All sources of risk facing farmers can be divided into production and price risks (Hardaker et al. 1997). Production risk is the result of agriculture's dependence on nature and includes risks from flood, droughts, pests and diseases etc. On the other hand, price risk is the result of farmers' participation in the input and output markets, where prices of some inputs and outputs are unstable. The type and severity of the risks confronting farmers vary with the farming system, and with the climatological, policy and institutional setting in which they operate (Hazell and Norton 1986).

According to (Hardaker 2000) there are three common definitions of risk, namely, risk as the chance of a bad outcome, risk as the variability of outcomes and risk as uncertainty of outcomes. Operationalization of the measurement of risk requires separating judgments about the uncertainty that affects the possible consequences of the decision, and the preferences of the decision maker for different consequences (Hardaker et al. 1997; Hardaker 2000). Most empirical measures of decision under risk are based on the expected utility (EU) approach (Berg 2003; Buschena and Zilberman 1994; Hardaker 2000) though few but a growing number of empirical models are depending on downside risk measures.

5.2.1 Expected Utility (EU) Approach

The EU approach has been the mainstay of the analysis of behavior under risk for the last 40 years and von Neumann and Morgenstern are the major contributors to a larger body of work that provides normative justification for the use of EU by rational decision makers (Buschena and Zilberman 1994). The EU model is based on a set of axioms, which impose intuitively possible restrictions on preferences. It states that a decision maker chooses between risky or uncertain prospects by comparing their expected utility values (Hardaker et al. 1997). That is:

$$V(\{x, p\}) = \sum_{i=1}^{n} U(x_i)\, p_i \qquad (5.1)$$

Where U(.) is the individual's utility function, **x** is a vector of goods in the i^{th} state of nature and p_i is the probability that the i^{th} state of nature will actually occur. The shape of the utility function characterizes a decision maker's risk attitude. The EV model, which represents Expected value (E) and variance (V), is a Taylor series approximation of the EU model. For normal distribution of outcomes or quadratic utility it is equivalent to the EU model. Otherwise, the approximation is good as long as the distribution of outcomes is symmetric. The EV model is widely applied in empirical analysis of decision under risk because of its deductive strength and its straightforward applicability in optimization models (Berg 2003).

However, in spite of its wider use, the EU model is criticized as a growing number of empirical observations reported violation of some of its axiomatic foundations and a divergence of observed decisions from what is predicted by the EU models (Atwood et al. 1988; Buschena and Zilberman 1994; Hazell and Norton 1986). The violation of the independence axiom, the axiom which allowed the representation of preferences over uncertain prospects as a linear function of the utility of the basic outcomes, is the major criticism of the EU model (Woodward 1998). Other criticisms include the EU model's lack of ability to account for the impacts of anxieties and worry associated with random outcomes or choices, or the effort and experience needed for optimal selection (Buschena and Zilberman 1994).

EU models are also criticized for failing to include elements other than income in the utility function. In particular, there is a lack of consideration of discrete variables that have strong impact on the quality of life, may be affected by the randomness of income, and consequently have a strong impact on risky decision making (Buschena and Zilberman 1994). For example, a farmer's utility from a certain income level may vary depending on whether he is above or below a destitute level of income or not. The advance of risk research that account for downside risks is one response to some of the observed shortcomings of the EU based models.

5.2.2 Measures of Downside Risk

Downside risk measures are based on the intuition that most decision makers including farmers would give more weight to negative deviations. There is a growing empirical evidence suggesting that most farmers exhibit decreasing absolute risk aversion (DARA) (Binswagner 1981), which implies that farmers are averse to "downside risk" (Antle 1987). (Roy 1952) was the pioneer in putting downside risks in perspective. The concept was further developed by (Markowitz 1959), who developed his concept for portfolio management developed his argument on the premise that investors are interested in minimizing downside risk for two reasons: (1) only down side risk or safety first is relevant to them and (2) security distributions may not be normally distributed. The most commonly used downside risk measures are the semi-variance (special case), the lower partial moments (general case) and Value at Risk (VaR) (Danielsson et al. 2005; Nawrocki 2005). Markowitz proposed a semi-variance computed from the mean return (SVm) and a semi-variance computed from a target return (SVt). The (SVm) can be defined as:

$$\sigma^{2-} = \int_{-\infty}^{\mu} (\mu - x)^2 f(x) dx \tag{5.2}$$

Where σ^{2-} is the population's semi-variance, μ is the population mean and *f(x)* is a probability density function (PDF). Likewise, the (SVt) will be defined as:

$$\sigma^{2-} = \int_{-\infty}^{\mu} (t - x)^2 f(x) dx \tag{5.3}$$

Where *t* is a target level of income from which deviations are measured. SVm and SVt compute a variance using only the returns below the mean-return and below a target return respectively as a result Markowitz called them partial or semi-variances.

5.2.2.1 Lower Partial Moment

The most important advance in the measurement of downside risks occurred with the development of the Lower Partial Moments (LPM) as an extension to the semi-variance measures by (Bawa 1975) and (Fishburn 1977). The major improvement of the LPM over the semi-variance measures is its independence from the assumption of a quadratic form for the utility function (Nawrocki 2005). The general form of LPM is:

$$\rho(\alpha, t) = \int_{-\infty}^{t} (t - x)^{\alpha} f(x) dx \tag{5.4}$$

Where $\rho(\alpha,t)$ is a LPM, *t* is a risk reference level of income, and $\alpha \geq 0$ is a constant measuring the degree of the LPM and serves as a measure of risk aversion (Biglova et al. 2005). Given a value of the target returns, *t*, Fishburn demonstrated the equivalence of the LPM measures to stochastic dominance for all values of $\alpha > 0$. He also showed that, $\alpha < 1$ captures risk seeking behavior, $\alpha = 1$ risk neutral and $\alpha > 1$ risk averse behavior. In general, the Fishburn family of LPM utility functions asserts that decision makers are risk averse below the target return and risk neutral above the target return (Nawrocki 2005).

5.2.2.2 Value at Risk (VaR)

The Value-at-Risk (VaR) is another measure of downside risk mainly applied by financial institutions to measure market risks. VaR is defined as a one-sided confidence interval on potential portfolio losses over a specific horizon. That is, given a portfolio *P* with returns $\tilde{r}_p$ over the specified VaR-horizon and given a confidence level α, the VaR is the negative of the portfolio return over the VaR-horizon that will not be exceeded with probability α (Grootveld and Hallerbach 2003).

5.2.3 Safety-First (SF) measures

The safety first model is a downside risk measure that precedes the semi-variance concept. The SF models are alternative risk modeling approaches that are more consistent with decisions made by large numbers of farm managers (Patrick et al. 1985). Because of their appeal in describing observed behaviors they are referred to as "*positive*" models (Buschena and Zilberman 1994). Under the SF models decision makers are concerned with (or constrained by) the probability of failing to achieve income goals (Atwood et al. 1988; Buschena and Zilberman 1994; Hazell and Norton 1986). The nature of this concern can be accounted by considering a utility function, $U(Z, g)$, that include a continuous variable for wealth or income increases (Z) plus a discrete element (g). In safety-first models, (Z) represents profit (or income), (g^*) is some critical level of profit/income, (α) is some critical probability level associated with (g^*), and p(x) denotes the probability of occurrence for event (x). In subsistence farming environment (g) could reflect the level of income below which the household would be destitute. The most commonly used safety-first models discussed in the literature are:

Roy's Approach: It was one of the earliest safety-first models proposed by (Roy 1952). The decision problem under Roy's criteria is to minimize the probability of income falling below a critical level. That is:

$$\begin{aligned} &\text{Mini: } \Pr ob(Z < g) \\ &\text{S.t.} \quad AX < b \end{aligned} \tag{5.5}$$

Telser's Approach: A safety-first model proposed by (Telser 1955), where the problem is that of maximizing expected income subject to satisfying probabilistic constraint upon the likelihood of low income level. That is:

$$\begin{aligned} &\text{Maxi: } E(Z) = E_y^{'} X \\ &\text{S.t:} \quad AX < b \\ &\qquad \Pr(Z < g) \le \alpha \end{aligned} \tag{5.6}$$

Kataoka's Approch: Another important contribution in the safety-first modeling approaches is the one by (Kataoka 1963). Here, the problem is finding the maximum income level (g) for which the probability of income falling below (g) is below a prespecified level. That is:

$$\begin{aligned} &\text{Maxi} \quad g \\ &\text{S.t:} \quad AX < b \\ &\qquad \Pr(Z < g) \le \alpha \end{aligned} \tag{5.4}$$

5.3. Empirical Specification of a Telser type Safety First Model

A Telser SF model which accounts for the rainfall risk and the subsistence level of farming in the UER of Ghana was specified as follows.

5.3.1. Objective function Specification

$$\text{Maximize: } E(Z) = \sum_{J=1} \overline{C_j} X_j^p - iX^c - \sum_{t=1}^{12} P_w^{'} X_t^F - \sum_{i=1}^{12} (1+i) P_w X_t^l + \sum_{t=1}^{12} P_w X_t^0 \tag{5.6}$$

Where:

$\overline{C_j}$ = expected gross margin of crop production activity j,

X_j^p = j[th] crop production activity measured in hectare,

P_w = wage rate in Cedis per Man-Days (MD),

$P_w^{'}$ = A reservation wage rate, which accounts for household leisure demand. It has been set in the range of 50% of P_w for commercial farmers and 0% of P_w to the subsistence farmers,

X_t^o = t[th] month off-farm activity, with MDs as its unit,

i = interest rate, a rate which accounts for the cost of capital and the transaction costs in the credit market was set in the range of 50% for subsistence farmers and 25% for commercial farmers,

X_t^l = t[th] month labor hiring activity, with MDs as its unit,

X_t^F = t[th] month family labor used for farming,

X^c = borrowing activity in Cedis,

$$\overline{C_j} = E(gm_j)$$

$$gm_{js} = y_{js} * P_j - X^c$$

$$E(gm_j) = \sum_{s=G,B,N} p_s y_{js} * P_j - X^c \qquad (5.9)$$

Where gm_{js} is gross margin per hectare, which is gross return, $y_{j*}P_j$, of crop j in state of rainfall *s*, less capital cost per hectare (X^c). The capital cost includes cash cost on fertilizer, seed, tractor/bullock and irrigation leavy. And y_{js} is the yield level of crop *j* in state of rainfall s. The rainfall condition is grouped into three states namely (G=good, B= bad and N= normal). The rainfall risk affects household income through its effect on crop yield, which will be specified as follows.

5.3.1.1 Specification of Traditional Crops Yield

For the sake of analysis, crops in the study area were grouped into two, namely tradition crops consisting of millet, groundnut, and beans and cash crops which contain rice and tomato. The traditional crops depend on rudimentary technologies as is the case for most of the SSA, where it can be fairly assumed that inputs are used in fixed proportion (Dutilly-Diane et al. 2003). The two most important factors determining the yield level of traditional crops are the prevailing rainfall condition and soil quality. Farmers in the area grow traditional crops on two types of plots, which vary in soil quality namely compound and bush plots. The compound plots by virtue of being around the homestead benefit from farm yard manure and they are usually planted with crops such as early millet and beans, which are crops of great importance in the household consumption bundle.

The yield level which accounts for both soil quality and state of rainfall can be specified as:

$$y_{jqs} = \min\{\alpha_{jqs} X_i\} \tag{5.10}$$

Where y_{jqs} is the yield level of crop activity *j* on soil type *q* under rainfall condition *s*, X_i is the level of the i^{th} input and α_{jqs} are constant production coefficients representing the necessary input of the respective factor per unit of output.

A panel data that captures the yield level of different crops under different states of rainfall is not available for the study area. This data gap was filled by subjectively eliciting the conditional yield levels of major crops as is reported in (Table 5.1).

Table 5.1: Mean Yield of Major Crops across States of Rainfall (kg/ha)

Crops	State of Rainfall		
	Good	Normal	Bad
Early Millet	723 (528)	413 (367)	161 (161)
Late Millet	712 (551)	390 (310)	172 (184)
Rice	1877 (1704)	1136 (1123)	556 (765)
Groundnut	1022 (628)	587 (425)	263 (223)
Guinea-corn	1023 (848)	619 (565)	256 (310)

Source: Own computation from HH survey 2003/2004; numbers in parenthesis are standard deviation

On average many farmers reported that the survey year 2003/2004 cropping season was a normal year, therefore it was taken as a reference to calculate the positive and negative deviations of the good and the bad states of rainfall respectively (Table 5.2).

Table 5.2: Farmers' Subjective Evaluation of Yield Deviation from Normal

Crop	Good Rainfall State	Bad Rainfall State
Early Millet	+75 %	-60 %
Late Millet	+ 80 %	-55 %
Rain-fed rice	+ 65 %	-50 %
Groundnut	+ 75 %	-55 %
Guinea-Corn	+ 65 %	-60 %

Source: Own Computation from Table

5.3.1.2 Estimation of Rice Yield

Rice is one of the crops enjoying modern technologies such as bullock/tractor traction, inorganic fertilizer and irrigation technologies. It is also the most important marketable crop in Ghana, where more than 40 percent of the national consumption is met with imports. Rice takes the lion share of irrigated land in the UER irrigation schemes. Its importance both for farmers and policy makers calls for its explicit representation in the farm model.

Farmers prepare rice land either with a combination of hand-hoe and bullock or tractor. Rice is also a crop which cuts across three water sources namely rain-fed, supplementary irrigation, which is irrigation system in which rice is cultivated during the rainy season on plots which are also used for irrigation during the dry season. In this system the fields get a supplementary irrigation whenever the rainfall is short of average. The third water use system is dry season irrigation on irrigation systems.

A detailed plot level input output data was collected in order to estimate a production function and account for the detailed features of rice production. The gross margin of a given rice activity will be a function of water source R, (rain-fed, supplementary irrigation or irrigation), the level of fertilizer, labor input and the output price level. Accounting for the interaction of the different technological sets can be well handled by econometrically estimating yield response functions.

5.3.1.2.1. Yield Response Function

There are two methods of empirically estimating a production function, namely primal and dual estimation methods (Mundlak 2001). In the primal approach production is estimated as a function of variable inputs and production function shifters. On the other hand the duality approach is based on behavioral functions, such as profit maximization or cost minimization. The most appealing feature of the dual approach is its explicitly incorporation of information on the behavior of the economic agent, which can be mapped on to the production function and add behavioral factors to the production function (Chambers 1988). The beauty of the dual approach is the possibility of switching from primal to dual and vice versa.

