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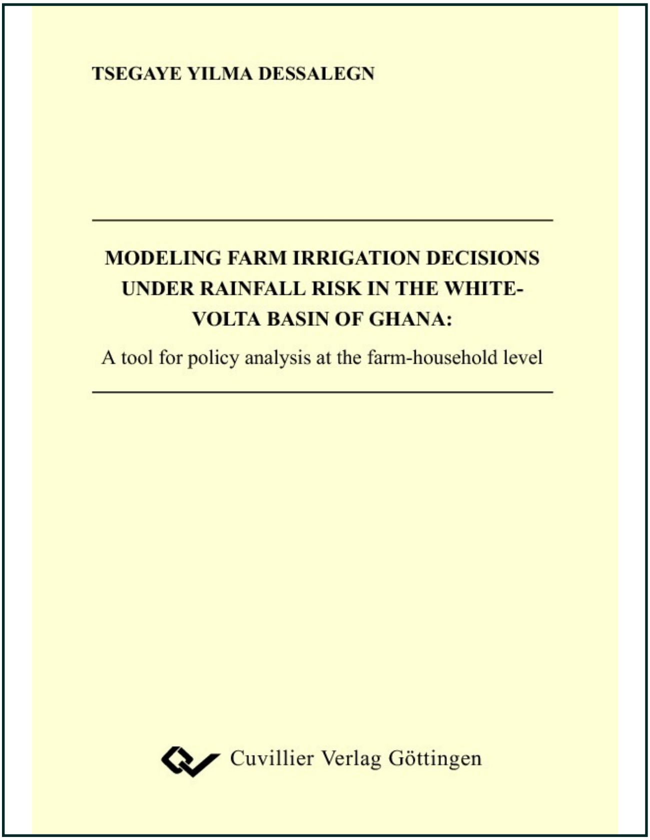
A tool for policy analysis at the farm-household level



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

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Cuvillier Verlag Göttingen

https://cuvillier.de/de/shop/publications/2154

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 their poverty status. 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 a rural based poverty alleviation strategy, the dependence of the agricultural sector on traditional technologies provides 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 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) was 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 when 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.

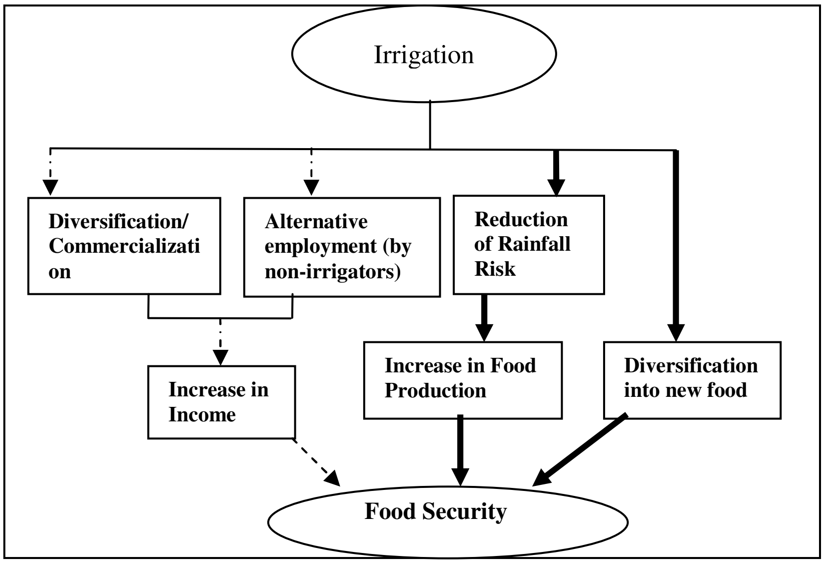


Diagram 1: Schematic Representation of Irrigation and Food Security Linkage

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 (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 benefits of irrigation in SSA.

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).

