

Small-Scale Irrigation, Farm Income and Access to Essential Services in the Busa Community of the Upper West Region of Ghana

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Abstract

The worsening poverty situation in the Upper West Region of Ghana coupled with the risky nature of farming due to the joint impacts of rain-fed dependence and minimal use of irrigation in Ghana called for the need to examine small-scale irrigation usage and its effect on farmers' income and access to essential services. The study was carried out in Busa where 300 farmers were randomly sampled. The Conditional Recursive Mixed-Processes (CRMP) was used to estimate two Probit and a multiple linear regression models. The study revealed that market information and participation as well as input cost affected farmers' decision to use irrigation. Also, irrigation usage, market participation and price information, capital invested and institutional support had significant effects on farm income. However, occupation, farmers' educational attainment and incomes were the significant determinants of access-to-essential services in this area. Hence, irrigation is relevant to promoting farm income in the area since its use translate into increased income. Farmers in the area would minimize production costs and risks when encouraged or motivated to initiate or participate in small-scale irrigation since such schemes are not cost and technically intensive.

Keywords: Access to Essential Services, Conditional Recursive Mixed-Processes, Farm Income, Regression, Small-Scale Irrigation

Introduction

Irrigation originated as a method for improving agricultural production by increasing the productivity of available land and expanding total farm output especially in arid and semi-arid regions. Globally, irrigated areas almost doubled over the past 50 years from 161 million hectares (ha) in 1961 to 318 million ha in 2010 (FAOSTAT, 2013). In the developing world, Asia has the largest share of irrigated land with 41% of the total cultivated area being equipped with irrigation; Latin America ranks second, with 6.7% of cultivated area irrigated; and Africa being last, with only 5% of cultivated area under

irrigation (FAO, 2011). Agriculture in Ghana is predominantly practiced on smallholder and family-operated bases, which produce about 80% of total agricultural output. It is estimated that about 90% of farms are on smallholder basis (less than 2 hectares in size) and the few large farms are either plantations of cash crops such as rubber, oil palm and coconut or to a lesser degree, maize, rice and pineapples (MOFA, 2013). As such cultivatable land is still available as only 55.9% of total agricultural land area is currently cultivated in Ghana (MOFA, 2012). Also, agriculture in Ghana is mainly rain-fed with minimal use of irrigation despite the constraints associated with reliance on rain for farming. MOFA (2012) indicated that only about 0.4% of agricultural land under cultivation was under irrigation amidst rains that are quite erratic and highly unpredictable. These erratic patterns and the limited capacity of the Ghana Meteorological Service to forecast rains with accuracy made agriculture a very risky sector to invest in Ghana.

In the Upper West Region, several environmental conditions prevail which make irrigation the issue of irrigation in the region quite important. The relatively, high temperature with a long term mean annual temperature reaching 27.2°C and with about 35.5°C and 18.8°C for the mean maximum and minimum respectively easily causes loss in soil moisture and death of other soil organisms. Also, the scattered trees and sparse vegetation cover of grasses aggravate this situation. Human activities such as bush fires, the felling of trees for fuel and other bad farming practices have also left severe destruction and degradation of the vegetation cover (MOFA, 2016). In respect of crop production and low output, the inadequate and uncertain rains have also been speculated to be amongst the prime causes and can be attributed partly to the short mono-modal (single) raining season experienced in this area (Kyei-Baffour & Ofori, 2006). The highest mean annual rainfall ever recorded in the region, for which data is available was 1,189 mm in 2003 (GMSD, 2010; MOFA, 2013). Also, the duration of the dry season in this area tends to be distinct and longer, spanning from October to the end of April. The annual rainfall and its distribution vary remarkably from year to year and in some years, a period of short dry spell of three to five weeks follows the first rains in April and/or May which causes severe loss of crops (MOFA, 2016). Another implication is that under this rain-fed conditions farming is possible for a period of about 3 months and the cultivation of crops with longer duration could be impossible or risky without irrigation.

Additionally, the predominance of farming as rain-fed that generally leaves farmers idle for most period of the year coupled with the minimal off-farm employment opportunities make the income status and access to services such as education, health and basic necessities of these farmers more disturbing. These partly explain the worsening poverty situation in the Upper West Region of Ghana in recent years. It is

currently the region with the highest prevalence of poverty in Ghana (GSS, 2014) even though it was hitherto ranked above the Upper East region in terms of poverty incidence. Another reason attributed to the poor farm performance and poverty status in the region is imperfect market. Farmers' participation in formal agricultural markets has been limited by access issues such as poor transport network and conditions and limited market information about prices, supply and demand for farm products. These led some farmers to sell their products in the community or in the farm at the farm gate prices. Hence greater margins of profit could accrue to the traders or the middlemen who buy at the farm gate and sell in major markets. Moreover, the impact of irrigation on poverty has been described as being constrained by inadequate performance and imperfect market (Eneyew, Alemu, Ayana, & Dananto, 2014) and Bhattarai, Sakthivadivel, and Hussain (2002) also indicated that the nature and scope of effects associated with access and impacts of irrigation on income and poverty are not clear cut as reported in the literature. Studies on the impacts of irrigation have focused largely on the direct impacts such as increased crop yield and farm income and not on indirect impacts such as employment and other welfare conditions (Bhattarai et al. 2002).