However, the journey from primal to dual and vise versa is simple only under self-duality that is when both technology and the dual function have closed-form expressions like in the case of Cobb-Douglas and CES functions (Chambers 1988). In the absence of self-duality the derivation of the behavioral functions will be direct but estimation of the production function requires the exact indirect computations that were to be avoided by moving to the dual function (Mundlak 2001). In addition to that in a cross-section data with little variations in prices the dual estimates will be inefficient (Lusk et al. 1999).

Thus, the anticipated advantage of duality over primal approach remains on a balance. Therefore, the choice of a primal or dual model specification ultimately depends on convenience to achieving particular research objectives (Shumway 1995) and criteria such as statistical efficiency. With respect to statistical efficiency, however, unlike direct estimators of the production function the duality approach does not utilize all the available information as a result it is inferior to the direct approach in studying production structures (Mundlak 1996). The current study is based on a cross-sectional data from a small geographical area with little price variation therefore a primal estimation will be more appropriate than a dual one.

5.3.1.2.2. Theoretical Foundations of Production Function Estimation

In a pure technical term a production function represents the maximum output that can be produce with a given combination of inputs. That is, as in (Diagram 3) the production function $Y = f(x)$ is only the surface of the hill, while the contours along the hill are isoquants representing different level of output.

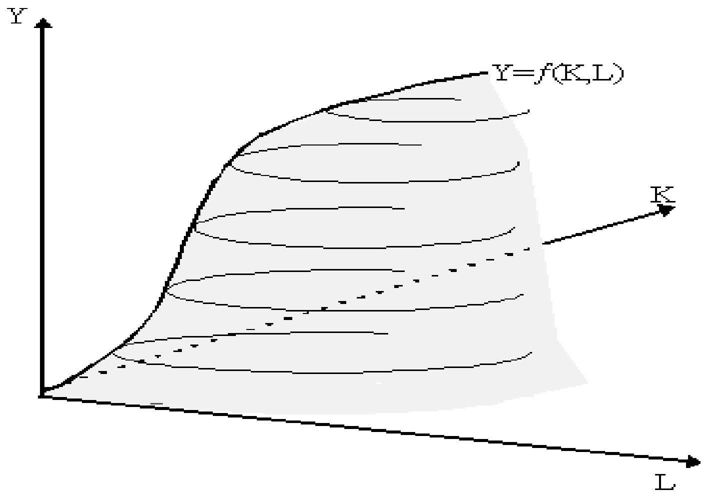


Diagram 3: Production Function for one-output/ two-inputs case

A production function's representation of the maximum possible output level is only a physical relationship and does not guarantee the explicit inclusion of economic behavior in the estimation of a production function. However, the primary goal of applied production analysis is the empirical measurement of the economically relevant information that exhaustively characterizes the behavior of economic agents. The representation of economic theory in an estimated production function requires the imposition of certain restrictions on $f(x)$ (Chambers 1988). Some functional forms require the imposition of few restrictions in order to represent economic behaviors while others require sets of restrictions to fully account for economic theory. Functional forms such as Cobb-Douglas easily satisfy the theoretical requirements while flexible forms such as quadratic form require ex-ante imposition of the regularity conditions.

However, the form of the functional relationship that represents the empirical observation and satisfy theoretical requirements can not be known with certainty before the estimation process. Previous knowledge and the theoretical requirement which the function has to satisfy can guide the decision on the choice of the functional form (Heady and Dillon 1961). Long practices in both theoretical and empirical spheres identified certain norms which a given functional form needs to comply to in order to be a tool for empirical and theoretical analysis of a given economic relationship (Lau 1986). The criteria are theoretical consistency, domain of applicability, flexibility, computational facility, and factual conformity.

Theoretical consistency implies that the functional form chosen must be capable of possessing certain theoretical properties required of the economic relationship under question for an appropriate choice of parameters. For example, a functional form representing a production relationship needs to be monotonic in inputs and concave.

5.3.1.2.2.1. Monotonicity

Monotonicity implies that additional unit of input can never lead to a decrease in output level. That is a rational producer will not add input level if that addition leads to a decrease in output level.

That is: if $X^{'} \geq X$, then $f(X^{'}) \geq f(X)$.

In the case of a differentiable production function this means that all marginal products should be greater than zero.

5.3.1.2.2.2 Concavity

Concavity and quasi-concavity are sufficient and necessary conditions respectively required to ensure the property of diminishing marginal productivity. Algebraically the satisfaction of concavity and quasi-concavity conditions can be verified by using the Hessian and Border-Hessian matrices respectively and both have to be negative semidefinite, i.e. its principal leading minors will alternate in sign. Under constant returns to scale quasi-concavity of the production function guarantees diminishing marginal productivity (Chambers 1988).

5.3.1.2.2.3 Flexibility

The flexibility of a functional form is its ability to have estimable relationships that place relatively few prior restrictions on the technology (Chambers 1988). Flexibility of a functional form is desirable because it allows the data the opportunity to provide information about critical parameters. An inflexible functional form such as a Cobb-Douglas functional form often prescribes the value, or at least the range of values, of the critical parameters (Lau 1986). In general, the degree of flexibility required depends on the application. For most applications involving producer or consumer behavior the flexibility required is that the own and cross-price derivatives (or equivalently the elasticities) of demand for inputs or commodities be free to attain any set of theoretically consistent values.

5.3.1.2.3.4 Comparing the Cobb-Douglas and Normalized Quadratic

The Cobb-Douglas and quadratic functional forms are the two most commonly used functional forms in production function analysis. Each has its own advantages and limitations; here we compared the suitability of the two forms for the empirical observation at hand.

The Cobb-Douglas functional form is represented as:

$$y_R = A \prod X_i^{\alpha_i}, \alpha_i > 0 \qquad (5.11)$$

It is the most extensively applied functional form both in empirical and theoretical discussions of production analysis. Its wide use emanates mainly from its simplicity in estimation and analytical derivation. A Cobb-Douglas function is monotonic as long as the elasticity coefficients are greater than zero. On the other hand it is concave when:

$$\frac{\partial^2 f(X)}{\partial X_j^2} = \frac{\alpha_j(\alpha_j - 1)}{X_j^2} A \prod_{i=1}^{n} X_i^{\alpha_i} < 0. \qquad (5.12)$$

That is, when the α's are less than one. In spite of its wide use the major limitation of the Cobb-Douglas functional form is its imposition of unitary elasticity of substitution on the parameters.

On the other hand the Normalized Quadratic is a flexible functional form as compared to a Cobb-Douglas form. The general form will be (Chambers 1988):

$$Y = \alpha_0 + \sum_{i=1} \alpha_i X_i + \sum_{i=1} \beta_i X_i^2 + \sum_{i \neq j} \delta_i X_i X_j + \varepsilon \qquad (5.13)$$

However, unlike a Cobb-Douglas functional form the Normalized Quadratic form will not automatically guarantee the satisfaction of theoretical requirements. The satisfaction of the theoretical requirements need to be checked ex-post or need to be imposed ex-ante, which will in most cases costs the statistical significance of the estimates.

5.3.1.2.3 Estimation

The three rice growing systems, namely rain-fed rice, supplementary-irrigated rice and irrigated rice are estimated in the following section. Descriptive statistics of the three production technologies are provided in (Table 5.3).

Table 5.3: Descriptive statistics of per Hectare Input Uses

	Rain-fed		Supplementary Irrigation.		Irrigated	
	Mean	Std. Dev	Mean	Std. Dev	Mean	Std. Dev
Yield (Kg/ha)	625.8	496	3467.3	4523	3592	2458.7
Labor (MDs/ha)	175	132	125.4	67.9	162.6	89.8
Fertilizer (Kg/ha)			154.5	84.1	187.2	84.3
Seed (Kg/ha)	54	51	150.9	86.1	166.5	115.9
Tractor (Dummy 1=use tractor, 0= no)	0.07	0.27	0.67	0.48	0.52	0.50
Observations	65		36		51	

Source: Household survey 2003/2004

The estimated functions are normalized by land and the units of measurements of output and inputs are as follows: the output level in Kilograms of rice per hectare, fertilizer in Kilograms per hectare, labor in Man-days per hectare, seed in Kilograms per hectare and tractor is a binary variable (1 if land is prepared by tractor and 0 otherwise). Farmers in the study area hardly use inorganic fertilizer on rain-fed crops including rice. Therefore, fertilizer was not included on the rain-fed rice function.

The Cobb-Douglas proper is a CRS function (Chiang 1984) and the estimated functions were tested for conformity to CRS assumption. Unlike the rain-fed function in both the irrigated and supplementary irrigation technologies the hypothesis that the function satisfies CRS is statistically significant. But in order to keep consistency in the three technologies CRS is also imposed on the rain-fed function. (Table 5.4) provides the estimates of the three production functions.

Table 5.4 Cobb Douglas Estimation of Rice Yields

Variables	Rain-fed	Supplementary Irrigation	Irrigated
Constant	1.89 (0.000)	2.71 (0.000)	2.79 (0.000)
LNFERT		0.72 (0.0017)	0.28 (0.08)
LNLAB	0.48 (0.000)	0.12 (0.54)	0.07 (0.60)
LNSED	0.52 (0.0000)	0.16 (0.35)	0.66 (0.000)
Tractor	0.43 (0.19)	0.27 (0.35)	0.32 (0.065)
Adj. R2	0.18	0.34	0.63
F-test	8.03 (0.0008)	6.96 (0.0010)	29.37 (0.000)
Observations	65	36	51

Numbers in Parenthesis are probability levels

With the imposition of CRS rain-fed rice estimation had still statistically significant parameters. The estimated Cobb-Douglas production functions had Adjusted R^2 ranging from 0.18 to 0.63 and significant F-statistics, which show that the functions fit their respective data very well. Since the rain-fed function does not include fertilizer a direct comparison of the elasticities of the functions is not possible. However, the supplementary and irrigated are in a comparable form.

Most of the elasticities of the supplementary irrigation technology out performed those of irrigated technology. For example, the elasticity of fertilizer under supplementary irrigation technology was three times that of the irrigated technology. The high response of fertilizer in the supplementary system has important implications on the relevance of soil and water conservation technologies in the area. That is, technologies that improve soil moisture retention can boost agricultural production tremendously. The supplementary irrigation system becomes particularly important in the long run as population pressure results in increasing water demand both for agriculture and for alternative uses such as domestic and industrial uses.

On the other hand, estimates of Normalized Quadratic function (Annexes 6 & 7) show that the monotonicity and curvature restrictions imposed on the quadratic function rendered estimates which are theoretically consistent but statistically insignificant. All of the estimated parameters are insignificant even at 10 percent level. In the restricted case in particular many estimates turned out to be zero or very small in magnitude and the F-statistics for the Supplementary irrigation is insignificant. Therefore, specifying a quadratic functional form for the problem at hand will not have add value so the Cobb-Douglas estimates was adopted for the programming model.

5.3.1.2.4 Incorporating the Yield Function in LP Matrix

The piece wise linearization of continuous functions like C-D is one way of incorporating a continuous function in a programming model (Hazell and Norton 1986). In the estimation both the water and land preparation technologies are discrete and can be incorporated through different combinations of land preparation and source of water. In addition, looking explicitly into the different levels of fertilizer and labor use, which are the most important inputs in the production process, increases the flexibility of the model in encompassing different management options. It will also help address major policy issues such as soil fertility management.

Since the levels of fertilizer and labor are continuous some logically sound discrete levels were identified. Eight levels of fertilizer namely 25, 50, 75, 100, 125, 150, 175 and 200 kgs per hectare were used. On the other hand the 25th, 50th and 75th quartiles of the observed labor allocation were used for the irrigated and supplementary irrigation system (Table 5.5). In the case of rain-fed rice labor is the major decision variable as a result a more disaggregated level is used, namely 40, 60, 80, 100, 120, 140, 160, 180 and 200 MDs per hectare. Therefore a rice activity in the LP tableau will represent a combination of land preparation technology, water source, fertilizer and labor.

Table 5.5 Quartiles of per hectare Fertilizer and Labor parameterized in the Matrix

Quartiles	Labor (MDs)
25th	82
50th	120
75th	196
Mean (St. dev)	168 (154)

The gross margin of a rice activity will be:

$$gm_{Rfl} = y_{RflTs} * p - X^c \qquad (5.14)$$

Where y_{RflTs} is the yield level of rice activity under *R* water technology, *f* fertilizer level, *l* labor level, under *T* land preparation technology and *s* state of rainfall and X^c represents cash expenditure. The expected gross margin of a rice activity will be:

$$E(gm) = \sum_{S} p_s (y_{RfITs} * p) - X^c \qquad (5.15)$$

Where p_s is the probability of state of rainfall s Since irrigation has yield risk reduction impact the yield levels of rice under the irrigated and supplementary irrigation systems will be the same under all states of rainfall.

5.3.2 Constraint sets:

In the following sections the different constraints incorporated in the programming model are discussed.

5.3.2.1 Land Constraint:

Four major land types are represented in the model. The first group is compound farm which is a plot located around the homestead and which is better endowed with organic manure. It is specified as:

$$\sum_{j=1} X_{jc}^{p} \leq L_C \qquad \text{Compound farm land constraint,} \qquad (5.16)$$

Where X_{jc}^{p} production activity of activity j on compound plots and Lc is is total compound land available. The superscript p indicates that the activity is a production activity on the other hand the suffix c indicates that the production activity is on compound land. The second group is bush land, which is located few Kilometers away from the homestead. It is mainly used for the production of groundnut, late millet, rice and other major crops.

$$\sum_{j=1} X_{j}^{p} \leq L_B \qquad \text{Bush \& valley Bottom Land Constraint,} \qquad (5.17)$$

Where X_{jB}^{p} production activity of activity j on compound plots and L_B is total bush land available. The superscript p indicates that the activity is a production activity on the other hand the suffix $_B$ indicates that the production activity is on bush land.

In the study area irrigated crop production is carried out under dams (large and small scale), dugouts, hand-dug wells and along riverbanks. Data on most of irrigation systems but the larger schemes is scant as a result the model explicitly accounts only for irrigation activities on the Tono irrigation scheme. In the Tono irrigation scheme plots are operated two times a year, during the dry season, referred to here as irrigated plot and during the rainy season, referred to here as supplementary irrigation. The major crops in this system are rice, tomato and soybean.

