MODELING THE CHOICE OF IRRIGATION TECHNOLOGIES OF URBAN VEGETABLE FARMERS IN ACCRA, GHANA

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Abstract

Irrigation is seen as the means of ensuring food security in a water-scarce urban economy such as the Accra Metropolitan Area of Ghana. The use of modern, advanced and resource efficient irrigation technologies is vital to increase farm output and take people out of poverty. The informal irrigation system is what is common among the urban vegetable producers in Accra. The study modeled the choice of informal irrigation technologies of urban vegetable farmers in Accra using the multinomial logit modeling Approach. A sample of 107 respondents provided information for the analyses. Farmers who have access to credit, frequently contact extension agents, operate larger farm size, have high labour cost of farm operations and use river as key source of irrigation water were likely to use the motorized pump with hose irrigation technology. It was suggested that extension agents should intensify education of the farmers on the benefits of modern irrigation technologies such as the motorized pump with hose. Also credit should be made available to the farmers by the government and other development partners so as to be able to invest in such water-saving and resource efficient irrigation technologies.

Key Words: Irrigation technologies, urban vegetable farming, motorized pump with hose, flooding, watering can

1 Introduction

The demand for and consumption of vegetables have been increasing in most countries due to growing population and urbanization (Figuié, 2004). Farmers have been responding to this by increasing and diversifying crop production in directions favorable to vegetables. It is no doubt that vegetable production is an essential component of rural, urban and peri-urban farmers' livelihood (Obuobie *et al*., 2006) and thus forms an integral part of Ghana's agriculture.

Depending on the ecological point of production, vegetable production is categorized into urban, peri-urban and rural (Obuobie *et al*., 2006). Urban vegetable production takes place in the urban areas and those produced at its periphery are the peri-urban vegetable production. The recognition of the contribution of urban vegetables to improved food security in cities of developing countries is a recent phenomenon (Figuié, 2004). It has gradually been accepted as a solution to food shortages caused by adverse economic and climatic events in most West African countries. Urban vegetable production was estimated to provide up to 90 percent of the most perishable vegetable (exotic vegetable) needs of the city of Kumasi and Accra and generate employment for some urban dwellers (van Veenhuizen *et al*., 2007).

However, in most developing countries where agriculture is the main source of employment and Gross Domestic Product (GDP), agricultural productivity is extremely low, though increasing agricultural productivity is critical to economic growth and development (Doss, 2006).

The introduction of yield-increasing innovations has been an important factor underlying the rapid growth of world agricultural output since 1960. Most notable is the "green revolution" technology consisting of high-yielding potential fertilizer-responsive seeds and related inputs (Feder, 1982). The use of fertilizer and agrochemicals particularly became a major policy strategy in the 1960s and 1970s in Ghana (Seini *et al*., 2004). However, inadequate knowledge of the use of fertilizers and agrochemicals has more often than not led to their misuse, leading to the degrading of the environment in a water-fed agriculture. In order to reduce the negative effects of agrochemicals on the environment, more advanced irrigation technologies have been proposed (Seini et al, 2004).

Irrigation is the artificial application of water to the soil and is usually used to assist in crops production in dry areas and during periods of inadequate rainfall. In contrast to irrigation, agriculture that relies only on direct rainfall is referred to as rain-fed farming. Irrigation is classified into two main groups; informal and formal large scale commercial irrigation depending on the degree of government involvement in its establishment and management (MoFA, 2007). When government establishes large scaleirrigation projects, they are categorized as formal. All private small scale projects (dug outs, wells, sprinklers etc) are categorized as informal.

Irrigation is one of the main production factors in urban vegetable production as most urban vegetable producers resort to different forms of irrigation techniques to supplement their crop's water requirement. Unlike most rural and peri-urban vegetable production that rely heavily on rainfall, urban vegetable production relies mostly on irrigation for its success. Small-scale irrigation technologies such as sprinkler, drip, motorized pumps with hose has several benefits including reduction of rainfall dependency, enhanced production security, additional agricultural income, crop diversification, and employment (Laube, 2008). However farmers in the urban areas make little or no investments in these irrigation technologies.