Thus the study seeks to estimate and discuss the factors that influence farmers' adoption of small-scale irrigation and also to assess the impacts of irrigation and market information and participation on farmer income and access to essential services in the Busa community. The rest of the paper is organized as follows including section one. The literature review is discussed in section two and section three focuses on the methodology of the study. Results and discussion are presented in section four and section five dwells on the conclusions.

Literature Review

The literature provides three categories of studies into irrigation and agriculture. These are studies that looked at only adoption (Ashante, 2013; Abdulai, Owusu & Bakang, 2011; Koundouri, Nauges, & Tzouvelekas, 2006; Moriana, Orgaz, Pastor & Fereres, 2003; Rahm & Huffman 1984) and those that examined only the impacts of irrigation (Alhassan, 2015; Beero & Narayanamoorthy, 2014; Banson, Asare, Heng, Cobbinah, & Adu-Sarkodieh, 2014; Kpieta, Owusu-Sekyere, & Bonye, 2013; Dinye & Ayitio 2013; Bhattarai et al. 2002). The third group examined both adoption and its impacts (Haji & Anam, 2013; Adeoti, 2009; Namara, Upadhyay, & Nagar, 2005) even though studies that focus on this category are quite scanty.

Adoption of Irrigation

Abdulai et al. (2011) investigated the usage of safe irrigation technologies and cropping patterns in southern Ghana using a two-stage conditional maximum likelihood

approach and found that age, education, farmer organization, distance of irrigation water source, extension contact and the production of some vegetables affected adoption of safer irrigation methods. The second stage estimates showed credit, rent, community, farm size, soil type and crop prices as significant factors that explained crop choice of farmers. A study in Greece examined the effects of risk preferences on the adoption of endogenous irrigation technology using a two-stage procedure and found that the probabilities of adopting and investing in new technologies respond to risk preferences (Koundouri et al. 2006). Another study by Genius, Koundouri, Nauges and Tzouvelekas (2014) in Greece developed a theoretical model of technology adoption and diffusion using duration analysis in order to assess the effects of extension services and social learning on technology adoption. They found that both extension services and social learning strongly affected technology adoption and diffusion and these two information channels were complementary in enhancing the effectiveness of each.

Other studies found farmers' education and age on one hand and the adoption of modern irrigation technologies on the other, to be highly correlated. Rahm and Huffman (1984) indicated that the higher the level of education attained by a farmer, the more the likelihood to adopt modern irrigation technologies faster because the perceived benefits from irrigation is expected to be higher in the case of farmers with more education. Farmers' age was found to have increased tendency for the adoption of irrigation technology if they are not faced with capital constraints and the need for future generations' welfare (Huffman & Mercier, 1991). Age was considered to have a strong correlation with experience and will provide increased knowledge about farmers' environment needed for decision making. Putler and Zilberman (1984) reported that larger farms may enjoy economies of scale and will be more able to switch to irrigation technologies compared to smaller farms and tree density was also found to have positive and significant effect on farmers' willingness to adopt modern irrigation techniques (Moriani et al. 2003).

Ashante (2013) examined the factors that explain the adoption and profitability of smallholder irrigation technologies in Ghana. Three separate Probit models were estimated (probabilities of adopting either ground water motor pump, ground water manual or the surface water motor pump irrigation systems). The results of the Probit models. The results showed the positive and significant determinants to be household size and belonging to farmer-based organization on the probability of adopting groundwater manual pump irrigation. Farmers' education, farm size, land tenure, household size and gender on the probability of adopting groundwater motor pump irrigation and farm size and extension on the probability of adopting surface water motor pump irrigation. The negative and significant determinants were the farm size and extension contact (for ground water manual pump), extension contact, experience

and farmer group association (for groundwater motor pump) and land tenure and association (for surface water motor pump). The modelling process adopted by Ashante (2013) could have been improved by using ordered, multinomial or multivariate Probit instead of estimating these models as separate equations which could result in concerns about efficiency of the estimates. These studies have mostly failed to consider the effect of market information and participation on farmers' decisions to adopt irrigation. A notable exception is Rossi, Filho and Carrer (2016) who estimated the effect of degree of risk preference with respect to commercialization on irrigation adoption. However, their study looked at the effect of risk aversion from the stance of farmer's attitude in the context of extent of commercialization and not based on market information and participation although external market factors could play significant role in farm decision processes.

Impact Studies

On the impact front, Kpieta et al. (2013) conducted qualitative assessment of the effects of small-scale irrigation on livelihood and youth out-migration in the Upper West Region and reported that these irrigation dams contributed to increased household food production and income and reduced youth out-migration from their communities. Banson et al. (2014) investigated the impact of small scale irrigation technology on poverty reduction among peri-urban and urban farmers in Kwabenya in the Greater Accra region of Ghana. The study used descriptive statistics in the analysis and showed that use of small-scale irrigation increased yields and savings levels of farmers and consequently contributed to reducing poverty gap among these farmers. This study could have benefited from the use of detailed statistical analysis to show whether the observed differences in these indicators among adopters and non-adopters were statistically significant. Bhattarai et al. (2002) examined the impact of irrigation on income inequality and poverty reduction and found that improved access to irrigation infrastructure increases crop output and yield, farm income, rural employment and reduces poverty within a region.