In the Tono irrigation scheme farmers obtain irrigable land from the irrigation authority on rental bases. Therefore, the irrigation land constraint in the model is accounts as a balance activity where the supply of land comes through renting land from the irrigation project. The constraint will look like:

$$\sum_{j=1} X_{jS}^{p} - L_{SI} \leq 0 \qquad \text{Supplementary Irrigation Land Constraint,} \qquad (5.18)$$

$$\sum_{j=1} X_{jI}^{p} - L_{I} \leq 0 \qquad \text{Irrigated Land Constraint,} \qquad (5.19)$$

Where L_{SI} and L_I are rented supplementary and irrigated plots respectively and X_{jS}^{p} X_{jI}^{p} are production activity of activity j on supplementary and irrigated plots respectively. The superscript p indicates that the activity is a production activity on the other hand the suffix $_S$ and $_I$ indicate that the production activities are under supplementary and irrigated lands.

5.3.2.2 Labor Constraint

Labor is the most important factor of production constraining agricultural production in the study area. There is a relatively working labor market so the model assumes that farm households can both hire-in and hire-out labor. Households make labor allocation decision both during the rainy and dry seasons. Traditionally the rainy season is a season of agricultural production and most labor is allocated to farming, while the dry season is a season of temporary migration, non-farm local employment and leisure. However, the expansion of irrigation agriculture during the dry season induced farm households to allocate labor across leisure, irrigation and off-farm activities. Thus the labor constraint can be represented as:

$L_R^F + L_D^F + L^O - L_R^H - L_D^H \le \overline{L}$,	Household annual labor constraint	(5.20)
$L_R^F - L_R^H \le L_1$	Rainy season labor constraint	(5.21)
$L_D^F + L_D^O + l - L_D^H \le L_2$	Dry season labor constraint	(5.22)

Where: $L_R^F, L_D^F, L^O, L_R^H, L_D^H, l, \& \overline{L}$ are rainy season farm labor, dry season farm labor, off-farm labor, rainy season hired labor, dry season hired labor, leisure and total household labor endowments respectively. L_1 and L_2 represent rainy season and dry season specific labor endowments. Disaggregating of the labor allocation schedule into shorter time intervals increases the precision of incorporating details of activities, so that labor allocation was disaggregated into monthly labor. In the study area, though households have access to the off-farm labor market there were reports of constraints. To account for the existing labor market constraints the model put a ceiling on the amount of labor the household can offer to the off-farm market.

The leisure demand by farm households is one important factor constraining decisions. Leisure is a luxury good whose demand increases as household income increases therefore, accounting for this feature is important in modeling household decisions. There are different methods of accounting for leisure demand in programming models the ideal approach could be to estimate a demand curve for leisure (Holden and Shiferaw 2004). For this study, household level data to account for the functional relationship between income and leisure was not available. So an alternative approach was adopted, where a reservation wage was charged to family labor at a cost reflecting the marginal value of leisure to the farm family (Hazell and Norton 1986). Finally the labor constraint was incorporated into the LP tableau as is presented in (Table 5.6).

Table 5.6 Tableau indicating labor constraints[6]

	Produce Crop (ha)	Family Labor (Months)	Hired Labor (Months)	Sell Labor (Months)	RHS
Obj. Fun.	+C	-αw	-w	+w	
Labor Balance	+A	-1	-1	+1	≤0
Family Time		+1			$\leq \overline{L}$
Off-farm cons.				+1	$\leq \overline{L}$

5.3.2.3 Fertilizer & Credit Constraints

These are the two important external inputs limiting agricultural production in the area. The fertilizer type commonly used in the study area is a combination of Nitrogen, Phosphorus and Potassium nutrients (NPK). Due to the risk associated with rainfall variability farmers apply fertilizer only on cash crops planted on irrigated fields. All fertilizer used is purchased from the market. The fertilizer constraints on these fields can be specified as:

$$\sum_{j=1} a_{fj} X_j^p - X_f \leq 0 \qquad \text{Fertilizer Balance,} \qquad (5.23)$$

Where a_{fj} = Kg. of NPK fertilizer required to produce a hectare of j[th] crop activity and X^f = Amount of fertilizer purchased in Kgs.

$$\sum_{j=1} a_{jk} X_j^p + \sum_{t=1} P_w X_t^l - X^k - \sum_{t=1} P_w X^o \leq K \qquad \text{Credit Constraint,} \qquad (5.24)$$

$$X^k \leq \overline{K} \qquad \text{Credit Market Constraint} \qquad (5.25)$$

Where:
a_{jk} = the amount of direct cash cost required to produce a hectare of the j[th] crop activity,
X^K = the amount of borrowed fund,
K = total available own fund in Cedis and
$\overline{K}$ =amount of cash available from credit (rationing in the credit market).

The rationing constraint accounts for the fact that under the existing market condition households can access to only limited amount of cash. The rationing system in the credit

[6] The C and A represent, respectively, sets of objective function coefficients and input-output coefficients. α <1 is the reservation wage factor

market can be clearly observed in agricultural input markets where farmers get fixed amount of in kind input credit. The general representation of fertilizer and credit constraints into the LP matrix is presented in (Table 5.7).

Table 5.7 LP Tableau with Credit and fertilizer Constraints

	Crop Prod. (ha)	Rent Land (ha)	Borrow (Cedi)	Hire Labor (Mds)	Sell Labor (Mds)	Buy Fert. (Kg)	Relation	RHS
Objective	+C	-C	-i	-C		-C		
Fertilizer Balance	+A					-1	≤	0
Credit	+A		-1	+A	-A	+A	≤	K
Rationing			+1				≤	$\overline{K}$

5.3.2.4 Consumption Constraint

Consumption decision is an important component in subsistence farm household's decision. There are different ways of accounting for household consumption requirements in programming models. Imposing a lower bound constraint on the production of the required food crops is the simplest and the most straight forward approach. However, setting a lower bound on consumption is very rigid because it does not allow the level of consumption to vary with the level of household income and other non-income factors, such as family size and geographical location.

The alternative and theoretically sound approach is to derive the set of demand functions from the utility maximization behavior of the consumer. The set of demand functions generated this way are called Marshallian demand functions. A Marshallian demand function defines the quantity of a commodity that a consumer will consume as a function of commodity prices and income. Mathematically this means for a household with a utility function of $U(q;Z)$ its problem will be to choose the combination of commodities that maximize its utility under varying prices and fixed income.

Where:

q =is a vector of n commodities, from which households generate utility and

Z=is a vector of utility shifters, such as household size and geographical location.

If Y is total income, then the household expenditure on consumption is constrained by the total available income (Eqn. 5.26). That is:

$$P^{'}q = Y \tag{5.26}$$

Where, P' is a row vector of prices of goods. Thus, the consumer problem can be summarized as:

$$\underset{q,\lambda}{Max}\, U(q;Z) + \lambda(Y - P^{'}q) \tag{5.27}$$

Where, λ is a lagrangian multiplier, which is a measure of the marginal utility of income. The solution to the consumer problem in (Eqn 5.27), will give us a set of demand functions and the arguments of the demand functions will be income, own price, price of other goods and household characteristics. That is:

$$q_i = q_i(P, Y; Z) \text{ i=1… n.} \tag{5.28}$$

The n demand equations will then contain n income slopes $\partial q_i / \partial Y$ or income elasticities $\eta_i = \frac{\partial q_i}{\partial Y}\frac{Y}{q_i}$ and n^2 price slopes or price elasticities $\varepsilon_{ij} = \frac{\partial q_i}{\partial P_j}\frac{P_i}{q_j}$. All this will generate a total of $(n+n^2)$ independent parameters. This implies that as the number of goods considered in the estimation increases the number of parameters to be estimated will increase geometrically. The derivation of the demand functions from consumer theory, in addition to giving theoretically consistent estimates, will establish a set of constraints which demand parameters must satisfy. The constraint set will thus limit the number of independent parameters to be estimated and ensures consistency in the results (Sadoulet and de Janvry 1995).

However, even after the imposition of these constraints the number of independent parameters to be estimated will usually be very large as compared to the available degrees of freedom from our data. In order to further reduce the number of independent parameters goods can be grouped into sub-groups such as food, non-food consumables etc. In the second stage of grouping each group can be subdivided into subcomponents such as cereals, livestock, beverages etc for the major group of food. Then, the demand functions can be estimated as a part of a multi-stage estimation and the concept behind this approach is called separability (for detail see (Sadoulet and de Janvry 1995).

Estimation of demand systems becomes even more difficult when one considers of estimating demand functions for households in developing countries where time series data are hardly available and in most cases the only available data are cross sectional. Cross sectional data from small geographical locations have limitation in the estimation of demand systems because they lack the necessary variability in price data. In that case the commonly used approach is to estimate Engel curves and generate the necessary parameters, such as income and price elasticities from the estimated Engel Curves.

5.3.2.4.1 Estimating Engel Curves

An Engel curve is represented as:

$$q_i = q_i(Y; z), \quad i=1,\ldots,n. \tag{5.29}$$

Where q_i is budget share of good i, Y is total expenditure and Z's are demand shifters such as age, occupation, geographical location etc.

Engel curves are not directly derived from the consumer problem of utility maximization. Therefore, they have to satisfy certain desirable properties in order to qualify as a demand function, which include according to (Sadoulet and de Janvry 1995):

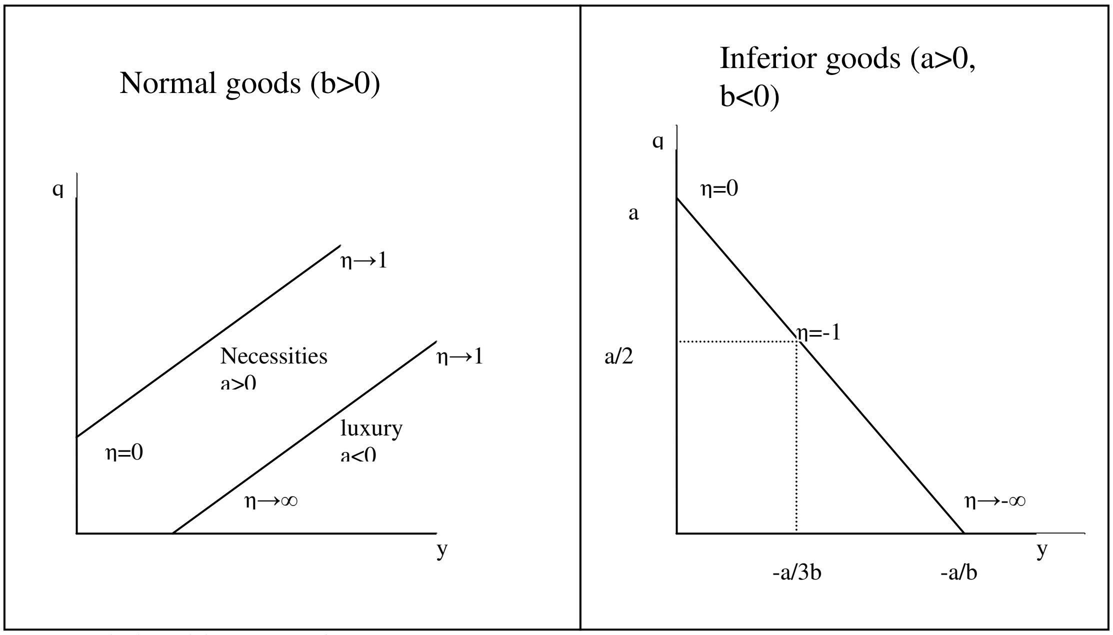
1. They should satisfy the budget constraint (predicted expenditure for each commodity should add up to total expenditure);

2. They should be able to represent luxuries, necessities and inferior goods;

3. They should have variable income elasticities due to the empirical fact that income elasticities tend to decline as income increases; and

4. The consumption of many commodities should reach a saturation point as income increases.

The most commonly applied functional forms are linear, double logarithmic, semi-logarithmic and logarithmic reciprocal. Except for the double logarithmic the other three have variable elasticities and only the linear form satisfies the Engel aggregation equation (Sadoulet and de Janvry 1995). Though the linear specification satisfies most of the requirements it does not allow for a decrease in elasticity of income.



Source: (Sadoulet and de Janvry 1995)

Diagram 4: Diagrammatic Presentation of a linear Engel curve

The households in the sample are subsistence for whom the short coming of ignoring decreasing elasticity of the linear form will not be very significant. Therefore, here a linear Engel curve was estimated and the corresponding, income and price elasticities are also presented as follows:

A linear Engel Curve $q = a + bY$,

Income Elasticity $\eta = \dfrac{bY}{a + bY}$,

Own Price Elasticity $E_{ii} = \dfrac{1}{\omega}\eta_i(1 - w_i\eta_i) - w_i\eta_j$,

Cross Price Elasticity $E_{ij} = -\dfrac{w_j}{\omega}\eta_i\eta_j - w_j\eta_i$, i≠j.

Where $\omega = \frac{\partial \lambda}{\partial Y}\frac{Y}{\lambda}$ is the flexibility[7] of money and w_i is the budget share of good i (see (Sadoulet and de Janvry 1995).

5.3.2.4.2 Estimation

Households in the study area consume a whole set of food and non-food items. Some of the consumables are produced either at home or purchased from the market. The major consumables are cereals such as Millet, Groundnut, beans and Rice. On the other hand households solely depend on the market for the purchase of some consumable items such as sugar, salt, root and tuber crops and non-food items such as kerosene.

Table 5.8 Descriptive statistics of expenditure variables

Variables	Mean	% of Cereal Expenditure	St. dev	Coefficient of Variation
Expenditure-Millet (Cedis)	299,321.2	55.1 %	198495.1	66 %
Expenditure-Groundnut (Cedis)	100,443.8	18.5 %	72736.6	72 %
Expenditure-Rice (Cedis)	142,415.6	26.2 %	129545.4	90 %
Expenditure-Beans (Cedis)	881.3	0.2 %	603.2	68 %
Total Cereal Expenditure	543,062			
Total-Expenditure (Cedis)	1,425,807.6		840623.4	
HH size	5.1		2.1	

The descriptive statistics in (Table 5.8) indicates that millet accounted for more than 50 percent of the cereal expenditure and about 20 percent of total household expenditure. On average rice accounted for about 25 percent of the cereal expenditure but with large variation, measured in the Coefficient of Variation (CV), in rice expenditure.