The modern irrigation technologies such as the drip, motorized pump with hose and the sprinkler have been described as water-saving; less labor intensive; results in less crop contamination and reduced health risks of the farmer (Drechsel *et al*., 2006; Obuobie *et al*., 2006). Adoption of modern irrigation technologies is often cited as a key to increasing water use efficiency in agriculture and reducing the use of scarce inputs while maintaining current levels of production (Green *et al*, 1996). For instance Negri and Brooks (1990) indicated that water-saving irrigation technology is playing an increasingly important role in reducing both energy costs and water use. They further indicated that improved irrigation technology, in which the plant uses a greater fraction of applied water, has the potential to conserve water with little or no loss in yields. However to effectively apply the drip, motorized pump with hose and sprinkler methods, for example, some level of training and financial investment is required, albeit with some possible adoption and adaptation problems.

As observed by Obuobie *et al*. (2006) and Drechsel *et al*. (2006) there is available labor saving irrigation technologies such as the motorized pump with hose for use in urban vegetable production. However, the continued use of traditional labor intensive irrigation technologies such as the watering can by urban vegetable farmers raises the issue of why these newer and labor saving irrigation technologies are not widely used in irrigated urban vegetable production.

The adoption decision of a farmer for these technologies depends on several factors ranging from socioeconomic, technical and institutional factors which are unknown. It is therefore imperative that a study such as the current is undertaken to identify these factors.

Against this background, the current study identifies the determinants of choice of informal irrigation technologies in urban vegetable farming in Accra, Ghana. The three informal irrigation technologies currently used in urban vegetable farming in the study area comprised watering can, flooding and motorized pump with hose.

In section 2, the informal irrigation technologies used in urban vegetable production are discussed. The methodological approach employed in the study is presented in section 3 whiles the study's results are presented and discussed in section 4. Finally section 5 contains the summary and policy conclusions emanating from the study.

2 Informal Irrigation Technologies used in Urban Vegetable Production

2.1 Watering cans

This irrigation technology is used in most of the vegetable growing areas in urban Accra and most of the farmers combine it with the other technologies. It is also the most precise one for fragile leafy vegetables and newly transplanted vegetables. Farmers use watering cans to fetch and manually carry water from a water source; mostly shallow dug wells, streams or dugouts, to the fields, followed by watering of crops through the spout or shower head of the can making it an overhead irrigation method. In many cases, farmers carry two watering cans at a time. One watering can as used in Ghana has a capacity of 15 liters of water (Obuobie *et al*., 2006). This irrigation technology is labor intensive and takes much of the time requirement in urban vegetable farming in Accra.

2.2 Flooding

This is a form of surface irrigation, mainly practiced in the La Sub-metro in Accra. La farming area is a comparatively wider open space with a topography that allows for flooding irrigation. The source of water is a drain that runs from the nearby Military Camp to its treatment plant. Farmers have constructed an open weir and diversion channel to irrigate their plots (fruit vegetables) downstream by furrows, or they divert water into dugouts from where they can fetch with a watering can and irrigate their leafy vegetables. The use of raised beds in this irrigation technology is for a variety of agro-technical reasons mostly unrelated to irrigation. The fact that the beds are raised above the water surface is an advantage of this method with effluent irrigation, since even crops with a low growth habit are further removed from contact with the water, provided they have erect stems (Shuval *et al*., 1986).

2.3 Motorized pumps with hose

This technology involves the placement of a small motor pump temporarily near a water source usually the bank of a river or a big stream and water is pumped through rigid plastic pipes or semi-flexible pipes which are connected to a flexible hosepipe at the end. It is mostly seen in peri-urban areas, but also becoming increasingly common in Accra. Farmers use the hose to apply water to their crops either overhead or near the roots on the surface. This irrigation technology helps to reduce transport ways since water can sometimes be pumped into a dugout on the vegetable field from where water is fetched with watering cans. Due to the high velocity of water from the pipes, watering can be done overhead even for tall vegetables like mature garden eggs. As the water pressure and the hose could damage leafy vegetables, usually only taller growing and stronger vegetables such as cabbage, cauliflower and green pepper are irrigated in this way (Obuobie *et al*., 2006).