Meliko and Oni (2011) observed that using modern irrigation system reduces the incidence, and severity of poverty as compared to farmers who used traditional irrigation system. Dinye and Ayitio (2013) found that the Tono Irrigation Scheme in Ghana created employment, increased agricultural income but had modest impact on poverty reduction. Beero and Narayanamoorthy (2014) also reported that irrigated areas had higher employment, incomes and spending among households and that the incidence of poverty was relatively lower in irrigated areas than unirrigated areas. Apam (2012) applied the "with and without" approach to assess the impact of irrigation and found that irrigation affected farmers living conditions by increasing yields, employment, asset holding and reducing hunger, food prices and migration. However,

the use of the “with and without” could be problematic because the levels and changes in these factors could also be due to other factors and not necessarily irrigation. Thus, the study would have benefited a lot from the use of regression or other econometric techniques that will help in dealing with the issue of attribution.

Peprah, Amoah, and Achana (2015) found in Sankana that irrigation had direct effects on output and income of farmers. It also provide auxiliary employment in terms of fishing and offer indirect benefits supporting households’ basic necessities and income for reinvestment. However, the implications drawn on the indirect effects were largely speculative and not based on statistical tests as applied in some relationships or effects of variables. Al-hassan (2015) conducted situational analysis across irrigator and non-irrigators and showed that increased access to water for agriculture through irrigation improves the food security situation of rural households although this improvement does not necessarily lead to poverty reduction. However, this study also suffers from the problem of attribution because it only involved a comparison of “with and without” actors. Despite these studies on the impact of irrigation on livelihoods, Bhattarai, et al. (2002) argued that there has not been clear-cut relationship between irrigation and poverty alleviation and that these impacts depend on a number of intermediate factors and this study considers some of these dimensions worth examining in considering the impacts of irrigation.

Adoption and Impacts

Namara, et al. (2005) examined the adoption and impacts of micro-irrigation technologies using logit model, principal component analysis and the transcendental model. The study revealed that social factors such as belonging to higher caste, poverty index, share of off-farm and non-farm income and other environmental and farming practices such as access to groundwater and share of livestock were significant in influencing farmers’ decision to adopt micro-irrigation technologies. Moreover, farmers who used the micro-irrigation technologies were reported to have extra yield advantage than farmers who were using the traditional irrigation methods. However, this study is limited in its investigation of the impact by focusing on agriculture neglecting other social factors of welfare such as access to education and health. Also, the estimation of these models at different stages, though could be consistent, albeit consistent, could yield inefficient estimates.

Haji and Anam (2013) found in Ethiopia that households’ dependency ratio, family size, education and land size were significant determinants of participation in irrigation schemes. Using the average treatment effect on the treated under the propensity score matching, the authors also showed that there was a significant difference in the consumption per capita between users and nonusers of irrigation, with the per

capita consumption of users being higher than nonusers. The use of Propensity Score Matching (PSM) limits the reliability of their study findings because of the restrictive assumption of PSM approach which states that comparison between groups is based on their observed characteristics (Rosenbaum and Rubin, 1983). Adeoti (2009) used the Heckman Two-Stage and the Ordinary Least Square models to examine the adoption of treadle pump technology and its impact on household poverty. The likelihood of adopting irrigation technology was affected by labour availability, extension visits and regional differences. Years of schooling, irrigated area and adoption of treadle pump had positive and significant impacts on per capita income whereas region had negative and significant impact on per capita income. The use of per capita income in measuring poverty is shrouded with limitations because per capita income is only a monetary indicator of poverty (see Meliko & Oni, 2011).

Methodology

The study employed a cross-sectional design where data were collected from farmers in Busa community about their household, farmer and farm level characteristics during the 2014/2015 farming season. The data was collected across users and non-users of the small-scale irrigation scheme in the community. This section presents discussion of the study area, sampling and data collection. It also outlines the theoretical and analytical frameworks of estimating the effects of farmers' use of irrigation and market information and participation on income and access to education, health and other basic necessities dubbed as access-to-essential services. It is hypothesized that market information and participation will positively influence irrigation scheme participation because of the effect of expected market incentives on motivating agricultural production. Also, participating in the irrigation scheme is expected to enhance farmers' income and access-to-essential services in the area.

Study Area, Sampling and Data Collection

The study was carried out in Busa which falls within the Guinea Savannah ecological zone of Ghana. The community is located in the Upper West Region of Ghana and its coordinates are 10° 1'0" N and 2°22'60" W in Degrees Minutes and Seconds. It shares boundaries with Jonga to the north and in the south with Biihee. It is also bounded by Kampaha in the west and Manwe in the east. The area experiences a unimodal rainfall season and as such irrigation farming is one of the major economic activities. The raining season normally occurs between the months of April to August followed by a long dry season from September to March. The area has an annual mean rainfall intensity of 1,000 mm to 1,150 mm. According to the GSS (2014) Busa has a total population of 1,392 made up of about 50.4% males and about 49.5% females. Farmers

constitute about 63.36% (882) of the population of the community and 300 farmers were drawn from these using stratified random sampling (Table 1).

Table 1: Sampling

Description	Farmers	Sample
Irrigators	468	159
Non-irrigators	414	141
Total	882	300

Source: Ghana Statistical Service, 2014

About 53% of the farmers in the community used the irrigation facility and about 47% were non-users. In lieu of this, farmers were allocated proportionately to both irrigator and non-irrigator groups and simple random was used in the selection of individual farmers from each stratum. As such 159 and 141, representing about 53% and 47%, irrigators and non-irrigators respectively were selected. Primary data was collected at the farmer level first by using a focus group discussion which provided situational and preliminary information for the development of the questionnaire. Subsequently, a structured questionnaire was developed and administered to the farmers using the face-to-face method. Because the study was a structured one, all the questions were closed ended questions.