In the linear programming Tableau production, sale and purchase activities of crops are presented in quantitative terms. Consumption estimates usually use Calories to measure the quantity of food consumed, this approach has advantage in aggregating different food types and also when there is policy interest to know the nutritional implication of the consumption decisions. In our case the main modeling interest is to incorporate the impact of consumption decision on overall household resource allocation decision, for

[7] The flexibility of money can be measured from knowledge of the own-price elasticity, the income elasticity, and the budget share for one separable group i (Sadoulet and de Janvry 1995).

which units like Kg. are useful than Calorie units, since farmers think in terms of Kg. not in Mega joules. Therefore, in order to keep consistency and ease of integration into the matrix the monetary values of consumption were converted into quantitative terms and then the estimates were done as follows.

Empirical specification of the Engel curves:

$$KG_p = \beta_o + \beta_1 TOTEXP + \beta_2 HHSIZE + \varepsilon_p \qquad (5.30)$$

Where:

KG_p = is Kg of crop P consumed, which includes Millet, Groundnut, Beans and Rice,

TOTEXP= is total household expenditure in ‘000 Cedis,

HHSIZE= is household size measured in the number of household members without accounting for age and sex, and

β’s = are parameters to be estimated while ε is the error term.

Finally millet, groundnut, rice and beans were included because of their important role in the households’ production and consumption decisions. (Table 5.9) presents the estimates of the Engel curves.

Table 5.9 Engel Curves of Major Consumables in the UER of Ghana

Variable	Millet (Kg.)	Groundnut (Kg.)	Rice (Kg.)	Beans (Kg.)
Constant	90.9	135.4	-28.6	12.5
EXPE. (‘000 Cedis)	0.15 (0.7)	0.07 (0.42)	0.19 (1.12)	0.03 (0.77)
SIZE	30.89	-6.3	8.5	
Adj. R^2	0.26	0.12	0.33	0.05
F-statistics	****	****	****	****
Observations	197	197	197	188

**** Significant at 1 %; the numbers in parenthesis are income elasticities.

The four crops namely millet, groundnut, rice and beans have exhibited price elasticities ranging from 0.42 for groundnut to 1.12 for rice. The magnitudes of the elasticities fully confirm empirical observations in the area. That is, for the majority of the households in the study area, rice is a luxury good, as compared to the other crops; therefore an income elasticity of 1.12 confirms this fact. The high income elasticity of rice has important implications in light of increasing income and urbanization in Ghana, which can lead to increased demand for rice. In this equation irrigation will be crucial in boosting local supply of rice and saving hard currency used for the import of rice.

5.3.2.4.3 Incorporating Engel Functions into an LP Matrix

The LP tableau does not explicitly account for variation in family size, therefore an average Engel curve conditional on family size was incorporated.

$$E(Exp_p / SIZE) = \beta + \beta_1 TOTEXP \qquad (5.31)$$

Where $\beta = \beta_o + \beta_2 * SIZE$

(Table 5.10) shows the representation of the different parameters of the consumption constraint in the LP Matrix. The positive and negative signs associated with each element in the matrix show whether an activity is demanding or supplying a unit to the constraint that is a row entry.

Table 5.10 LP Tableau of Consumption Constraint

	Produce Crop	Rent Land	Labor Sell/ Buy	Input Buy	Interest	Crop Sell	Crop Cons.	Income Identity	RHS
Objective	+C	-C	-/+C	-C	-C				
Income Identity	+C	-C	-/+C	-C	-C			-1	= F
Crop Balance	-A					+A	+A		= 0
Consumption							+A	-β	≥ B

The values in the tableau C, A, F, B and β are coefficients representing activity values, input-output coefficients, farm fixed cost, autonomous consumption and marginal propensity to consume respectively. Income is defined as total gross margin plus wage income less variable cash costs, such as hiring labor and fertilizer purchase, plus farm fixed cost.

5.3.2.5 Risk Constraints and Application of the LPM

The probabilistic constraint in a Telser's SF model is specified as:

$$pr(Z < g) \leq \alpha \quad (5.32$$

Where (Z) is income level, (g) is exogenously determined minimum level of income a household must earn to meet obligations of high priority, pr (.) is the probability of event (.), and (α) is an acceptable limit on the probability of goal failure. In order to incorporate the probabilistic constraint into a linear programming model one need to either make assumption on the distribution of income or use distribution free methods. Here, we implemented (Atwood 1985) where an LPM based constraint which allows optimization algorithms to endogenously select the appropriate and least constraining level of (t) given a statistical data set. That is for a discrete population the LPM will have the form:

$$R(a,t) = \sum_{z_i \leq t} (t - Z_i)^a f_i \quad (5.33)$$

Where R(a,t) is the LPM, t is a reference level below which deviations are measured, Z_i is the value of Z should rainfall state i occurs, a>0 is the power to which deviations below (t) are raised, and f_i is the probability that rainfall state i occurs. (Atwood 1985) demonstrated that:

$$\Pr(Z \leq g) = \Pr(Z \leq t - pQ(a,t)) \leq (1/p)^a \quad (5.34)$$

Where $Q(a,t) = [R(a,t)]^{1/a} > 0$ and P is a constant greater than zero. If P is defined as: $P \equiv (t - g)/Q(a,t)$, where t>g and Q(a,t)>0, then the above probability function can be written as:

$$\Pr(Z \leq g) = pr(Z \leq t - pQ(a,t)) \leq [Q(a,t)/(t - g)]^a \quad (5.35)$$

If either Q(a,t)=0 or t=g, the stochastic inequality is inapplicable as P or Q(a,t)/(t-g) is undefined. As (a) can take any value greater than 0, (Atwood 1985) took a=1 and define a linear lower partial moment, denoted as Q(t)=Q(1,t)=R(1,t), which will lead to:

$$\Pr(Z \le g) = \Pr(Z \le t - pQ(t)) \le Q(t) / (t - g) \quad (5.36)$$

It was shown that if Q(t) is greater than zero and t>g, enforcing the constraint

$$t - L^{*}Q(t) \ge g \text{ [8]} \quad (5.37)$$

is sufficient to guarantee that

$$\Pr(Z < g) \le \alpha . \quad (5.38)$$

(Atwood et al. 1988) demonstrated that when α=1 the sufficiency condition ($t - \frac{1}{\alpha}Q(t) \ge g$) can be easily stated as linear constraints in a Target MOTAD model, a model whose solutions are usually members of the second-degree stochastic dominance efficient (Tauer 1983).

The difference between the ordinary Target-MOTAD (Tauer 1983) and (Atwood 1988) is that the Target-MOTAD model determines a feasible choice vector *x*, which maximizes expected aggregate income while requiring that probability-weighted deviations below *t*=*g* not exceed *k*, which is a tolerable limit of the deviation. In the (Atwood 1988) model, which we call a modified Target-MOTAD, the deviation reference level *t* will not be equal to *g*. It will be endogenously determined by selecting the least constraining linear lower partial moment from the set of lower partial moments for which ($t - \frac{1}{\alpha}Q(t) \ge g$).

Finally, the set of constraints that are required to implement the LPM based probabilistic constraint are presented below. A constraint accounting for the deviation of income from the target income at each state of rainfall was captured by:

$$\sum C_{js} X_j - t + d_s \ge 0 , \quad (5.39)$$

[8] L^* is the inverse of the probability limit, that is 1/α.

Where C_{js} is gross margin of crop production activity *j* in sate of rainfall *s* and d_s is the deviation of income from *t* in sate of rainfall *s* and it will be zero if income exceeds the target level. All negative deviations from *t* are collected by a balance row:

$$\sum_{s=1}^{3} p_s d_s - Q(t) = 0, \qquad (5.40)$$

Where Q(t) is the LPM and P_s is the probability of state of rainfall *s*. Finally, the sufficiency constraint necessary to impose the probabilistic constraint, (Pr (Z<g) ≤1/α):

$$t - L^* Q(t) \geq g. \qquad (5.38')$$

All the risk related constraints were incorporated into an LP tableau as indicated in Table 5.11 below.

Table 5.11 LP Tableau of Safety-first Constraint

Row	$X_i^{'s}$	T	d_k	TQ(t)	Tobj	*RHS*
Obj					1	*Max*
Resource	a_{ij}					<= b_j
Cond. Income	Y_{is}	-1	1			>= *0*
Q(t)			P_k	-1		= *0*
Sufcon		1		-L*	0	>= *g*
Exp. Income	$\overline{Y_i}$				*-1*	>= *0*

s- state of rainfall (good, bad and normal), *i*-types of crop farm activities, *j*-resource (land and labor).

And the following non-negativity conditions must also hold: $X, d, \geq 0$

6: Policy and Technology Scenario Analysis

6.1 Introduction

The scenario analysis in this section is based on the household model developed in the preceding section, which provided a full set of the modeling tool and its descriptions. Validation tests were performed to evaluate the appropriateness of the model for scenario analysis. The base runs of the different farm groups were compared with their respective observed values taken from 2003/2004 household survey. Parameters such as interest rates, subsistence level of incomes, available own funds, etc were based on empirical data and expert knowledge. A sensitivity analysis was done to check their consistency.

Data on the amount of own funds, farm fixed costs and income goals, which the household model takes as a target in its decisions were difficult to capture using the structured questionnaire developed for this study. However, the survey captured data on household fixed assets such as farm equipment and livestock. Data on available own fund, income goal and farm fixed costs were then parameterized as 10% and 25% of the farm fixed asset respectively.

As is discussed in Chapter 3 the sample households were grouped into four clusters. Undertaking "what-if" experiments on each farm group is necessary since each group is distinct and would potentially respond differently to similar policy interventions. In this chapter, simulation analysis of policies and technologies on two of the clusters, namely the subsistence and the commercial farm groups was done. These two clusters were chosen for the simple reason that they represent extreme cases in our data set.

6.2 Base Run and Sensitivity Tests

A model's stability within a broader change of parameter variation (Berger 2001) and its ability to depict observed outcomes of the system modeled (McCarl and Apland 1986) determine a model's usefulness for scenario analysis. In modeling a decision environment a modeler tries to incorporate as much information as possible.

Modeling becomes a challenge when one tries to address farm households in developing countries, where there are multiple sources of risk and lack of data does not allow full accounting of the complex environment. In that case one is forced to make informed assumptions on certain parameters. The appropriateness of a model for policy analysis depends on the consistency of the model outputs under changing parameters. The method of testing whether the model is consistent under changing parameters is called sensitivity analysis. The models were tested for consistency under changing assumptions on these parameters.

6.3 Model Validation and Robustness Test

One of the challenges in modeling agricultural farm households for policy analysis is building a model that represents the observed decision process. Any model depicting a farm household decision process can not be utilized with confidence unless it is considered a valid portrayal of the system under investigation. Model validation is fundamentally subjective, because modelers choose the validation tests, the criteria for passing those tests, what model outputs to validate, what settings to test in, what data to use, etc (McCarl and Apland 1986).

In the most ideal case a valid model replicates each and every empirical observation. However, this can not be realized because of the information gap between the modeler and the decision maker. So a more realistic approach will be to see the extent to which certain model outputs, which are of policy and research interests, are depicted. For example (Kruseman 2000) used the cereal area, which provides sufficient variability in the results, as the main criteria to check for model validity. Similarly, (Berger 2001) and (Woelcke 2003) used land use as indicator variable in their model validation.

In our case the degree of accuracy in depicting land allocation across different land use types is of much importance, therefore it will be taken as an indicator variable. (Table 6.1) presents the major indicator variables used in validating the model at hand.

Table 6.1: Comparison of Model Results and Observed Values

Farm Groups	Land Use Types	Model Result	Observed Values
Cluster 1	Millet-mix	1.23	1.39
	Groundnut Total	1.22	0.85
	Groundnut Mix Cpd.	0.49	0.46
	Rice Supp. Irrigation	1.41	1.6
	Rice Irrigated	1.13	1.43
Cluster 4	Millet Mixed	0.77	0.91
	Groundnut	0.63	0.56
	Groundnut Mix Cpd.	0.51	0.31
	Groundnut Mix Bush	0.00	0.17
	Rice Rain-fed	0.29	0.2

Regression techniques have been used to measure the associations with observed values, in which case model results are regressed on observed values. That is, for a case where land use is the indicator variable:

$$X^M = \beta_0 + \beta_1 X^O$$

Where X^o is observed land use, X^M is model land use while β_i's are parameters to be estimated. For a valid model, where there is high degree of association between the model results and observed values, the intercept will be zero while the slope will be one. However, this test will be inefficient if the correlation coefficient between the model and observed values is less than one (Kleijnen et al. 1996 & Kleijnen 1998 as quoted by (Kruseman 2000).

In our case the correlation coefficient between the observed and model values is 0.93, which is almost a perfect correlation. This implies that, the regression of model values on the observed ones can be an efficient measure of model validation. (Table 6.2) presents the parameter estimates and probability levels of the regression equation.

Table 6.2: Regression results to test model validation

	β_0	β_1
Values	0.135	0.803
Sign.	0.256	0.000

The regression resulted in a slope of 0.803 and significant at 1 % level while the constant was not significantly different from zero. In addition, an R^2 of 0.85 implies that there is a very good association between the observed and modeled land uses. Therefore, based on only the validation test the models can be used for simulation purposes. (Berger 2001) recommended testing for robustness in cases where the model includes data from informal observations and random-generated synthetic data. In our case we do not have such data types; therefore we have not tested for robustness.

6.4 Simulation Experiments

The modeling framework used here for scenario analysis links agro-ecological and economic data, and takes production and consumption decisions into account, allowing land use and production technology adjustment in accordance with farm household objectives. A validated model can be used as a tool to test a range of experiments called scenarios. Generally, policy debates serve as sources of scenario. The most commonly used policy instruments which are considered in policy analysis are increased infrastructural investment, access to credit, decreasing transaction costs through institutional reforms etc. In the UER of Ghana the growing interest to expand irrigation agriculture and its anticipated effect on welfare and supply of domestic products is of greater policy interest.