3 Methodology

3.1 Choice of irrigation technologies

The decision on whether or not to adopt a new technology is considered under the general framework of utility or profit maximization. The utility maximization approach assumes that economic agents make choices based on the satisfaction or utility that they expect to derive from that choice. Although utility is not directly observed, the actions of economic agents are observed through the choices they make. The profit maximization approach assumes that economic agents make choice based on the amount of profit or benefits that are expected to accrue to them. They are therefore willing to make the needed investments based on the expected profit. The current study utilize the profit maximization approach because it is the more widely used in the irrigation technology adoption literature (Caswell and Zilberman, 1985; Green *et al*., 1996). Also the profit maximization approach is used because in the choice of irrigation technologies, capital and other financial investments are expected to be made with which the farmer expects a net profit or benefit in monetary or physical terms. Here it is assumed that economic agents such as smallholder subsistence urban vegetable farmers, adopt a new technology only when the perceived profit or net benefit from using such a method is significantly greater than is the case without it.

The urban vegetable farmer decides which irrigation technology j, to adopt on a given field by estimating the expected profits under each of the j irrigation technologies, while taking into account crop type, the field and farmer characteristics (Green *et al*., 1996). Each irrigation method is associated with constant returns-to-scale technology and the farmer maximizes his expected profits (Caswell and Zilberman, 1985). The urban vegetable farmer will make the irrigation technology choice that will maximize expected profits, given that crop choice has already been made. The expected per unit profits of the i^{th} farmer using irrigation technology j, π_{ij} are composed of two independent elements;

$$\pi_{ij} = \beta_j' X_i + \varepsilon_{ij} \quad \ldots \quad 1$$

where β_j' is the non-stochastic vector of parameters to be estimated and X_i is the vector of observed variables associated with the i^{th} farmer and j^{th} technology. The unobserved characteristics are represented by ε_{ij} so that if the i[th] farmer is selected at random, then ε_{ij} is a random variable (Caswell and Zilberman, 1985).

Suppose that π_{j1} and π_{j2} represent a household's perceived profits for two irrigation technology choices. The linear perceived profit model could then be specified as:

$$\pi_{j1} = \beta'_{j1}X_i + \varepsilon_{j1} \; and \; \pi_{j2} = \beta'_{j2}X_i + \varepsilon_{j2}$$

where π_{j1} and π_{j2} are perceived profits of irrigation technology j_1 and j_2 respectively, X_i is the vector of explanatory variables that influence the perceived desirability of the method, β_{j1} and β_{j2} are parameters to be estimated, and ε_{j1} and ε_{j2} are error terms assumed to be independently and identically distributed (Greene, 2003). In the case of choice of irrigation technology, if a vegetable farmer decides to use option j_1, it follows that the perceived profit or benefit from option j_1 is greater than the perceived profit from other options (say j_2) depicted as:

$$\pi_{j1}\left(\beta'_{j1}X_i + \varepsilon_{j1}\right) > \pi_{j2}\left(\beta'_{j2}X_i + \varepsilon_{j2}\right), j_1 \neq j_2 \ldots\ldots\ldots\ldots 2$$

The probability that a household will use method j among the set of irrigation technology options could then be defined as;

$$P(Y = 1|X) = P(\pi_{j1} > \pi_{j2})$$

$$P(\beta'_{j1}X_i + \varepsilon_{j1} - \beta'_{j2}X_i - \varepsilon_{j2} > 0|X)$$

$$P(\beta^* X_i + \varepsilon^* > 0|X) = F(\beta^* X_i) \ldots\ldots\ldots\ldots 3$$

where P(.) is a probability function,

π_{j1} and π_{j2} are the perceived profits for choice one and two respectively

X_i is the vector of the explanatory variables

$\varepsilon^* = \varepsilon_{j1} - \varepsilon_{j2}$ is a random disturbance term,

$\beta_j^* = (\beta'_{j1} - \beta'_{j2})$ is a vector of unknown parameters that can be interpreted as a net influence of the vector of independent variables influencing the choice of the technology.