Analytical Framework

The assessment of the adoption of irrigation and its impact on farmers income and access-to-essential services (AES) (namely education, health and basic necessities) can be represented with a utility function that assumes that farmers desire to maximize income and welfare are the underlying factors for their quest to use irrigation. The utility function can be expressed as

$$U_i = u_i(I, Y, A), \tag{1}$$

where U_i is the conditional utility that individual farmer expects; I is the irrigation use, Y is farm income and A is the Access to Essential Services (AES). Following Place and Hazell (1993) and Matchaya (2010), the first order conditions for maximization produce the following structural equations in a recursive form as

$$I = f(X, M), \tag{2a}$$

$$Y = f(X, M, I), \tag{2b}$$

$$A = f(X, M, I, Y), \tag{2c}$$

where I , Y and A are endogenous variables, M represents market information and participation and X constitutes farmer, farm and selected household characteristics. To facilitate empirical observation and econometric estimation of these functions require a restatement under the assumption that the utility function is stochastic and can be shown as

$$I = X + M + e^a, \tag{3a}$$

$$Y = X + M + I + e^b, \tag{3b}$$

$$A = X + M + I + Y + e^c, \tag{3c}$$

where the variables are as defined earlier and $e^{a, b \& c}$.

Estimation Techniques and Empirical Specifications

Binary and multiple linear regression models were the two main techniques employed in estimating these three equations. Farmers’ adoption of irrigation and access to essential services can be modelled using the Linear Probability, Logit and/or Probit models. However, the limitations of the Linear Probability Model (LPM) (see Woodridge, 2009) called for the adoption of more versatile binary response model which is the Probit in this case. The probability of response is the prime motive in binary response models such as

$$P(Y = 1 | \mathbf{X}) = P(Y = 1 | X_1, X_2, \dots, X_n), \tag{4}$$

where \mathbf{X} consists of a set of explanatory variables that explain irrigation adoption and access-to-essential services and an indicator variable for irrigation usage in the access-to-essential services model.

Given a class of binary response model where Z is a function that assumes the values strictly between 0 and 1 ($0 < Z(g) < 1$) for all real numbers g

$$P(Y = 1 | \mathbf{X}) = Z(\alpha_0 + \alpha_1 X_1 + \dots + \alpha_n X_n) = Z(\beta_0 + \mathbf{X}'_i \beta). \tag{5}$$

This overcomes the limitation of the LPM by ensuring that the estimated probabilities of response are largely between 0 and 1. Although a number of nonlinear functions have been proposed for the Z function, to ensure that the probabilities are constrained between 0 and 1, the Probit model defines this as a standard normal cumulative distribution function (cdf) and expresses it as an integral

$$Z(g) = \Phi(g) \equiv \int_{-\infty}^g \phi(v) dv, \tag{6}$$

where $\phi(g)$ is the standard normal density function and represented as

$$\phi(g) = (2\pi)^{-1/2} \exp(-g^2/2). \quad [7]$$

The Probit model is developed based on the following regression model where y_i^* is a “latent” variable of (either irrigation adoption or access-to-essential services) that is not observed and expressed as

$$y_i^* = \alpha_0 + \sum_{j=1}^n \alpha_j x_{ij} + \varepsilon_i. \quad [8]$$

However, what is observed is y_i called a dummy variable and therefore

$$y_i = \begin{cases} 1 & \text{if } y^* > 0 \\ 0 & \text{otherwise.} \end{cases} \quad [9]$$

Given that the magnitudes of each α_j 's are not in themselves very useful, estimating the effects of x_{ij} on the probability of success requires finding the partial (marginal) effects using calculus on a continuous explanatory variable as

$$\frac{\partial p(x)}{\partial x_j} = (\alpha_0 + \alpha x) \alpha_j, \text{ where } Z(g) \equiv \frac{dZ}{dg}(Z) \quad [10]$$

and for a discrete explanatory variable, the partial effect for changing x_i from 0 to 1, *ceteris paribus*, is

$$Z(\alpha_0 + \alpha_1 x_1 + \alpha_2 x_2 + \dots + \alpha_n x_n) - Z(\alpha_0 + \alpha_2 x_2 + \dots + \alpha_n x_n). \quad [11]$$

The estimation of these was based on the Maximum Likelihood Method which aided in overcoming the limitations of the Ordinary Least Square and the Weighed Least Square Methods in not adequately handling nonlinear functions.

The other analytical method used was the Multiple Linear Regression and was represented as

$$\Gamma_i = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \dots + \beta_n x_n + \mu_i, \quad [12]$$

where β_0 is the intercept and the β_1 to n are the parameter estimates of x 's, Γ_i is a continuous variable (in this case farm income) and μ_i is the error term.