The major points of interest to policy makers therefore, will be to identify determinants of irrigation decision and to measure the impact of different policy incentives on different farm groups, such as poor and rich farmers. That is, the efficiency and equity effects of interventions plus the effect of the different interventions on the natural resource base. Econometric models were used to get a general picture of the important determinants of irrigation decision. The result is reported and discussed in detail in Chapter 4. The major factors include access to credit, access to off-farm market and resource endowment. A simple rule of thumb was then used to identify policy experiments from the above factors identified as determinants of irrigation decision. In a rule of thumb approach the most important decision is the determination of the ranges to be used for the policy variables. These ranges need to be realistic in terms of possible policy measures and the applicability of the model. For example, a 100 percent level of fertilizer subsidy will not be a realistic policy scenario in countries like Ghana which are undergoing macro-economic reforms and the state will not be in anyway in a position to supply inputs for free under a normal condition.

6.4.1 Incentives for Irrigation Decision

In this section the impact of policy instruments on the irrigation decision of the subsistence and commercial farm groups is discussed. There is a significant difference between the commercial farm group, which is already engaged in some irrigation activities, and the subsistence farm group, which is not practicing irrigation farming in their response to irrigation incentives. The subsistence farm group, which is characterized by a poor resource endowment, starts engaging in supplementary irrigation in response to incentives like absence of constraint in the off-farm market or a 50 percent increase in credit supply combined with improvement in output prices. That is, since rice is the only crop considered under irrigation improvement in rice price combined with credit access induces the subsistence group to participation in irrigation.

The response of subsistence farmers towards supplementary irrigation suggests the technologies importance to this farm group. Currently the focus of irrigation and rice production is mainly directed towards the dry season activity. But for the subsistence farmers the availability of the supplementary irrigation during the rainy season gives them the possibility of reallocating resources during the rainy season and to continue their off-farm participation during the dry season. Therefore in public irrigation schemes, such as the Tono irrigation schemes, alternatives technologies such as supplementary irrigation need to be sought for smaller farmers in order to keep equity in the community.

Full expansion of irrigation to all rice fields in the study area will not be realistic because of resource and technical limitations. One important implication of the above simulation result is soil and water conservation technologies need to be part and parcel of the development endeavor in the study area. The welfare effect of the household resource allocation decision can be measured by looking at the effect on household consumption level, used here as a proxy for welfare. All the three interventions simulated above resulted in an increase in the consumption level of the subsistence farm group (Table 6.3). In the scenario where farmers do not face any constraint in their off-farm participation the consumption of rice, which is a luxury good for this specific farm group increased by more than 300 percent.

Table 6.3: Percentage change in the consumption level

Crops	No Constraint in off-farm Labor market	50% credit & 15% Paddy price Increase	100% credit & 25% paddy price Increases
Millet	5 %	4 %	5 %
Groundnut	5 %	4 %	5 %
Rice	386 %	6 %	7 %
Beans	7 %	6 %	7 %

On the other hand the commercial farmer's farm plan combines both supplementary and dry season irrigations. Unlike the subsistence farm group the commercial farm group responds to an increase in credit access significantly. The area under irrigation increases as commercial farmer's access to credit increases (Figure 6.1).

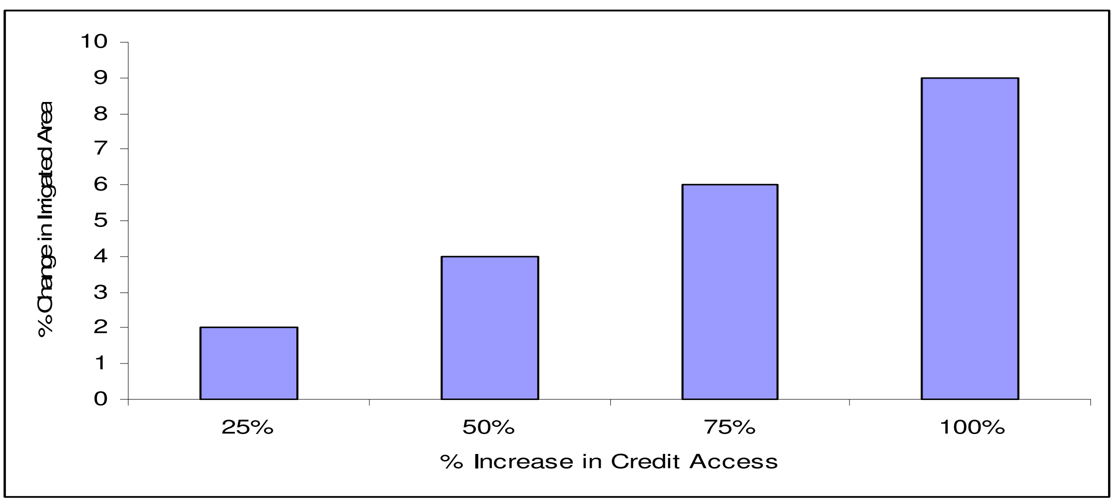


Figure 6.1: Impact of credit access on irrigation by commercial farmers

In the model both irrigated and supplementary lands are acquired through renting from ICOUR and the nominal price of irrigated plots is higher than that of supplementary ones. The commercial farm group responds positively and with multiple implications to a change in the price of supplementary irrigation. As the price of supplementary irrigation decreased there was an increase in supplementary irrigated land while there was a resulting decrease in irrigable land (Figure 6.2). The resulting expansion in the supplementary irrigated area leads to an increase in the marketable surplus.

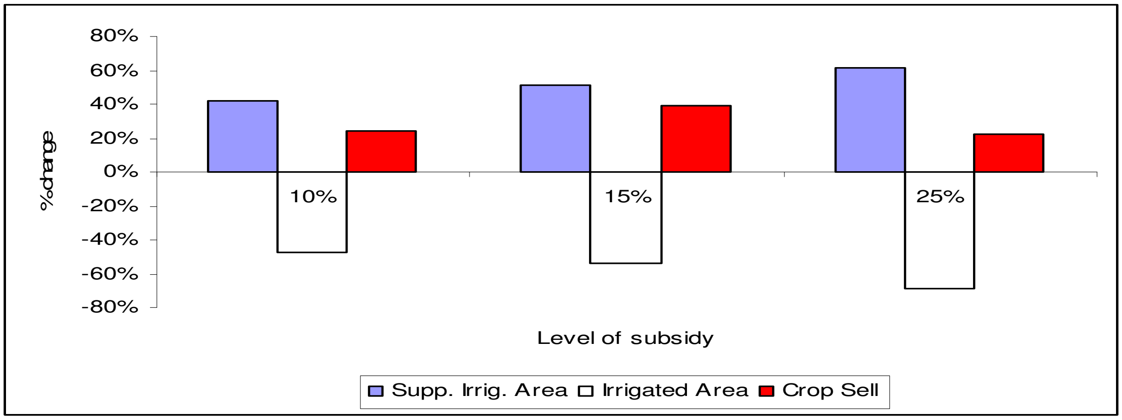


Figure 6.2: The effect of supplementary irrigation subsidy

The positive supply response is particularly interesting for a country like Ghana, where encouraging local production and limiting imports is on top of the economic priority. The complementarity of policy interventions is another important experiment for a policy analysis. A subsidy on irrigation will have more effect when it is accompanied by a relaxation in the credit constraint (Figure 6.3). For example, a 10 percent subsidy on irrigation accompanied by an increase in credit access results in an increasing level of irrigated area. This could be an indication of the importance of agricultural finance in the study group's irrigation decision.

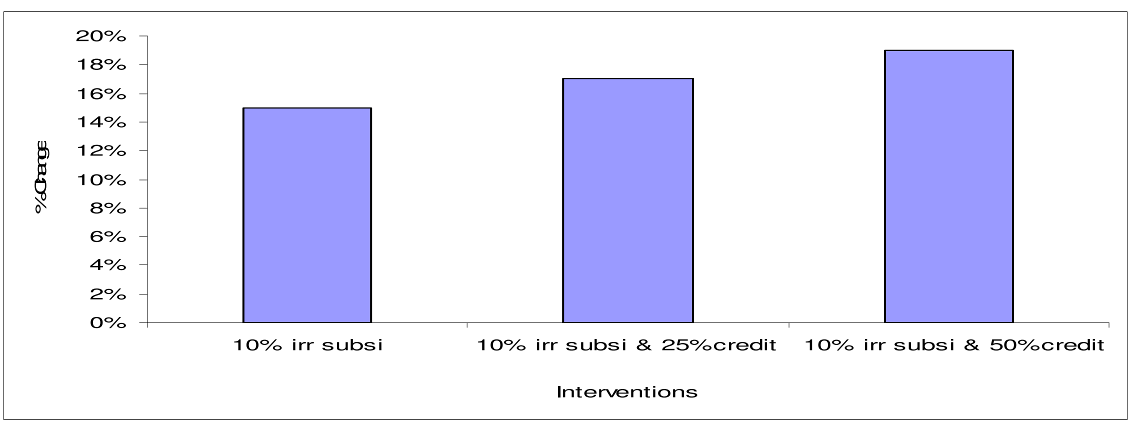


Figure 6.3: Complementarity between credit access and irrigation cost

6.4.2 Credit Access and Labor Market Participation

During the farm survey limited access to financial capital but not the cost of capital was mentioned as a major bottleneck. This observation confirms with a report by the World Bank that there is a huge gap between effective demand for credit and the available loans to the sector (Seini 2002). Though the supply of subsidized credit used to be seen as a rural development strategy other factors such as ease of securing credit, timeliness of loans, transaction costs and collateral requirements are becoming more important in influencing the use of formal credit than the rate of interest charged (Upton 1996).

One of the findings of the econometric analysis in chapter 4 was the relationship between credit and off-farm participation. There is substantial evidence that as farmers' access to formal credit becomes limiting, they resort to alternative sources of finance. Off-farm market participation is one of the most commonly used alternative financial sources (Lamb 2001). In our case, for example the subsistence farm group's demand for credit depends on its level of access to off-farm labor market. When it does not have access to off-farm market but can borrow cash at a rate of 50 percent interest rate it absorbs all the supplied cash, in this case the average currently used cash for the subsistence farm group amounted to 43343 Cedis. On the other hand if the household does not have any restriction in the labor market and can also borrow at a rate of 50 percent then the household depends fully on the labor market and avoid borrowing.

The commercial farm group on the other hand responds differently. This group was already absorbing the lion share of the available credit and is able to profitably utilize additional cash. The commercial farm group due to its capacity to absorb more financial resources engages both in the off-farm labor and credit markets and cash borrowing. It absorbs the whole finance available that is Cedis 312,500 at a 25 percent interest rate. The credit level of 312,500 corresponds to the average credit utilized by the farm group. Interestingly a complementarity between credit and off-farm participation is observed when there is relaxed credit constraint and the farm group is allowed to borrow as much as it can but at 25 percent rate.

Under the base run the commercial farm group participated in off-farm labor market only as a seller and sold 20 man-days of labor every month. However, when the credit constraint is relaxed to the level that the household can borrow without restrictions the commercial farm group participates more in hiring-in of labor than it sold-out. Only in two months within a year it sells labor in the remaining ones it hired-in. The amount of hired labor under unrestricted credit access went up to 700 man-days (Figure 6.4). The implication is that the trickle down linkages of development intervention could be valid policy interventions. That is by encouraging commercialization by few farm households, who could afford to do so, the demand for labor can be raised and employment and income opportunities could be created to farm households that are not directly benefiting from the irrigation interventions. This analysis and scenario output is in line with the findings of (von Braun 1994) where commercialization of vegetable production in Guatemala led to a 45 % increase in employment while commercial rice production in the Gambia led to a 56 % increase in employment.

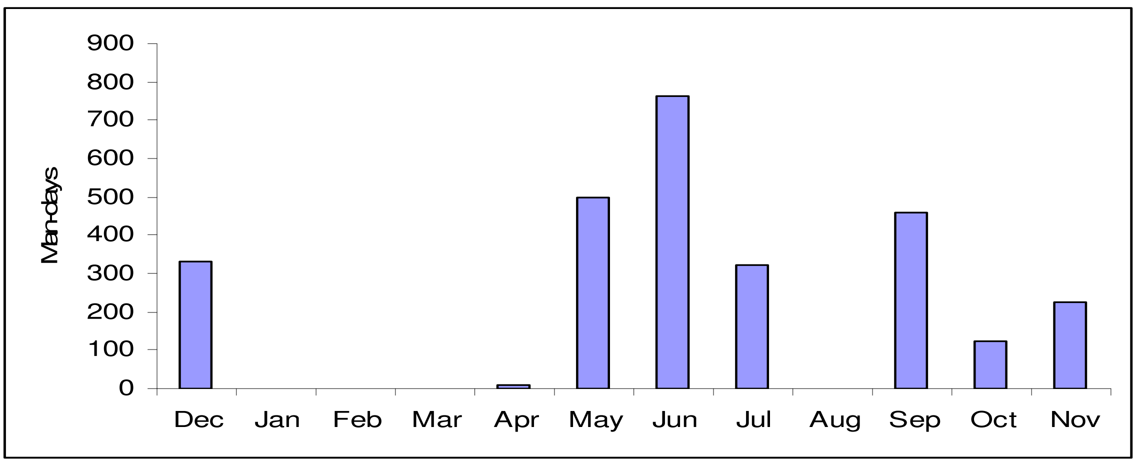


Figure 6.4: Effect of Credit Access on Hiring-in of Labor by Commercial Farmers

The impact of policy interventions, such as credit, on farm household income, household consumption, and labor market participation is observed through their direct effects on household's land use decisions. The effect of different intervention can best be observed through their impacts on the rain-fed land use, because it is the major agricultural activity for the majority of farm households in the study area. (Figure 6.5) illustrates the impact of off-farm labor market participation on subsistence farm household's land use decisions.