$F(\beta^*X_i)$ is a cumulative distribution function of ε^* evaluated at β^*X_i.

The exact distribution of *F* depends on the distribution of the random disturbance term, ε^*. Thus depending on the assumed distribution that the random disturbance term follows, several qualitative choice models can be estimated (Greene, 2003).

3.2 Identifying the determinants of choice of irrigation technologies

The analytical approaches that are commonly used in an adoption decision study involving multiple choices are the multinomial logit (MNL) and multinomial probit (MNP) models (Green *et al*., 1996; Larson *et al*., 2001; Deressa *et al*., 2008; Hassan and Nhemachena, 2008). Both the MNL and MNP are important for analyzing farmer adoption decisions.

This study used a MNL model to analyze the determinants of urban vegetable farmers' decisions to choose from alternative irrigation technologies because it is the more widely used in adoption decision studies involving multiple choices and is easier to estimate than its alternative, the MNP (Hassan and Nhemachena, 2008).

This model provides a convenient closed form for underlying choice probabilities, with no need of multivariate integration, making it simple to compute choice situations characterized by many alternatives. In addition, the computational burden of the MNL specification is made easier by its likelihood function, which is globally concave (Hausman and McFadden, 1984; Hassan and Nhemachena, 2008). The main limitation of the model is the independence of irrelevant alternatives (IIA) property, which states that the ratio of the probabilities of choosing any two alternatives is independent of the attributes of any other alternative in the choice set (Hausman and McFadden, 1984; Tse, 1987).

On the other hand, the multinomial probit model (MNP) specification for discrete choice models does not require the assumption of the IIA (Hausman and Wise, 1978; Hassan and Nhemachena, 2008), and a test for this assumption can be provided by a test of the 'covariance' probit specification versus the 'independent' probit specification, which is very similar to the logit specification. The main drawback of using the MNP is the requirement that multivariate normal integrals must be evaluated to estimate the unknown parameters. This complexity makes the MNP model an inconvenient specification test for the MNL model (Hausman and McFadden, 1984; Hassan and Nhemachena, 2008).

Let Y_i be a random variable representing the irrigation technology chosen by the representative urban vegetable farmer. It is assumed that each urban vegetable farmer faces a set of discrete, mutually exclusive choices of irrigation technologies. The choices made from these irrigation technology alternatives are assumed to depend on a number of socioeconomic characteristics, and technical and institutional factors. Following from Greene (2003), the MNL model for irrigation technology choice specifies the following relationship between the probability of choosing option Y_i and the set of explanatory variables X

$$Prob(Y_i = j) = \frac{e^{\beta'_j x_i}}{\sum_{k=0}^{J} e^{\beta'_k x_i}}, j = 0,1, \dots, J \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots.4$$

where β_j is a vector of coefficients on each of the independent variables X. equation 4 has indeterminacy , so that only J parameter vectors are needed to determine the J+1 probabilities. This indeterminacy is removed through normalization of one of the irrigation technology alternatives which assumes that $\beta_o = 0$ and the corresponding probabilities can be estimated as:

$$Prob(Y_i = j|x_i) = \frac{e^{\beta'_j x_i}}{1 + \sum_{k=1}^{J} e^{\beta'_k x_i}}, j = 0,2, \dots, J, \beta o = 0 \dots\dots\dots\dots\dots\dots\dots\dots.5$$

Estimating the above equation yields the J log-odds ratios given below as;

$$ln\left[\frac{P_{ij}}{P_{ik}}\right] = x'_i(\beta_j - \beta_k) = x'_i\beta_j, \quad if\ k = 0\ (the\ base\ category\ ) \ldots\ldots\ldots\ldots\ldots\ldots\ldots .6$$

The dependent variable is therefore the log of one alternative irrigation technology (flooding and motorized pump with hose) relative to the base traditional irrigation technology alternative (watering can).