The estimation of equations 5 and 12 brings to bear the kind of framework to use because studies have estimated these equations as single and independent which can sometimes is at the expense of efficiency and consistency of the estimates (Matchaya, 2010; Haji & Anam, 2013; Eneyaw, et al., 2014). To overcome this, some studies employed the Two-Stage Least Squares (2SLS) procedure which albeit produces consistent estimates but fails to account for all information produced by the various equations in the model (Foning, Kane, Ambagna, Sikod & Oyekale, 2014) and as such compromises efficiencies

of the estimates. This called for procedures that estimate these equations jointly and the mixed nature of these equations (i.e. binary, continuous and binary dependent variables) necessitate the adoption and implementation of the Conditional Recursive Mixed-Processes (CRMP) framework. The CRMP framework is a recursive structural form system of equations that contains both continuous and discrete right-hand side models and this has advantage in obtaining efficient estimates compared to the individual estimation of these equations (Roodman, 2011). Also, the structural equations framework can give the impacts of irrigation on income and access-to-essential services directly and finally CRMP retains all the merits of Maximum Likelihood (ML) when the system is fully modeled and recursive (Roodman, 2011).

The empirical specification in a recursive form of these models are represented in equations 13a, b and c.

$$P(I = 1 | x) = \Phi(\alpha_0 + X'_{i1}\alpha_i + \varepsilon), \quad [13a]$$

$$Y = \beta_0 + X'_{i2}\beta_i + I'_2\theta_2 + \mu, \quad [13b]$$

$$P(A = 1 | x) = \Phi(\gamma_0 + X'_{i3}\gamma_i + I'_3\theta_3 + Y'_3\delta_3 + e). \quad [13c]$$

Where α_0 , β_0 and γ_0 are constants; X'_{i1} is a matrix of variables (gender, household size, educational attainment, market participation and information and input cost/acre); X'_{i2} is a matrix of variables (gender, age, household size, capital invested, institutional support, education and market access and information); X'_{i3} is also a matrix of variables (gender, marital status, household size, occupation, education, institutional support and off farm income); I , Y and A are as defined earlier; α_i , β_i , γ_i , θ and δ are parameter estimates and ε , μ and e are the error terms. The definitions and measurements of these variables are shown in Table 2.

Table 2: Definitions and measurements of variables

Variable	Definition and measurement
Dependent variables	
Irrigation	<i>Irrigation status</i> 1 if a farmer is an irrigator and 0 if a farmer is non-irrigator
Farm income	<i>Annual farm income</i> Annual farm income of the farmer measured in Gh¢
Access to Essential Services	<i>Access to education, health and basic necessities measured in terms of affordability index:</i> 1 if a farmer is able to afford at least two of these services (i.e. have access) and 0 if a farmer is able to afford at most one of these services (i.e. not having access)
Independent variables	
Sex	<i>Sex of a farmer</i> 1 if a farmer is male and 0 if female
Age	<i>Age of farmer</i> Number of years completed by a farmer
Married	<i>Marital status of farmer</i> 1 if ever and/or still married and 0 if never married
Household size	<i>Household size</i> Number of persons in a farmer's household
Education	<i>Educational attainment of a farmer</i> Number of completed years in school
Occupation	<i>Main occupation</i> 1 if farming is the main occupation and 0 if otherwise
Off-farm income	<i>Off-farm income of farmer</i> Annual off-farm income of the farmer measured in Gh¢
Market	<i>Market information & participation</i> 1 if a farmer sells most output in the market and have prior price information and 0 if a farmer sells less or no output in the market and/or have no prior price information.
Input cost	<i>Average input cost/acre</i> Average cost incurred in farming an acre measured in Gh¢.
Capital invested	<i>Average capital invested/acre</i> Average amount of capital invested/acre per season measured in Gh¢
Inst. support	<i>Institutional support</i> 1 If farmer ever received any institutional support in cash and/or kind and 0 if otherwise.

Results and Discussion

$$P(I = 1 | x) = \Phi(\alpha_0 + X'_{i1}\alpha_i + \varepsilon), \quad [13a]$$

$$Y = \beta_0 + X'_{i2}\beta_i + I'_2\theta_2 + \mu, \quad [13b]$$

$$P(A = 1 | x) = \Phi(\gamma_0 + X'_{i3}\gamma_i + I'_3\theta_3 + Y'_3\delta_3 + e). \quad [13c]$$

Where α_0 , β_0 and γ_0 are constants; X'_{i1} is a matrix of variables (gender, household size, educational attainment, market participation and information and input cost/acre); X'_{i2} is a matrix of variables (gender, age, household size, capital invested, institutional support, education and market access and information); X'_{i3} is also a matrix of variables (gender, marital status, household size, occupation, education, institutional support and off farm income); I , Y and A are as defined earlier; α_i , β_i , γ_i , θ and δ are parameter estimates and ε , μ and e are the error terms. The definitions and measurements of these variables are shown in Table 2.

Socioeconomic Characteristics of Farmers

The summary statistics of socioeconomics characteristics and variables of interest are given in Table 3 for all farmers and across irrigators and non-irrigators. The results show that irrigation farming in the area is dominated by females with the percentage of female irrigators generally higher than male irrigators. There is a slightly significant difference in the sex of irrigators and non-irrigators with the latter being male dominated. The results also show that the age and marital status of farmers were not statistically different across irrigators and non-irrigators. The mean completed years of schooling is significantly higher for irrigators than non-irrigators. The input cost per acre and capital invested are significantly different between irrigators and non-irrigators with the average input cost and capital invested being higher for non-irrigators. These differences in average costs and capital invested can be attributed to spending on shallow wells by some farmers who were not under the irrigation scheme. There is no significant difference in institutional support, occupational status and off-farm income across these groups of farmers. The three variables of interest; market information and participation, farm income and access-to-essential services, show significant difference between irrigators and non-irrigators. The percentage of farmers who had prior market information about prices and highly participated in markets is higher for irrigators than non-irrigators. Also, the mean farm income and the proportion of farmers with access-to-essential services (which are the outcome variables of interest) are higher for irrigators than non-irrigators.