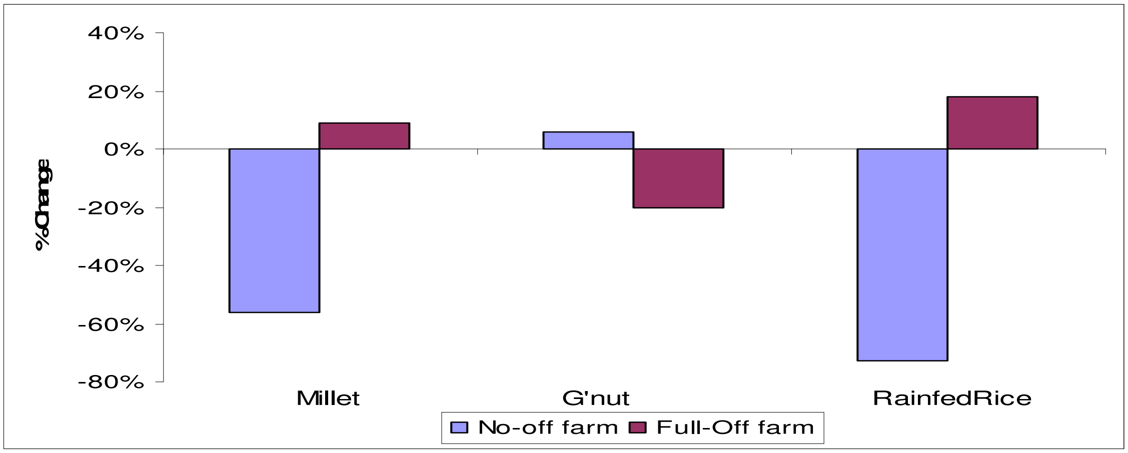


Figure 6.5: Effect of Off-farm Participation on Land Use of Subsistence Farmers

For this group, when there is no off-farm access, the farm group increases area allocated to groundnut, a crop used as a major cash source. On the other hand, the lack of off-farm income leads to a drastic drop in the area of land allocated to both millet and rice in the magnitude of 60 to 80 percents respectively. The major factors for the drop in area allocated to these two cereals is lack of cash for the purchase of seed and hiring of oxen for land preparation. As is indicated in Chapter 3 most farmers in the sample do not have oxen and spend significant proportion of agricultural cash expenditure on hiring in of oxen. Therefore, in the absence of alternative financing a drop in the access to the labor market will further dry out the household source of liquidity.

On the other extreme the relaxation of the off-farm labor market constraint led to an increase in the area allocated to millet and rice and a drop in the area of groundnut. The area allocated to rice in particular increases by a larger proportion than the area allocated to millet. This particular scenario indicates the type of policy interventions required to boost domestic rice production. In general the relationship between off-farm participation and land allocation to cash crops showed the important role of off-farm income in agricultural finance.

Off-farm work particularly during the dry season is an important source of income for the rural farm households in the study area. (Table 6.4) shows simulation result of the impact of access to off-farm labor market on subsistence and commercial farm households' land use and welfare.

Table 6.4: Effect of off farm Market Access

	Commercial Farmers		Subsistence Farmers	
	No-Access	Full-Access	No-Access	Full-Access
Land Use				
Millet	-47%	0%	-56%	9%
G'nut total	-3%	0%	6%	-20%
Rain-fed Rice	0%	0%	-73%	18%
Supplementary Rice	-100%	41%	0%	∞%
Irrigated Rice	59%	-4%	0%	0%
Consumption				
Millet	-22%	9%	-44%	5%
G'nut	-25%	11%	-49%	5%
Rice	-93%	95%	-71%	386%
Beans	-31%	14%	-66%	7%
Income	-42%	35%	-70%	34%

A total absence of off-farm income leads to a significant drop in household income. Income of subsistence farmers dropped by up to 70 percent while that of commercial farmers dropped by about 40 percent. The magnitude of drop in income shows the dependence of both farm groups on off-farm income. The absence of off-farm income has not only led to a drop in cash income but also a drop in the consumption level of both staples such as millet, groundnut and beans and also that of rice. Though the consumption level drops in both groups of farm households the impact was very high on the subsistence farm group. In the case of the commercial farm group a total absence of access to off-farm labor markets leads to a 100 percent and about 50 percent drop in land allocated to supplementary irrigated rice and millet respectively. On the other hand land allocated to rain-fed rice and millet drops by about 70 and 60 percents respectively in the subsistence farm group. A full relaxation of the off-farm labor constraint led to a 20 percent increase in rain-fed rice and the inclusion of supplementary rice in to the farm plan of the subsistence farm group.

On the contrary, an increase in the labor market led to an improvement in the welfare of both of the farm household groups. A lift of labor market restrictions leads to a 35 percent increase in income in both groups. For example, the consumption level of rice, which is a luxury good for the subsistence farm group increases by about 400 percent as a result of full access to the labor market.

6.4.3 Price Experiment

Looking into farm household's supply response is another important policy experiment. In Ghana millions of USD is spent on rice imports, therefore understanding the supply response of producers is a relevant policy exercise. However, experience in sub-Saharan Africa shows that farmers hardly respond to price changes and this makes price policies ineffective tools to promote economic growth and sustainable land use (Delgado et al. 1994). Low supply response is usually related to failures in market infrastructure and associated risks that induce farm households towards income diversification and safety-first strategies (Reardon et al. 1988). Therefore, price experiments need to be undertaken in combination with other structural policies such as credit provision. (Table 6.5) provides the response of the commercial farm group to a price incentive under different credit market conditions.

Table 6.5: The Effect of a 25% Increase in Paddy Price under Different Credit Scenarios

	Existing Credit Condition	With a 25% increase in Credit Access	No limit in Credit Access
Total Rice Area	-18%	-18%	1677%
Rain-fed Rice Area	0%	0%	
Supplementary Rice Area	28%	30%	271%
Irrigated Rice	-77%	-77%	3308%
Rice-consumption	18%	20%	2758%
Income	12%	12%	22%

Under the existing liquidity conditions a 25% increase in paddy price will lead to a 30 percent increase in supplementary rice area and a significant drop in irrigated rice area. However, both the levels of rice consumption and of household cash income show a significant increase. For a normal good like rice consumer theory would predict a decrease in consumption for an increase in price. This is because traditional approach to consumer-demand analysis accounts only for the substitution and income effects of the same change in the price of rice. This is because the substitution effect will lead to a shift to cheaper goods while the increase in price will lead to decrease in real income which will also result in a decrease in consumption. However, an integrated agricultural household model allows for an additional effect-the profit effect, which shows that when the price of rice increases farm profit increases and lead to an increase in consumption (Singh et al. 1986).

6.4.4 Effect of Research and Development

The growing cost of expanding irrigation agriculture and the potential sidelining of the rural poor in irrigation schemes which are operating under cost recovery programs call for the inclusion of yield improvement of traditional crops as a necessary development intervention. Research and development efforts to increase the yield level of traditional crops such as rain-fed rice, millet and groundnut, which are the major crop activities of the poor, were tested to measure their effects on the welfare of the poor. (Figure 6.6) presents simulation results of the effect of a 25 percent increase in the yield of millet, groundnut and rain-fed rice on the consumption and income level of the subsistence farm group.

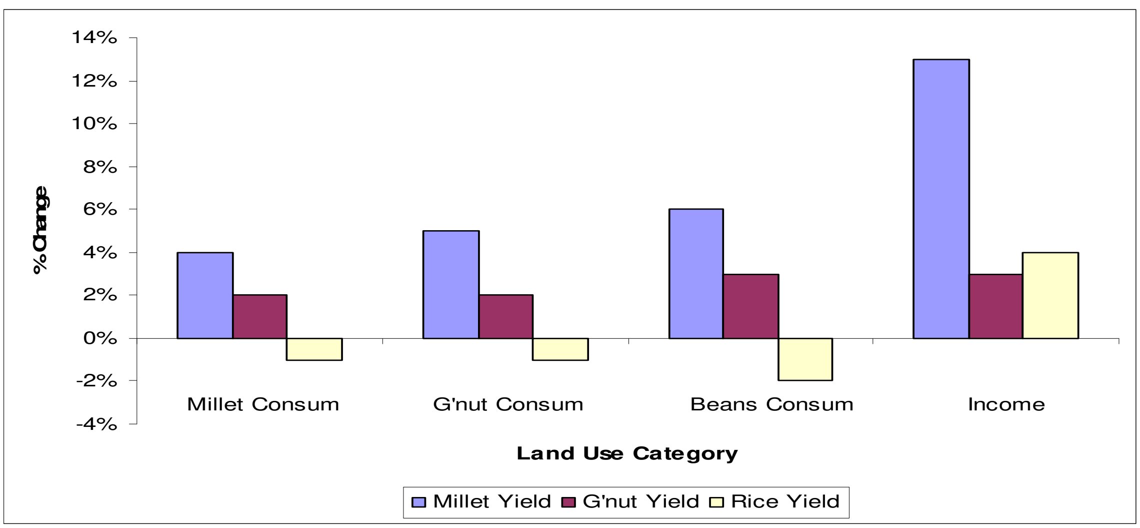


Figure 6.6: Effect of a 25 % Improvement in the Yield of Traditional Crops

In comparison the two traditional crops namely millet and groundnut positively contribute to the consumption of the subsistence farm group than rice. Improvement in millet yield in particular contributes the largest to household consumption of millet, groundnut and beans. Improvement in millet has not only leads to an increased level of consumption but also to a significant increase in income. Given the existing gaps between the potential yield level and farm level yield of major crops the scenario looks like a realistic output (Schreinemachers 2005). Particularly at the moment when direct subsidies for inputs are not affordable and are also politically sensitive policies governments should consider the improvement of traditional crops as a rural development strategy.

7: Summary and Conclusions

7.1 Summary

The performance of the agricultural sector in SSA is the worst among the developing world. The yield level of major crops has either declined or remained where it was decades ago, unable to match the population growth rate. This resulted in an increase in the level of poverty in many parts of SSA particularly in the rural parts of the semi-Arid tropics of West Africa, where the UER of Ghana is located. In the UER of Ghana both bio-physical and socio-economic factors led to increase in the rural poverty levels. The erratic nature of rainfall in particular plays a crucial role by increasing production risk in agriculture. Its impact on agricultural production is both by directly reducing yield and indirectly by limiting the adoption of soil improving and other yield enhancing technologies. Therefore, brining significant increase in crop production and reducing poverty in the semi-arid areas of the UER of Ghana call for a significant technological change in the agricultural sector.

The Green Revolution experience of many Asian countries, which managed to boost agricultural production and curb mass hunger in the 1960s and 1970s, raised the enthusiasm that technological changes can also be powerful tools to reduce poverty in SSA. Irrigation was particularly an important technology that enabled achieving food self sufficiency in Asian and has been seen as a promising development strategy for the semi-arid tropics of northern Ghana, where the UER is located. The expansion of irrigation into the northern regions of Ghana, regions which lie in the semi-arid agro-ecology, was long perceived as a policy strategy to break the evil marriage of poor rainfall condition, low use of agricultural technologies, and low agricultural productivity. In addition to that, irrigation's contribution towards poverty alleviation through the creation of local employment and limiting out-migration was also seen as a solution to the historical migration of the young and able bodied northerners to southern Ghana.

The policy interest of expanding irrigation agriculture as a development strategy in Ghana still plays a crucial role in the country's poverty reduction strategy, where it is pointed out that meeting the country's targets of poverty reduction demand an increase in the total irrigation area by 5000 ha per year to 100,000 ha by the year 2015. However, the increasing interest to expand irrigation services is constrained by the macro-economic conditions which limit the state's capacity to provide irrigation infrastructure and management, agricultural credit and supply complementary inputs such as fertilizer. In addition to that, the increasing demand for water from industry and domestic sectors also limited the supply of water for irrigation agriculture in the semi-arid areas of Ghana.

Relevant information for policy advice on the above discussed irrigation food security linkages in the UER of Ghana is either scant or unavailable. This research work is part of the Federal Government of Germany's funded research on global hydrological cycle in the Volta basin of West Africa, called the GLOWA-Volta project. The GLOWA-Volta project is designed with the core objective of developing a scientifically sound Decision Support System (DSS) for the assessment, sustainable use and development of water resources in the Volta-Basin. This particular sub-project adds to the overall endeavor of the GLOWA-Volta project through its objectives such as: analyzing the determinants of farm household irrigation decisions, developing a modeling tool to analyze policy and technology interventions, and finally analyzing the effects of irrigation technology on household welfare. In order to address these objectives this study raised the following questions: what are the major determinants of irrigation participation in the UER, which structural and price incentives help subsistence farmers to engage in irrigation farming, and what are the impacts of irrigation participation on subsistence farmers?

To this end both primary and secondary data sources were used. The primary data was collected using a standardized questionnaire administered between November, 2003 and January, 2004 on 10 communities within the white-Volta sub-basin of Ghana. A sample of 20 households from each community was interviewed. In addition to the primary household data, key informant interviews were conducted with key experts of the Ministry of Food and Agriculture (MoFA), commercial farmers, Tindans (land priest), chiefs and assembly men. The survey also benefited from farm records kept by some commercial farmers in the Biu community. Finally, a secondary data set from the fourth round of the Ghana Living Standards Survey (GLSS) was used to supplement the household data set.

The data analysis was conducted at two stages. First, a probit model was estimated to identify major determinants of household irrigation decisions. Similarly a Heckman two stage model was estimated to measure the impact of irrigation on household mineral fertilizer use. The econometric model measuring irrigation decisions was based on a theoretical model in which it was shown that in the absence of credit markets household irrigation decisions depend on the cost of irrigation, the level of income from off-farm employment, output price and transaction costs in the output market. The empirical analysis gave special attention to the relationship between irrigation decision and off-farm income. In Ghana as a result of macro-economic reforms, the agricultural sector faced a significant drop in budget, which led to the removal of price supports for major inputs such as mineral fertilizer. With increasing cost of agricultural inputs and lack of agricultural credit, farmers resort to alternative sources of finance such as off-farm income.

Farm households' resource endowment positively and significantly determined irrigation use. The household resources serve as sources of irrigation finance. This implies that in the absence of credit the poor can be marginalized from the use of irrigation technologies. The other finding of this research is that both the absolute family size and off-farm participation had positive effects on irrigation decisions. The positive impact of off-farm labor on irrigation, in spite of the fact that both off-farm and irrigation were undertaken during the same season, implies that they are complimentary activities. Since both irrigation and off-farm income depend on the same family labor pool, in the long term if the credit constraint continues, then they can induce pressure on the family size and lead to increase in family size to meet both demands.

The access to irrigation facilities and markets also had positive impacts on irrigation decisions. This is because irrigation is principally used for the production of cash crops. This implies that, the negative impacts of macro-economic reforms through the reduction of direct agricultural supports, in terms of subsidized inputs, can be undone by investments in infrastructures such as road that decrease transportation and other transaction costs. Therefore, provision of complimentary infrastructural services, such as roads, need to be give due attention during the designing of irrigation projects in rural areas.