Like in most non-linear choice models, the MNL coefficients are difficult to interpret, and associating the β_j's with the j^{th} outcome is inappropriate and misleading. The marginal effects are therefore estimated and they give the actual magnitude of the effect of changes in an explanatory variable on the probability of adopting an alternative irrigation technology. Following from Greene (2003), this is estimated using the following specification

$$\delta_j = \frac{\partial P_j}{\partial x_i} = P_j\left(\beta_j - \sum_{k=0}^{J} P_k\beta_k\right) = P_j(\beta_j - \bar{\beta}) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots .7$$

It must be emphasized that the signs of the marginal effects and respective coefficients may be different, as the former depend on the sign and magnitude of all other coefficients (Greene, 2003).

The irrigation technologies available and with potential in urban vegetable production in Ghana include drip irrigation, sprinkler irrigation, motorized pump with hose, flooding, watering can and bucket. However the current study considered the watering can, the flooding and the motorized pump with hose; these irrigation technologies were identified on the urban vegetable farms visited in Accra during a pre-data collection and other workshop activities.

The dependent variable therefore comprised motorized pump with hose, flooding and watering can irrigation technologies. As stated earlier, watering can was used as the base alternative with the other technologies. The details are presented in Table 1 below.

Table 1 Description of the dependent variable

Value of Y	Description of Y (type of irrigation technology)
Y = 0	Bucket/Watering can
Y = 1	Flooding
Y = 2	Motorized pump with hosepipe

The description and measurement of the explanatory variables comprising socioeconomic characteristics of the urban vegetable farmer and technical and institutional factors are shown in Table 2.

Table 2 Determinants of farmers' choice of alternative irrigation technologies

Variable	Description	Measurement
FMSZ	Farm size	Hectares
NEXT	Number of extension contacts in a year	Number of times
CRDT	Access to credit	Dummy: 1 = yes, 0 = no
HHSZ	Household size	Number of members
LBC	Labour cost of farm operations	Amount in Ghana cedis
DIST	Distance to the source of irrigation water	Distance measured in meters
OFAI	Off farm income	Dummy: 1 = if respondents has off farm income, 0 = no
RIVE	Source of irrigation water	Dummy: 1 = river, 0 = otherwise
FBO	Membership of an FBO	Dummy: 1 = yes, 0 = no
SOIL	Quality of the soil	Dummy: 1 if the soil is perceived to be good and 0 otherwise
SLOPE	Slope of the land	Dummy: 1 if the slope of the land is flat and 0 otherwise

The empirical multinomial logit model for the choice of irrigation technologies is given as follows

$$ln\left[\frac{P_{ij}}{P_{ik}}\right] = \beta_0 + \beta_1 EDUC + \beta_2 FMSZ + \beta_3 NEXT + \beta_4 CRDT + \beta_5 HHSZ + \beta_6 LBC + \beta_7 DIST + \beta_8 OFFI + \beta_9 RIVE + \beta_{10} FBO + \beta_{11} SOIL + \beta_{12} SLOP \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots .8$$

3.3 Data Source and Study area

The study was conducted in Accra which is the capital city of Ghana within the Accra Metropolitan Assembly (AMA The primary data used in the study was collected through questionnaire administration to urban vegetable farmers in Accra. Initially, a workshop was organized for farmers in Korle-bu and Dzorwulu to have first knowledge of farming operations and innovations in urban vegetable production in the study area. Farmers were then randomly selected with special consideration given to the number of urban vegetable farmers in the communities involved. The questionnaires solicited information on their socioeconomic characteristics; irrigation technologies used; land, soil characteristics and inputs used in production; output from urban vegetable production and some institutional factors relevant to achieving the objectives of the study. The vegetable growing areas in urban Accra included in the study comprised Dzorwulu, Airport residential area, La, Korle-bu, Plant-pool, Roman Ridge, Marine drive and Motorway that are located in 4 out of the 11 municipal assemblies and sub-metros in Accra. These 4 are the main vegetable producing sub-metros in Accra (Obuobie *et al*., 2006). The details of the communities visited within the study area as well as the samples taken from each community are given below.