Table 3. Characteristics of farmers, irrigators and non-irrigators

Variable	All farmers	Irrigators	Non-irrigators	Diff.	T-test/ χ^2 value
Sex (%)	47.50	38.33	56.67	18.4	2.029 ^{†*}
Age	39.25	38.90	39.60	0.700	0.398
Married (%)	54.16	58.33	50.00	8.333	0.911 [†]
Household size	4.783	5.033	4.533	0.500	1.378
Education	4.808	6.650	2.967	3.683	6.509 ^{***}
Input cost	112.2	52.33	172.2	119.8	2.961 ^{***}
Capital invested	274.3	176.3	372.2	195.8	7.646 ^{***}
Inst. support (%)	59.17	63.33	55.00	8.333	0.924 [†]
Occupation (%)	77.50	73.33	81.67	8.333	1.089 [†]
Off-farm income	245.7	223.1	268.4	45.35	1.086
Market (%)	45.00	56.67	33.33	23.33	2.621 ^{†**}
Farm income	882.4	1019.3	745.5	273.7	3.103 ^{***}
Access-to-essent. (%)	64.17	75.00	53.33	21.67	2.519 ^{†**}

Source: Field Survey, 2015

“***”, “**” and “*” significance at 1%, 5% and 10% respectively. [†]chi-square values

Determinants of Irrigation Adoption

Table 4 shows the results of the model estimates for the Conditional Recursive Mixed-Process (CRMP) framework. The $\text{atanhrho}_{\epsilon\epsilon}$ and $\text{atanhrho}_{\mu\epsilon}$ are statistically significant at the 5% and 1% levels suggesting correlation between the error terms of equations 13a and 13c on the one hand and that of between equations 13b and 13c on the other hand. This implies the presence of unobserved heterogeneity among farmers in the area. Also, the p-value of the Wald test at the bottom of Table 4 rejects the null hypothesis of no endogeneity. These imply that estimating each of these models independently, as has been done in the literature instead of a system or simply comparing irrigators to non-irrigators, would have led to biased estimates. Hence this makes the current estimates relatively more efficient and reliable. This study also overcomes the problem of confounding factors which is attributable to qualitative studies or studies that only compared “with and without” irrigation in assessing the impacts of irrigation (especially in Ghana) by accounting also for observed characteristics of farmers in the model. Failure to account for these observed characteristics as in other studies (Apam, 2012; Peprah et al., 2015; Al-hassan, 2015) could lead to biased and inefficient estimates of the impacts of irrigation adoption on farm income and access-to-essential services.

Table 4: Determinants of use of irrigation, farmer income and access-to-essential services

Variable	CMP estimation		Marginal effects	
	Coefficient	Std. error	Coefficient	Std. error
Irrigation				
Sex!	-0.546*	0.293	-0.230*	0.115
Household size	0.264***	0.079	0.095***	0.032
Education	0.568***	0.114	0.189***	0.050
Market!	0.767**	0.307	0.317**	0.119
Input cost/acre	-0.009***	0.003	-0.004***	0.001
Constant	-2.179***	0.583		
Farmer income				
Sex!	33.193	75.770		
Age	-0.098	3.637		
Household size	-76.264***	19.916		
Education	6.815	10.797		
Irrigation!	624.952***	125.626		
Capital invested	1.011***	0.262		
Inst. support!	212.613***	69.846		
Market!	253.527***	82.821		
Constant	372.854**	178.374		
Access				
Sex!	-0.085	0.316	0.056	0.103
Married!	0.411	0.278	0.076	0.102
Household size	0.057	0.095	-0.006	0.027
Education	0.338**	0.139	0.058	0.042
Irrigation!	-0.659	0.498	0.167	0.109
Occupation!	0.962**	0.372	0.419***	0.136
Income	0.002***	0.001	0.001***	0.000
Inst. support !	0.055	0.337	0.073	0.104
Off farm income	-0.001*	0.001	-0.001*	0.000
Constant	-2.577	0.715		
Insig_2	5.927***	0.074		
atanrho_	-0.311	0.312		
atanrho_	1.167**	0.589		
atanrho_	-0.681***	0.195		
sig_2	375.075	27.904		
rho_	-0.301	0.284		
rho_	0.823	0.189		
rho_	-0.592	0.127		
CMP model	Wald X²=170.93; P>X²=0.000			

Source: Field Survey, 2015.

(!) dy/dx is for discrete change of dummy variable from 0 to 1. "****, ** and *" implies significant at 1%, 5% and 10%, respectively.

Market information and participation are key components that studies explaining determinants of irrigation use have mostly left out. Market information and participation have positive and significant effect at the 5% level on farmers' participation in the irrigation scheme. The marginal effect of this shows that the likelihood of participating in the irrigation scheme increases by 0.317 when a farmer have prior information of prices in the market and sells most of the output in the market (Table 4). This suggests that market factors are important in influencing farmers' participation in the scheme in this area and not necessarily only their attitude towards risks as indicated by Rossi et al. (2016). Market information and participation decisions are important because market information provides farmers the opportunity to take advantage of good prices and market margins and subsequently reduces, especially, the fixed transactions costs in market participation decisions. The associated gains in participating in markets translate into increased earnings and resource endowments which inform farming decisions (Eskola, 2005; von Braun, 1995) including irrigation usage.