Another important finding of this study is access to irrigation significantly and positively affected both fertilizer adoption and amount of fertilizer use per hectare in the study area. The irrigation variable was the most significant variable and its parameter was more than four times the magnitude of most of the other explanatory variables included in the model. This implies that, the risk associated with rainfall variability is important in determining fertilizer use. That is, for the same level of family labor and household farm equipments the probability of fertilizer use varied significantly depending on whether the household was living in communities with irrigation facilities or not. In general, the study showed that the provision of irrigation facilities to farmers in the semi-arid parts of Ghana has multifaceted benefits, one of which is investment in soil improvement, an investment very important for semi-arid areas like the study area.

Though the econometric models provided policy relevant information for a cross section of households, they lack depth in explicitly accounting for the interaction of household production and consumption decisions in determining the household irrigation decisions. To account for this gap a household model that explicitly incorporates farmer's subjective risk evaluation, consumption, production and labor supply decisions under a Safety First framework was developed. The model was calibrated to fit the specific conditions of four representative farm household types, namely Commercial Farmers, Non-Irrigating Labor Selling Farmers, Small Irrigator Farmers and Non-Irrigating Subsistence Farmers. The four representative farm households were identified by using a combination of factor and cluster analyses. A detailed documentation of the mathematical programming model is provided in Chapter 5 of this dissertation.

The household models for the commercial and subsistence groups were validated and used to run selected policy scenarios. The policy experiments that were run with these models included incentives for irrigation, the impact of credit access on household labor market participation, price experiments and the effects of research and development on household welfare. There is a significant difference in the response to irrigation incentives between the commercial farm group, which is already engaged in irrigation activities, and the subsistence farm group, which is not practicing irrigation farming. The subsistence farm group, which is characterized by a poor resource base, started engaging in the supplementary irrigation in response to incentives such as absence of constraints in the off-farm labor market or a 50 percent increase in credit combined with improvements in output prices. That is, since rice was the only crop considered under irrigation in our model, improvement in rice price combined with credit access pushed the subsistence farm group to participate in irrigation.

The decision of subsistence farmers for supplementary irrigation indicates the importance to be attached to this technology. Currently the focus of irrigation agriculture is mainly directed towards the dry season irrigation. The result from this study implied that for the subsistence farmers, the availability of the supplementary irrigation during the rainy season gives them the possibility of reallocating resources during the rainy season and to continue their off-farm labor participation during the dry season. This result is in line with the report by (Brown and Thomas 1990; Postel 1992) where it is pointed out that, the high start-up costs of large surface irrigation in Africa imply alternative source of irrigation such as small scale irrigation and water harvesting have bigger roles to play. Therefore, irrigation scheme need to fully incorporate the supplementary irrigation for the benefit of small-holder farmers and for the sake of equity in the community.

Another important result from this study is that the subsistence farm group's demand for credit depended on its level of access to off-farm labor market. When the group did not have access to the off-farm labor market but could borrow cash even at 50 percent interest rate then it absorbed all the supplied cash of 43,343 Cedis, which is the amount of credit used by the group currently. On the other hand when the household does not face constraints in the labor market and could also borrow at a rate of 50 percent then the household will fully depend on the labor market and avoid borrowing.

On the other hand, the commercial farm group, which was already absorbing the lion share of the available credit, engaged both in the off-farm labor and credit markets. In the base run, the commercial farm group participated in the off-farm labor market only as a seller and sold 20 man-days of labor every month. However, when the credit constraint was relaxed to the level that the household could borrow whatever amount of credit it demanded the commercial farm group participated more in hiring-in of labor than hiring-out.

A scenario in which there is no access to off-farm income opportunities led to a significant drop in household income of both subsistence and commercial farm groups. Income of subsistence farm group dropped by up to 70 percent while that of commercial farm group dropped by about 40 percent. The magnitude of drop in income shows the dependence of both groups on off-farm income. The total lack of access to off-farm income did not only lead to a drop in cash income but also a drop in the consumption level of cereals such as millet, groundnut, beans and rice. Though the consumption level dropped in both groups of farm households, the impact was very high on the subsistence farm group. In the case of the commercial farm group a total lack of access of off-farm income led to a 100 and 50 percent drops in land allocated to supplementary irrigated rice and millet, respectively. On the other hand, in the case of subsistence farmers land allocated to rain-fed rice and millet dropped by about 70 and 60 percents respectively. A full relaxation of the off-farm labor constraint led to a 20 percent increase in rain-fed rice and also the inclusion of supplementary rice in to the farm plan of the subsistence farm group.

The growing cost of expanding irrigation agriculture and the sidelining of the rural poor in irrigation schemes which are operating under cost recovery programs call for the inclusion of yield improvement of traditional crops as a necessary development intervention. Research and development efforts to increase the yield levels of traditional crops such as rain-fed rice, millet and groundnut, which are the major crop activities of the poor, were simulated to see their effect on the welfare of the poor. Improvement in millet yield in particular contributed the largest to household consumption of millet, groundnut and beans and also to a significant increase in income. Given the existing gaps between the potential and farm level yields of major crops the scenario looks a realistic output. Particularly at the moment when direct subsidies for inputs are not affordable and are also politically sensitive policies, governments can look into politically correct strategies such as research and development.

7.2 Conclusions and Implications

The following conclusions and implications were drawn from this study. First, there is still strong policy interest to expand irrigation agriculture in Ghana as a strategy to increase self-sufficiency in imported goods such as rice. In this study it was found out that rice has a large income elasticity, which implies that with growing income and urbanization there is a growing demand for rice. The limit, to which agricultural area can be expanded, particularly in the semi-arid agro-ecologies, and the potential pressure on hard currency from meeting increasing demands with imports, call for increased intensive farming. Therefore, there is indisputable role for irrigation agriculture to play in boosting local production and fighting poverty in the semi-arid tropics of Ghana.

Second, with increasing cost of agricultural inputs and lack of agricultural credit, farmers resort to alternative sources to finance agricultural investments. The use of income generated from off-farm labor market is one common source. Both family size and off-farm participation had positive effects on household irrigation decisions. The positive effect of off-farm labor on irrigation, in spite of the fact that both are undertaken during the same season, implies that they are complimentary activities. The complementarity can lead to increased pressure on household labor pool if households maintain their dependence on off-farm income to finance agricultural investment such as irrigation.

Third, this study found out that household resource endowments such as farm-equipments, total operated land significantly determine irrigation decisions. This implies that the household resources serve as sources of irrigation finance. Resource endowments particularly farm equipments determine a household's ability to prepare land for irrigation and also to dig out water, in cases where dugouts and hand dug wells are sources of irrigation water. From the different sources of irrigation, the better off farmers engage in the bigger irrigation schemes where agricultural production is at a larger scale and is mainly for the market. The majority of the poor either engages in off-farm labor market or do garden irrigation using hand dug wells. This implies that the existing irrigation systems marginalize the poor. Therefore, policy measures which increase the direct and indirect benefits of the poor from irrigation services need to be sought.

Fourth, irrigation expansion in addition to its direct effect can indirectly boost agricultural production by decreasing the risk of mineral fertilizer use. Semi-arid areas like the study area are known for their poor soil quality; however, in spite of this fact the use of mineral fertilizers is limited. The major factor for the low use of mineral fertilizers being the risk associated with rainfall variability in these areas. Irrigation can play a central role by limiting the risk associated with rainfall variability. In this study the risk reduction role of irrigation can be seen from the finding that irrigating farmers use more mineral fertilizers than non-irrigating ones. Therefore, policies to expand irrigation in these areas need to duly value this indirect but important role of irrigation technology.

Fifth, farm households in the study area differ in many aspects and respond to policy and technology interventions accordingly. The policy simulations conducted in this study indicated a marked difference between subsistence farmers and commercial farmers in their response to policy interventions. At least two conclusions can be drawn from this difference in response. The first one is, policy makers need to account for differences in farm households when they design and implement policy interventions. Lack of doing so can result in unintended outcomes such as increasing inequity in a society. The second conclusion is that, there is a potential spill over effect of irrigation use by commercial farmers on subsistence farmers, through commercial farmers increased demand for agricultural labor which can be supplied by the subsistence farmers.

Sixth, currently the discussion on irrigation agriculture is solely focused on the dry season activity. However, results from this study indicated that for the subsistence farmers in particular the availability of supplementary irrigation during the rainy season is an opportunity to be exploited. Two policy relevant implications can be drawn from this result. The first one is irrigation schemes need to fully incorporate the supplementary irrigation opportunity in their planning. The second implication of this result is in the study area soil and water conservation technologies that can increase availability of soil moisture during the rainy season could play an important role. This is because, soil and water conservation interventions play a role of increasing soil moisture which is similar to what a supplementary irrigation does.

Seventh, the growing cost of expanding irrigation agriculture and the sidelining of the rural poor in irrigation schemes, which are operating under cost recovery programs, call for the inclusion of alternative strategies in the intervention package. One such intervention is capitalizing on the existing yield gap between potential and observed yield levels of major traditional crops. Particularly at the moment when direct subsidies for inputs are not affordable and are also politically sensitive policies, the government can look into politically correct strategies such as research and development.

7.3 Insights for Future Policy and Research Directions

- In order to alleviate poverty through the expansion of irrigation agriculture at the local level and boost national crop production different mechanisms of agricultural finance such as the provision of formal credit and increasing the input delivery system need to be boosted.
- Any effort to increase off-farm income as a source of agricultural finance need to account for the potential pressure on household labor.
- The current research focused only on irrigation farming on medium scale irrigation schemes. Future research need to be undertaken to fully account the contribution of other forms of irrigation such as hand-dug wells, micro dams etc in the country's food security endeavor.
- Farm households vary significantly in their resource endowments and their response to policy and technological interventions, therefore policy incentives need to be tested for their efficiency and equity effect by accounting for these differences across farm households.
- Finally, though accounting for risk in farm household modeling in the semi-arid tropics of northern Ghana is a must to do thing lack of time series data limited the quality of output of this study. The elicitation of subjective evaluation of states of nature and the conditional performance of different production activities was

taken as a strategy to fill the data gap. However, this strategy suffers form long recall periods and a simple guess by respondents, who do not have the experience of keeping farming records. Therefore, research interested in modeling farm household decision need to invest much resource in collecting quality data.

- One other limitation of this study is, it did not account the dynamic process in decision making and the impact of interaction among economic agents. Multi Agent models could be potential tools to address the effect of interactions among economic agents on each agent's decision.

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Annex 1: Descriptive Statistics of the Four Clusters

	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Total
Observation	14	28	52	102	196
HH has irrigated	1	0	1	0	0
Dist. Irrig km	5.77	10.36	4.20	7.75	7.04
HH near irrigation project	0.93	0.00	0.65	0.10	0.29
Irrigated land in hec.	4.15	0.00	0.74	0.00	0.49
Land in hec.	7.38	3.36	3.03	2.06	2.88
Family Size (#)	6.4	12.5	8.5	6.1	7.7
Family labo (ME)r	4.20	8.81	6.02	4.26	5.37
No.of Male < 15	1.64	2.21	1.62	1.01	1.39
No. Of Female < 15	1.5	2.18	1.42	1.44	1.55
No. of Adult male	1.29	3.14	2.35	1.57	1.98
No. of Adult female	1.64	4.14	2.65	1.66	2.28
No. Of Male > 50	0.21	0.57	0.27	0.28	0.32
No. Of Female > 50	0.07	0.29	0.19	0.19	0.19
No. Of Male Off Farm	0.21	0.75	0.48	0.35	0.43
No. Of Female Off Farm	0.71	1.25	0.81	0.28	0.59
Livestock in Million Cedis	22	7.5	6.8	2.9	6
Farm equipment in Million Cedis	1.5	0.3	0.4	0.08	0.3
Credit in 000 Cedis	312.5	14.3	134.	43.3	82.5
HH Head Education	1.7	1.4	1.4	1.3	1.4
Cluster Identification	Commercial Farmer	Non-irrigating Labor Selling	Small Irrigators	Non-irrigating Subsistence	

Annex 2: Area Coverage of Major Crops across Clusters

	Cluster 1		Cluster 2		Cluster 3		Cluster 4	
Crop	Area	%	Area	%	Area	%	Area	%
Millet	1.39	21%	1.38	50%	1.04	40%	0.91	52%
Guinea corn	0.06	1%	0.14	5%	0.01	0%	0.03	2%
Groundnut Total	0.85	13%	0.85	31%	0.74	29%	0.56	32%
cpd. sole	0.03		0.14		0.04		0.04	
Bush sole	0.03		0.04		0.05		0.04	
cpd. Gnut-bam	0.46		0.37		0.18		0.31	
bush Gnut-bam	0.33		0.2		0.47		0.17	
Rice	3.18	48%	0.33	12%	0.64	25%	0.2	11%
Irrigated	1.43		0		0.3		0	
Rain-fed	0.15		0.33		0.12		0.2	
Supplementary	1.6		0		0.22		0	
Others	1.08	16%	0.07	3%	0.15	6%	0.06	3%
Soybean	0.62	9%	0.06	2%	0.12	5%	0.04	2%
Maize	0.46	7%	0.01	0%	0.03	1%	0.02	1%
Total	6.56		2.77		2.58		1.76	

Annex 3: Descriptive Statistics of Variables used in the logit estimation

Variable	Mean	Std. Dev	Minimum	Maximum
SEXHEAD	0.85	0.36	0	1
AGEHEAD	44.87	13.97	15	82
EDUDUMY	0.22	0.41	0	1
PROPOFF	0.19	0.19	0	1
FAMLAB	5.42	3.08	1	20.95
IRRIVILA	0.29	0.46	0	1
DISTMKT	4.4	4.25	0.2	40
DISTROAD	1.7	2.08	0	15
LNFARMEQ	11.4	1.39	8.52	15.39
CREDIT	11.21	48.3	0	580

Source: 2003/2004 UER Own Survey

Annex 4: 2004 Dry Season ICOUR Service Charges

1. Irrigation Levy	Cedis per Unit
Rice	312,500 / ha
Tomato	422,500 / ha
Other Crops	211,250 / ha
2. Mechanical Levy	
Plough	350,000 / ha
Harrow	175,000 / ha
Ridge	236,500 / ha
Rotovation	550,000 / ha
Wet Level	375,000 / ha
Slashing	225,000 / ha
Dry Level	165,000 / ha
Crawler Combine	700,000 / ha
2-Wheel Combine	560, 000 / ha
Tractor & Equipment hire	862, 000 / day

Source: ICOUR Notice Board, Navrongo, December 22, 2003.