Table 3 Districts and community of Respondents

Sub metro	Frequency	Percent	Community	Frequency	Percent
Ayawaso West	57	53.3	Dzorwulu	18	16.8
			Plant pool	6	5.6
			Roman ridge	12	11.2
			Airport residential area	14	13.1
			Motorway	7	6.5
La	18	16.8	La	18	16.8
Osu Klottey	16	15.0	Marine drive	16	15.0
Ablekuma South	16	15.0	Korle-bu	16	15.0
Total	**107**	**100**		**107**	**100**

Source: Author's computation from field Data

4 Results and Discussions

In this section, the results of the study are presented and discussed. Given that farmers use combination of irrigation technologies on the same farm land at different times during the production season, it was difficult to measure the dependent variable. In this case, the farmer was asked to indicate which technology he used most during the production season. Table 4 below gives the details of the use and mostly used irrigation technologies in urban vegetable farming in Accra. The descriptive statistics of the variables relevant for the study are also presented in table 5 below.

Table Irrigation technologies used and mostly used by respondents

Irrigation Technology	Used		Mostly Used	
	Frequency	Percent	Frequency	Percent
Watering Can	90	84.1	59	55.1
Flooding	17	16.8	17	15.9
Motorized Pump with Hose	34	31.8	31	29.0

Source: Author's computation from field data

Table 5 Descriptive statistics of the variables included in the study

Variable	Min.	Max.	Mean
Age	18	80	41.09
Years of education	1	19	9.05
Household members who work on the farm (#)	1	4	1.23
Household size (#)	1	15	4.95
Distance to source of water (meters)	4	99	29.64
Total land holding (ha)	0.01	4.0	0.28
Number of hired labors per season	1	12	1.50
Labor cost of farm operation per year	20	900	133.37
Amount of inorganic fertilizer used per year (Kg)	3	800	140.68
Amount of organic fertilizer used per year (Kg)	75	7500	1523.89
Yearly income from vegetable (GH¢)	200	23,147	4889.83
Number of extension visits per year	1	52	11.62
Amount of credit received per year	30	1000	379.15

Source: Author's computation from field data

4.1 Multinomial Logit Estimates of the Determinants of Choice of Irrigation Technologies of Urban Vegetable Farmers

A multinomial logit modeling approach was employed to identify the determinants of choice of irrigation technologies of urban vegetable farmers in Accra. In estimating the multinomial logit model for this study a normalizing procedure was undertaken where the watering can irrigation technology was normalized and used as the "reference point"or category with which the other irrigation technologies were compared. The results are presented in Table 6 and Table 7 below.

The chi-square value of 136.406 which is the likelihood ratio statistic is highly significant at the 1 percent significant level. This indicates that the explanatory variables included in the multinomial logit model jointly influence the farmer's choice of alternative irrigation technologies in urban vegetable farming.

Table 6 Multinomial logit estimates of the determinants of choice of irrigation technologies of urban vegetable farmers

	Flooding		Motorized pump with hose	
Variable	Coefficient	Std. Errors	Coefficient	Std. Errors
C	-6.8925	2.5962	-3.8376	1.5618
Education	3.0244*	1.8297	0.9005	1.0287
Farm size	11.9699***	3.6351	4.9408**	2.3404
Extension	0.0125	0.0984	0.0116*	0.0339
Credit	-0.8033	1.4232	0.8927**	0.7133
Household size	-0.5887*	0.3569	-0.1122	0.1391
Labour cost	-0.0050	0.0144	0.0091*	0.0052
Distance to water source	0.0256	0.0231	0.0077	0.0146
Off farm income	-0.2983	1.519	0.0078	0.7775
Source of water	1.9126	1.9387	4.7159***	1.2366
Member of an FBO	0.8031	1.3723	0.7087	0.8017
Perceived quality of soil	3.1812*	1.7399	-0.3180	0.7459
Slope of land	-0.5226	1.5423	-1.3105	0.8593