Sex of the farmer has a negative and significant effect on participation in the irrigation scheme suggesting that female farmers are more likely to participate in the irrigation scheme than their male counterparts. The marginal effect in Table 4 shows that the probability of participating in the scheme decreases by 0.23 among men and this explains the dominance of women farmers under the scheme. Household size and educational attainment are both positively and significantly related to participation in the irrigation scheme in the community at the 0.01 alpha. The marginal effect of household size suggests that an increase in the household size by an additional member (person) increases the probability of participating in the irrigation scheme by 0.095. This reflects the fact that family size is still considered important for farming in the area and having bigger families is normally perceived as an avenue of reducing labor cost and affording farmers the means to cultivate their farms effectively. Educational attainment has a marginal effect of 0.189 which indicates that the probability of participation in the scheme increases by this margin with an additional year spend schooling. These confirm other findings that family size and education were significant determinant of farmers' participation in irrigation schemes (Haji & Anam, 2013; Abdulai et al., 2011; Rahm & Huffman, 1984). Finally, input cost has a negative and statistically significant effect on farmers' participation in the scheme at the 1% significance level. This has a marginal effect of 0.004 which shows that a Cedi increase in average input cost decreases the probability of participating in the scheme by this magnitude in the area. This means that cost of production is critical in farm decision process in the community.

Impact of Irrigation Adoption on Farm Income

The estimated coefficient of the impact of participating in irrigation on farm income under the regression approach is Gh¢624.95 (Table 4) and the simple difference in income between irrigators and non-irrigators is Gh¢273.7 (Table 3) which are very different. This shows that failure to account for other observed characteristics of farmers could bias the estimates. Thus, the regression estimates are desirable in this case because it accounts for both observed and unobserved characteristics of farmers. The estimated coefficient of irrigation impact on farm income is significant at the 1% and implies that farmers who participate in the irrigation scheme have Gh¢624.95 higher in farm income compared to non-irrigators. This indicates that the scheme enhances farm income by reducing the risk of crop/output losses due to varied and unfavorable rainfall and could also serve as an avenue for promoting cultivation more than once in a season. This finding is in conformity with past studies (such as Dinye & Ayitio, 2013; Kpieta et al., 2013; Bhattarai et al., 2002; Koundouri et al., 2006) who indicated that irrigation significantly contributes to the income of farmers by supporting farm production. Market participation and price information have positive and statistically significant effect on farm income. Farmers who had prior price information and sold most of their output in the market had Gh¢253.53 higher in farm income than farmers who had either of these or none of these at all. This also underscores the importance of market information and participation in improving farmers' income status particularly in the area for the reason that it will reduce fixed transactions costs, tendency of farmers to be *ripped off* and promote accrual of farm incomes to farmers instead of the middlemen.

Household size has a negative effect but statistically significant at the 1% significance level. The coefficient indicates that an increase in the number of members of households in the area reduces farm income by Gh¢76.26 suggesting that having larger families or households do not necessarily complement farming. This implies that the use of family labour is outside the efficient production set and farmers are experiencing negative returns to scale in the use of labour from the household in the area. Financial capital invested per acre has a positive and significant effect on farm income at the 1%. A Cedi invested in an acre of farmland increases farm income by Gh¢1.011. The opposing effects of labour (negative) and capital invested (positive) further show that these farmers tend to disproportionately employ labour and capital on their fields. Also institutional support aid in enhancing farm income and farmers who received institutional support either in cash and/or in kind had Gh¢212.613 higher income than those who were found not to have received any form of institutional support. In effect farmers under the scheme are able to improve their farm incomes by indulging in efficient financial investment and liaising with institutions for both technical and financial assistance.

Impact of Irrigation Adoption and farm Income on Access to Essential Services

Results in Table 4 shows that the effect of irrigation on access-to-essential services (i.e. education, health and basic necessities) is not statistically significant. This justifies the flaws the simple comparison of welfare conditions between irrigators and non-irrigators as shown in Table 3 and partly explains the divergence in findings between this and most other studies. Whereas in Table 3 the effect of irrigation on access-to-essential services is statistically significant in favor of irrigators, the regression based results (Table 4) suggest otherwise because irrigation impact on access-to-essential services is not only statistically insignificant but also shows a negative effect. This implies that the effect of the irrigation scheme in the area is more substantial in the case of income – which is quite direct and immediate as an outcome – than that of access-to-essential services which is indirect and also takes relatively longer time to manifest.

Some of the reasons for the negative effect of the irrigation scheme on access-to-essential services in the area could be the scheme's state of incompleteness and dilapidation as well as staleness between the community on one hand and the other project stakeholders (namely International Fund for Agricultural Development, the regional office of the Ministry of Food and Agriculture and the Municipal Assembly) on the other which Knutson (2001) described as responsible for disappointment and frustration among community members. Others also complained about the fact that the water level of the irrigation canals is low and not able to flow to their farms. These inhibit the continuous use of the irrigation and some farmers have engaged in construction of shallow wells on their farms for farming. Yirenkyiwaa (2012) also argued that farmers tend to rely on shallow wells which result in them spending more time and resources on these wells instead of on the irrigation scheme in Busa. Another explanation could be the fact that access to these services (education, health and other basic necessities) goes beyond the demand side motivations to also envelop their supply side issues and farmers may not be able to access these services due to the limited presence of the services in the area.