Annex 5: Restricted Normalized Quadratic Estimate of Rice Production Function

	Irrigation		Suppl. Irrigation		Rain-fed	
Variables	Estimates	t-values	Estimates	t-values	Estimates	t-values
Labor	0.00	0.00	0.00	0.00	0.41	0.30
Fertilizer	7.49	0.51	21.17	0.39		
Seed	8.22	0.90	2.70	0.05	0.08	0.02
Lab2	0.00	0.00	0.00	0.00	0.00	0.00
Fert2	-0.02	-0.16	-0.04	-0.15		
Seed2	0.01	0.25	-0.01	-0.06	0.04	1.06
Lab*Fert	0.00	0.00	0.00	0.00		
Lab*Seed	0.00	0.00	0.00	0.00	0.00	0.00
Fert*Seed	0.03	0.28	0.05	0.12		
Tractor	654.06	1.19	1072.09	0.47	244.18	1.19
Constant	116.79	0.07	-863.62	-0.11	419.26	2.30
F-stat	7.29****		0.40		4.37****	
R-squr	0.65		0.14		0.31	
Observations	51		36		65	

Source: Own Computation; **** Significant at 5 % level

Annex 6: Unrestricted Normalized Quadratic Estimate of Rice Production Function

	Irrigation		Suppl. Irrigation		Rain-fed	
Variables	Estimates	t-values	Estimates	t-values	Estimates	t-values
Labor	13.22	1.05	20.68	0.39	2.49	1.92
Fertilizer	1.71	0.12	46.59	0.87		
Seed	8.37	0.97	38.88	0.79	0.94	0.27
Lab2	-0.07	-1.23	0.02	0.06	-0.01	-2.42
Fert2	-0.01	-0.10	-0.06	-0.26		
Seed2	0.06	1.59	-0.12	-0.87	0.01	0.20
Lab*Fert	0.07	0.98	-0.23	-0.48		
Lab*Seed	-0.11	-1.64	-0.12	-0.34	0.02	1.19
Fert*Seed	0.02	0.24	-0.04	-0.09		
Tractor	823.22	1.59	1220.65	0.55	165.22	0.85
Constant	-440.96	-0.30	-6517.79	-0.89	220.95	1.28
F-stat	8.63****		0.55		5.89****	
R-squr	0.68		0.18		0.38	
Observations	51		36		65	

Source: Own Computation; **** Significant at 5 % level

Annex 7: Yield Level of Major Production Activities (Kg/ha)

Activities	Plot	Early Millet	Late Millet	Guinea-corn/	Beans	Groundnut	Bambara-beans	Gross Margin (‘000 Cedis/he)
Em-Lm (50,50) Early	Compound	327	286					456.6
Em-Lm (50, 50) Late	Compound	330	208					395.6
Em-Gc (50,50) Early	Compound	327		252				403.5
Em-Gc (50,50) Late	Compound	216		271				328.2
Gc-Em-Lm (40,30,30) Early	Compound	223	225	393				575.9
Gc-Em-Lm (40,30,30) Late	Compound	136	161	174				325.4
Lm-Em-Be (50,40,10) Early	Compound	309	361		113			620.3
Lm-Em-Be (50,40,10) Late	Compound	359	526		272			965.8
Em -Gc-Be (50,40,10) Early	Compound	244		353	69			476
Em -Gc-Be (50,40,10) Late	Compound	247		392	92			530.9
Em-Gc-Lm-Be (40,30,20,10) Early	Compound	352	197	492	65			789.8
Em-Gc-Lm-Be (40,30,20,10) Late	Compound	171	115	230	79			450.4
Gn (100)	Compound					684		958.5
Gn-Ba (70,30)	Compound					635	221	1119.2
Gn-Ba (90,10) Male	Compound					722	212	1236.0
Gn-Ba (90,10) Female	Compound					527	121	888.3
Gn-Be-Ba	Compound				76	566	120	1026.5
Lm-Be (90,10) Early	Bush		396		136			245.3
Lm-Be (90,10) Late	Bush		269		83			89.6
Gn (100) Male plot	Bush					1346		1733.1
Gn (100) Female plot	Bush					684		840.2
Gn-Ba (70,30)	Bush					513	280	814.5
Gn-Ba (90,10) Male plot	Bush					654	181	868.5
Gn-Ba (90,10) Female plot	Bush					965	209	1484.9

Annex 8: Output prices (Cedis/ Kg)

Items	Prices
Millet	770
Guinea-Corn	660
Beans	1150
Groundnut	1620
Bambara-bean	1150
Paddy Rice	1430

Annex 9: Input Prices

Items	Units	Prices
Fertilizer	Cedis/ Kg	3000
Tractor	Cedis/ Ha	350,000
Bullock	Cedis/ Ha	200,000
Dry Season Rice Irrigation levy	Cedis/ Ha	312,500
Rainy Season Rice Irrigation levy	Cedis/ Ha	252,170
Wage Rate	Cedis/ Man-Days	15,000

Annex 10: Parameters Used in the Programming

Items	Cluster 1	Cluster 4
Interest Rate	25%	50%
Reservation Wage	50% of Market Wage	0
Available own fund	10% of Household Asset	10% of Household Asset
Farm Fixed Cost	25% of Household Asset	25% of Household Asset
Income Goal	10% of Household Asset	10% of Household Asset

Annex 11: Labor Calendar

Items	Units	Dry Season	Rainy Season
Hours Worked- Male	hrs	5.1	5.1
- Female	hrs	5.1	3.7
No. of Days worked	No.	5	5

Annex 12: Cropping Calendar of UER of Ghana

Months	*Season*	*Major Activities*
January	Dry	Fertilization / Land Preparation and Planting
February	Dry	Weeding & Fertilization & Planting
March	Dry	Weeding
April	Dry/Rainy	Harvest/Land Preparation
May	Dry/Rainy	Harvest/Land Preparation
June	Rainy	Land Preparation
July	Rainy	Land Preparation/ Fertilization & Weeding
August	Rainy	Fertilization & Weeding
September	Rainy	Harvesting
October	Rainy	Harvesting
November	Rainy	Harvesting
December	Dry/Rainy	Land Preparation/ Harvesting

Annex 13: The Lower Partial Moment

Practically speaking most decision makers would like to avoid down side risks and care little to upper side deviations. A down side risk can be captured by accounting for only part of the variance here referred to as semi-variance (Markowiz 1970). The mean semi-variance can be defined as:

$$\sigma^{2-} = \int_{-\infty}^{\mu} (\mu - x)^2 f(x)dx$$

Where σ^{2-} is the population mean's semi-variance, μ is the population mean and *f(x)* is a probability density function (PDF). The implication of this semi-variance mean parameter is that decision makers are concerned only with the negative deviation of income from mean. But if the reference level of income used to measure deviation is a value different from the mean, say for example the minimum income required to meet certain demands, the Markowitz's mean semi-variance parameter will not be of use. (Porter 1974) introduced a different parameter similar to the Markowitz's but which uses a value different from the mean and the parameter is called a fixed-reference-point semi-variance parameter, which is:

$$\rho(2,t) = \int_{-\infty}^{t} (t-x)^2 f(x)dx$$

Where ρ(2,t) is the fixed-reference point semi-variance and *t* is a fixed risk reference level of income. (Fishburn 1977) introduced a more general form of the LPM, which is defined as:

$$\rho(\alpha,t) = \int_{-\infty}^{t} (t-x)^{\alpha} f(x)dx$$

Where ρ(α,t) is a LPM, *t* is a risk reference level of income, and α is a constant ≥0. Fishburn proved that a model which examines a tradeoff between μ and ρ(α,t) would generate solutions which were a subset of the second-degree stochastically dominant set if α≥1 (Atwood 1985).

All the LPM parameters introduced so far require knowledge of the probability of goal achievement failure. However, the exact probabilities can only be obtained with knowledge of the CDF or the PDF of income, knowledge which is frequently not available. The most commonly used approach therefore, is to use a distribution free general inequality, such as Chebyshev's inequality to calculate upper limit on the probability of goal failure. The use of general inequalities usually requires only the knowledge of certain parameters, such as mean and variance, to estimate upper limits. However, the upper limits which result will generally be considered overestimations of the actual probabilities of interest.

General inequality suggested by (Fishburn 1977) has the potential to narrow the conservativeness of Cheybshev probability limits. The use of absolute deviation parameters in the general inequality results frequently in more accurate probability limits than squared parameters.

Cheybshev Inequality

$$pr(|x-\mu| \geq k\sigma) \leq 1/k^2$$

Where k is some constant and σ is the standard error. This means that, with any PDF the probability of income falling more than k standard errors from the mean is less than the inverse of k^2. For example the probability of income falling more than two standard errors below the mean will be less than 0.25 ($1/2^2$).

(Berck and Hihn 1982) introduced an inequality which offers significant potential to provide less conservative probability limits than Chebychev's inequality. Their inequality utilizes the population mean and negative mean semivariance. The inequality is:

$$pr(x \le \mu - m\sigma^{-}) \le 1/m^2$$

Where μ is the population mean, σ^{-} is the semistandard error, and m is some constant greater than zero. It places an upper limit of $1/m^2$ on the probability of income falling more than m standard errors **below** the mean. This limit may be less than that calculated by the Cheybchev inequality if the population is asymmetric. Berck and Hihn's inequality is a special case of the following general inequality.

$$pr\left[x \le t - p\theta(\alpha,t)\right] \le 1/p^{\alpha}$$

Where t is a reference level of income, θ(α,t) is the positive α^{th} root (with α strictly >0) of Fishburn's LPM ρ(α,t) and p is a constant greater than zero. This probability places an upper limit on the probability of x falling more than p θ(α,t) units below t.

$\theta(\alpha,t) = \left[\rho(\alpha,t)\right]^{1/\alpha}$ & θ (α,t)≥0. If p>0 then,

$$t - p\theta(\alpha,t) \le g.$$

$$\rho(\alpha,t) = \int_{-\infty}^{t} (t-x)^{\alpha} f(x)dx = \int_{-\infty}^{t-p\theta(\alpha,t)} (t-x)^{\alpha} f(x)dx + \int_{t-p\theta(\alpha,t)}^{t} (t-x)^{\alpha} f(x)dx$$

This implies that since

$$\int_{t-p\theta(\alpha,t)}^{t} (t-x)^{\alpha} f(x)dx \ge 0, \text{ then}$$

$$\rho(\alpha,t) \geq \int_{-\infty}^{t-p\theta(\alpha,t)} (t-x)^{\alpha} f(x)dx.$$

Over the interval [-∞,t-pθ(α,t)] the expression $(t-x)^{\alpha} \geq p^{\alpha}\rho(\alpha,t)$ holds (Atwood 1985). Thus, the term $p^{\alpha}\rho(\alpha,t)$ can replace $(t-x)^{\alpha}$ in:

$$\rho(\alpha,t) \geq \int_{-\infty}^{t-p\theta(\alpha,t)} p^{\alpha}\rho(\alpha,t) f(x)dx$$

$$\rho(\alpha,t) \geq p^{\alpha}\rho(\alpha,t) \int_{-\infty}^{t-p\theta(\alpha,t)} f(x)dx$$

The integral $\int_{-\infty}^{t-p\theta(\alpha,t)} f(x)dx$ is the probability that *x* falls below t-pθ(α,t). After some rearrangement the above equation will yield:

$$pr[x \leq t - p\theta(\alpha,t)] \leq 1/p^{\alpha}$$

This inequality effectively places an upper limit on

$pr(x \leq g) = pr[x \leq t - p\theta(\alpha,t)]$ with

$g = t - p\theta(\alpha,t)$ and $p = (t-g)/\theta(\alpha,t)$.

Selection of some level of *t* between *g* and μ will often result in probability limits that are closer to the actual probability than both Chebychev's and Berck and Hihn's parameters. In addition, the choice of α=1 will often result in lower probability limits than setting α=2. Should α=1, the inequality is expressed in terms of absolute deviations below *t*. An interesting sidenote is that since the mean does not enter in the above proof, there is no requirement that the mean, variance, or semivariance of the distribution exists. However, it requires that ρ(α,t) exists and is finite.

But the arbitrary selection of the appropriate level of *t* will be difficult in applied research. (Atwood 1985) showed that, should the level of t chosen be too close to either g or μ the probability limit provided by the generalized LPM will be conservative than Chebychev's and Berck and Hihn's parameters. Therefore, choosing the level of t is an important element. However, identifying the level of t exogenously without complete knowledge of the underlying distribution will be impossible.

Annex 14: Questionnaire for Subjective Rainfall Evaluation

1. Rainfall Variability Question:

1.1How was the rainfall condition this year? **1**. Good **2**. Normal **3**. Bad

1.2 For this locality, when is a rainfall condition referred as bad season/ year?

1. When the rain comes very late,

2. When the rain stops very early,

3. When there is long dry spell between June & July,

4. When the annual rainfall is very low,

5. When the annual rainfall is very high.

1.3 Subjective probability: Between the periods 1990 and 2000, how many years were Good, Normal and Bad?

Rainfall Condition	Number of Years	Which year is a typical example of the condition?
1. Good		
2. Normal		
3.Bad		
Total	10	

1.4 Subjective probability: What is your expectation of rainfall for the coming 10 years 2004 to 2014, how many years will you expect to be Good, Normal and Bad?

Rainfall Condition	Number of Years
1.Good	
2. Normal	
3. Bad	
Total	10

1.5 How is the variation in yield across the different rainfall conditions?
Yield of Major Crops (Mini bag/
Acre)

Major Crops	Seed Type	Rainfall Condition		
		1. Good	2. Normal	3. Bad
Early Millet	Local seed			
	Improved Seed			
Late Millet	Local seed			
	Improved Seed			
Rice	Local seed			
	Improved Seed			
Groundnut	Local seed			
	Improved Seed			
Guinea Corn	Local seed			
	Improved Seed			

1.6 How is the variation in yield across the different rainfall conditions, on the irrigated fields?
Yield of Major Crops (Mini bag/
Acre)

Major Crops	Seed Type	Rainfall Condition		
		1. Good	2. Normal	3. Bad
Rice	Local seed			
	Improved Seed			