Base category watering can
Chi squared 136.406
Prob [ChiSqd > value] 0.0000
Pseudo R-squared 0.64339
Mean predicted probability; watering can = 0.5421, flooding = 0.1682, motor pump with hose = 0.2897

*, ** and *** means significant at the 10%, 5% and 1% probability level, respectively

Table 7 Marginal effects of the multinomial logit model for choice of irrigation technologies

Variable	Watering can	Flooding	Motorized pump with hose
Education		0.098	
Farm size	-0.133	0.373	0.958
Extension			0.002
Credit			0.191
Household size		-0.020	
Labour cost			0.002
Source of water	-1.047		1.039
Perceived quality of soil		0.120	

The corresponding Pseudo R-squared is 0.64339. This means that about 64 percent of the variation in the choice of alternative irrigation technologies is explained by the full set of the independent variables. The mean predicted probability of choice of irrigation technology options were 0.5421 for watering can, 0.1682 for flooding and 0.2897 for the motor pump with hose irrigation technology.

Farm size positively influences the probability of an urban vegetable farmer choosing the flooding and the motorized pump with hose irrigation technologies relative to the watering can. The marginal effect indicates that, an additional hectare of land under urban vegetable farming will increase the probability of adoption of the flooding and the motorized pump with hose irrigation technologies by 0.37 and 0.96 respectively compared to that of the watering can. This result conforms to earlier findings such as Green *et al*. (1996) who found a positive significant effect of farm size on the probability of adoption of sprinkler and drip irrigation technologies and a negative effect on the probability of choice of the flooding irrigation technology. This indicates the vital role played by farm size in the adoption of agricultural technologies.

The number of annual extension visits received by the farmer had no significant effect on the farmers' decision to choose flooding but had a positive significant effect on the probability of choice of the motorized pump with hose irrigation technology relative to the watering can. This result is expected considering the continuous interaction of the extension agents with these farmers. Similarly, the credit variable which measures whether or not the farmer had access to credit of any form, had a significant positive effect on the probability of choice of the motorized pump with hose irrigation technology. This means that the farmer's decision to adopt the motorized pump with hose relative to the watering can will increase as the farmer gets access to credit to invest in this irrigation technology. Thus urban vegetable farmers will invest any available credit in a more sophisticated motorized pump irrigation technology rather than go for the flooding. Also the positive sign of credit access on the marginal effect value of watering can indicates that farmers in the study area tend to use certain proportion of available credit in purchasing watering cans for irrigation. This is not surprising as it is used in combination with the other irrigation technologies. This result conforms to earlier findings such as Foltz (2003) who found a positive significant effect of access to credit on farmer's adoption of water-saving irrigation technologies in Tunisia. He finding indicate that farmers who have greater knowledge of the technology and have access to sufficient capital tended to be earlier adopters of drip irrigation. In a related study, Deressa *et al*. (2008) found a positive significant effect of credit access on the choice of irrigation as an adaptation strategy to climate change in Ethiopia. The current result indicates the important role increased institutional support will play in choice of irrigation technologies in Accra.

The source of the irrigation water (which took a value of 1 for river and 0 otherwise) had a positive significant effect on the probability of adopting the motorized pump with hose irrigation technology but had no significant effect on that of the flooding irrigation technology. This result is not the first of its kind as Green *et al*. (1996) found a positive relation between surface water as source of irrigation water and the probability of choice of drip irrigation technology and a negative effect on the probability of choice of sprinkler irrigation technology in Central California. Similarly, Caswell and Zilberman (1985) found a positive relation between ground water and the choice of sprinkler and drip irrigation technologies in California. In case of the current study, the significant of the source of irrigation water in the choice of irrigation technologies means that year round water availability (in the form of river flowing year round) is a requirement for the use of the more sophisticated irrigation technologies.