The findings corroborate that of Dinye and Ayitio (2013: 129) that irrigation farming makes modest contribution to living conditions of farmers because most irrigation farmers indicated “desperate” living conditions under the Tono project in the Upper East region of Ghana. The differences in results of the effects of irrigation on income and access-to-essential services suggest that the impact of irrigation on livelihood depends on the outcome variable (whether economic or social) and this adds to Bhattarai, et al. (2002) that the impacts of irrigation on poverty varies according to the dimension of poverty under consideration. The findings are, however, at variance with the apriori expectation of this study and with those of (Kpieta et al. 2013; Bhattarai, et al. 2002)

that small scale irrigation contributes positively to rural livelihoods and poverty by providing farmers with increased incomes to spend on family upkeep and education of children. A key reason for this could be the context specific of irrigation effects which vary not only based on the state of the project but also by community or location. For instance, even within the Upper West region, Kpieta, et al. (2013) argue that benefits of irrigation are different across districts and that farmers in the Wa West District have benefited more from small-scale irrigation than farmers in the Wa Municipality and the Nadowli District.

Farm income is a factor that significantly affect farmers' access-to-essential services. Farm income had a positive and statistically significant effect on farmers' access-to-essential services at the 1% implying that a Cedi increase in farm income increases the probability of farmers' access to essential services by 0.001 in the area. This implies that farm income is a key determinant of farmers' access to essential services in the area because farmers with higher incomes from the farm are more able to cater for their basic and essential needs. However, off-farm income has a negative and statistically significant effect, at the 10% level, on farmers' access. The marginal effect indicates that a Cedi increase in off-farm income reduces the probability of farmers' access to essential services by 0.001. This irony can be explained by the general depravity in living conditions in the area (see also Yirenkyiwaa, 2012) and the lack of adequate off-farm paying employment opportunities. These cause farmers to spend most of their additional earning (either from farm or off-farm) on farming which is seen as their main source of food and income⁹. Also, the marginal effect of occupation reveals that the probability of farmers' access-to-essential services increases by 0.962 if the farmer has farming as the main occupation than otherwise. This further shows the inclination of farmers to improving their access-to-essential services through farming compared to any other income source in the area and also adds to the rationale for the limited, but rather negative, direct effect of off-farm income on access-to-essential services. Finally, additional year of schooling attained by a farmer increases the probability of access-to-essential services by 0.058 although the marginal effect is not significant.

Conclusions

The supply and availability of labour have imperative ramification not only on the production process but also on the decision of farmers to utilize the irrigation facility. Famers with large family size were found to be more likely to participate in the irrigation scheme because of the felt security in respect of labour supply. However, large household or family sizes partly lead to decreases in farm incomes because of the inefficient

⁹ T-test statistic of 0.132 shows no significance difference in financial investment on farm between farmers who had off-farm income and those who did not have.

engagement and application of these labour. Hence, labour supply concerns need to be adequately dealt with, either by encouraging the optimal/efficient use of labour through extension advice and/or by encouraging farmers to invest in augmenting the contribution of the fixed input which in this case is mostly land. This will facilitate the compatibility among labour use, adoption of irrigation and farmer income in the most efficient way.

Also availability of market information about prices and participation in markets encourage farmers to adopt irrigation because of the reduction in fixed transactions costs and market risks and consequently contribute to increased farm incomes. As such interventions to promote the use of this irrigation facility need to see marketing issues as a necessary condition in influencing farmers' decision to use the scheme and promoting rural incomes. This also means that an integrated program which brings to bear issues of adequate water, efficient labor use, education and training as well as market information and access (to enhance the efficiency of farmers, use of the irrigation facility and contribute to improving farmers' income and welfare) should be the focus of any rural development program targeted at promoting irrigation in the area.

Irrigation is an essential factor that contributes to improvement of farmers' incomes in the area because farmers who were part of the irrigation scheme were found to have relatively higher income than their counterparts who were not engaged in the scheme. This confirms the relevance of irrigation in agriculture and rural development in Ghana because improved irrigation has mostly been expected to translate into growth in farmer and rural incomes. Farmers need to strengthen the use of irrigation either by taking the initiative themselves and/or be encouraged by promoting the use of small-scale irrigation schemes which are less costly and technology intensive. However, the effect of irrigation on access-to-essential services appears to be limited, indirect and negative. There is therefore the need to consider improving the current conditions of the irrigation facility and resolving the underlying misgivings among the stakeholders to promote the long-run use of the facility and to engender its effects on long term welfare conditions. It is also recommended that further investigation be done into understanding how the supply of essential services (education, health and other basic services among others) affect farmers' access to these services in the area.

The link between farm income and access needs not be overemphasized because farmers who had higher incomes from the farm were more likelihood and able to access their basic and essential needs. This shows that farm income is fundamental to the living standards of these inhabitants because of the dominance of agriculture in the community. This also implies farm income has greater impact on access relative to the off-farm income. Therefore, farmers who specialize by investing much attention and resources and have farming as their main occupation would be able to turnout higher

incomes and consequently increase their access-to-essential services in the area if their efforts are complemented by improved conditions of the scheme.

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