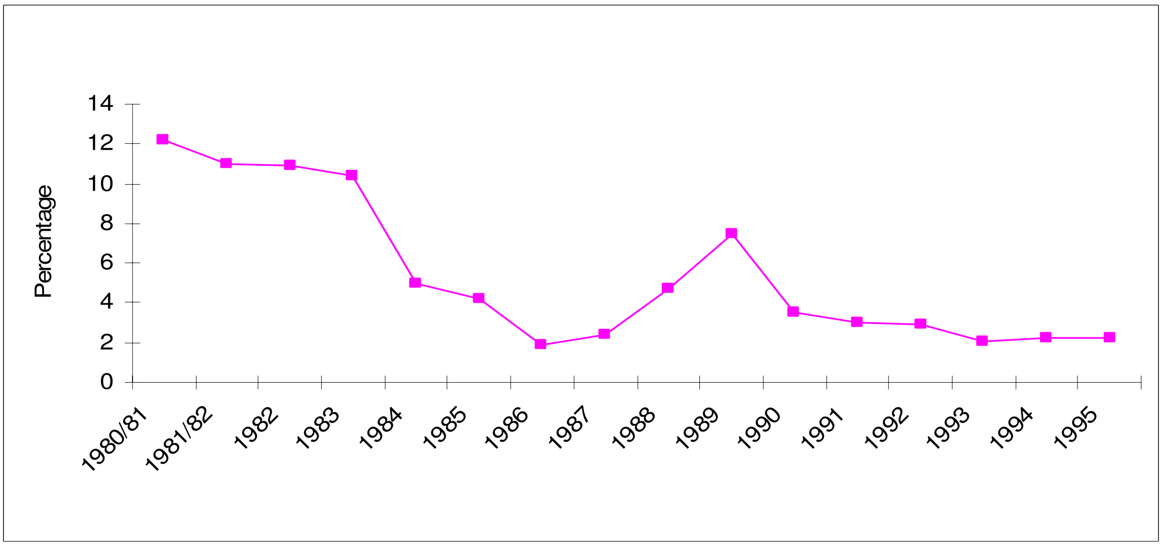
Even today, the increasing gap between local production and demand for cereals like rice keeps irrigation expansion as a core strategy in Ghana's rural development endeavors. Ghana's poverty reduction strategy stressed that in order to meet the country's targets the total irrigation area need to be increased 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 in 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. Consequently, there is immense interest both from policy and research to understand the economic drives behind farm household irrigation decisions. However, 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 and other associated costs such as output market support. 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).

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 reforms also led to the 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 and services.

[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.

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).



Source: (Nyanteng and Dapaah 1997)

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

Internationally too, the financial constraint on irrigation development has become more and more binding as 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 cost of irrigation and ultimately on farm households' irrigation decisions, the contribution of irrigation agriculture to food security and poverty alleviation. Therefore, it is imperative to analyze the farm household level irrigation decisions in the UER of Ghana.

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2 This ratio measures the Kg. of rice required to purchase one Kg. of fertilizer.

1.2.1 Objectives of the study

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 household's welfare?

1.2.3 Central Hypothesis

Given the need for a wider use of irrigation technology in semi-arid regions like the White Volta Basin of Ghana and the existing constraint in the credit market, therefore the following hypotheses were put for test:

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

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

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 tries to lay ground for efforts made to address the research questions.

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

Chapter 4 presents a theoretical model developed to capture irrigation decision under the assumption of credit market constraint and a working labor market. The chapter continues by empirically testing 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 serve as bases for the identification of policy instruments, which were later 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 incorporated into a linear programming framework can be used to account for perceived rainfall risk.

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.

One important demographic feature in the study area is the migration of labor to the southern part of Ghana and the most important pattern is seasonal migration of labor during the dry seasons. 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 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 and unit of analysis in this study. However, hereafter for the sake of simplicity the term household will be used in this study whenever reference is made to the micro-households.

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. In some communities in the absence of a husband the eldest son, who could be less than 15 years old, is considered by the society as a head. Theoretically, he can make decisions which include selling out farm products without the consent of his mother.

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.