The number of years of education had a positive significant effect on the probability of choice of the flooding irrigation technology and no significant effect on that of the motorized pump with hose irrigation technology. This is against the background that education plays a significant role in technology adoption. However, the effect of education on the choice of agricultural technologies has been mixed in the literature. For instance, Deressa *et al*. (2008) observed a positive significant effect of education on the choice of adaptation measures in Ethiopia. Similarly, Larson *et al*. (2001) found education to have no significant effect on the choice of adaptation measures to urbanization in Pennsylvania. However, in general, education favors rather than hinders adoption of improved technologies.

Household size which in adoption literature tend to decrease the adoption of labor-saving technologies, is significant and negative in the case of the flooding but has no significant effect on the choice of the motorized pump with hose irrigation technology. The negative effect means that as the size of a particular respondent's household increases, the farmer will choose to use the flooding irrigation technology to the watering can. The positive coefficient of the marginal effects of household size on the probability of choice of watering can attests to the fact that the use of watering can is tedious and hence requires more labor to do that. This also confirms why watering can irrigation technology users spend most of their time on irrigation.

The labor cost of farm operations had a significant positive effect on the probability of adoption of the motorized pump with hose irrigation technology. The higher the labor cost of farm operations (including the labor cost of irrigation), the greater the probability of the farmer choosing the flooding irrigation technology that is less labor demanding to the watering can. This result is in line with earlier researchers as Zibaei and Bakhshoodeh (2008) found a positive relation between labor cost and adoption of sprinkler irrigation technology in Iran.

The slope of the vegetable farming land is negatively related to the choice of the flooding and the motorized pump with hose irrigation technologies although the coefficients are not statistically significant. This result is not surprising as the effect of field slope on the choice of irrigation technologies have been contradictory in the literature. For instance Zibaei and Bakhshoodeh (2008) found a significant negative effect of the slope of the land on the adoption of sprinkler irrigation technology in Iran. However, Green *et al*. (1996) found a positive relation between field slope and the choice of sprinkler and drip irrigation technologies in Central California.

Membership of a farmer based organization had the expected positive sign but no significant effect on the choice of the flooding and the motorized pump with hose irrigation technologies. However, from the positive sign, it can be inferred that social networks increase awareness and use of irrigation technologies.

5 Conclusions

Urban vegetable production forms an integral part of some urban dwellers in Accra. Irrigation is a key requirement for stable yield due to the low rainfall regime of the Accra metropolis. This study modeled the determinants of the choice of alternative irrigation technologies of urban vegetable farmers in Accra. The study considered the watering can, flooding and the motorized pump with hose irrigation technologies. Though the motorized pump with hose is seen as the most recent and modern irrigation technology among the study’s relevant technologies, the mostly used irrigation technology by urban vegetable farmers in the study area was watering can (55.1%), followed by the motorized pump with hose (29%) and the flooding (15.9%).

The multinomial logit modeling approach was employed to identify the determinants of choice of irrigation technologies of urban vegetable farmers in the study area. The watering can irrigation technology was normalized and used as the reference point for which the other irrigation technologies were compared.

Based on the findings, the following conclusions can be drawn from the study. Farmers use diverse irrigation technologies (watering can, flooding and motorized pump with hose). The significant determinants of choice of the motorized pump with hose were farm size, access to credit for urban vegetable farming, number of extension contacts received by the farmer and river as the source of irrigation water. Thus, farmers who have access to credit, frequently contact extension agents, operate larger farm size, have high labor cost for farm operations and use river as key source of irrigation water were likely to use the motorized pump with hose irrigation technology.

Similarly the significant determinants of farmer's adoption of the flooding irrigation technology were household size, the perceived quality of soil, farm size and the years of education of the farmer. Extension agent's visits to these farmers are vital in disseminating information on the motorized pump with hose irrigation technology and other modern irrigation technologies so as to increase their probability of adoption. Given the vital role of farm size and the fact that urbanization is craving most of the agricultural land in urban Accra, the government, development partners and the farmers should collaborate to secure land just outside the Accra city so that these farmers can expand their farms, adopt modern irrigation technologies and increase the cultivation of vegetables for the city's consumption.

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