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Determinants of improved chickpea variety adoption in high barind region of Bangladesh

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A B S T R A C T

Chickpea production in Bangladesh has been decreasing over time. Comprehensive farm-level adoption of modern chickpea varieties can change the scenario. This paper endeavours to ascertain the determinants of adoption and adoption intensity of improved chickpea variety in the high barind region of Bangladesh. The outcomes from Cragg's double hurdle model showed that organization membership, information sources, crop diversification index, and village location are the crucial factors that positively influenced both the adoption and adoption level. Farmers with organization membership are 15.5% more probable to adopt improved chickpea while by adding one more information source, the adoption probability can be increased by 6.3%. Meanwhile, women's decisions, training, credit accessibility, and farm size have effects only in favour of initial adoption. The adoption probability is approximately 15% more in the household where women can participate in the decision-making process. Adopters with higher formal education, off-farm income, and mobile usage capability devote a greater proportion of their land to the improved variety cultivation. Strengthen of the network among farmers and their information sources should be emphasized to stimulate the diffusion process of the improved chickpea variety. Besides, training should be available for both female and male of the farm families since women also affect the adoption decision.

Keywords: Adoption level, Adoption probability, Cragg's double hurdle model, High barind region, Improved chickpea variety.

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Introduction

Chickpea (*Cicer arietinum)* is the third important food legume after dry bean and pea in the world which covered almost 20% of world pulse production (Akibode and Maredia, 2012; Mazid *et al.*, 2009). Although worldwide chickpea production was only 8.34 million tons in 1997, it surged up to 14.78 million tons in 2017 (FAO, 2019). The area and production of chickpea have increased over the years in the world. Alternately, those digits have dipped over time in Bangladesh because of reducing agricultural land and enhancing the production of rice. The country experienced 61,485 tons chickpea with 84,435 hectares of land in 1997. Nonetheless, in 2017, land under chickpea decreased to only 5,917 hectares which provided 6,237 tons chickpea even though yield soared from 0.73 to 1.05 t ha^{-1} over those two decades. In order to fulfill the consumption demand, Bangladesh imported 190,322 tons chickpea in 2017. The fact of the concern is that the imported amount of chickpea was 96% of the total chickpea supply in the market in that year (FAO, 2019). Hence, it is urgent to raise the production of chickpea to combat the import bill of the country. Increasing productivity of chickpea through inaugurating improved variety can be a potential way to reduce the import cost.

Most of the chickpea in Bangladesh have been grown in the high barind tract, which includes Rajshahi, Chapai-Nawabganj, and Naogaon districts (Rashid *et al.*, 2017). The undulating, dry and less fertile part of the barind region is acquainted as the high barind tract (HBT). The HBT area is characterized by low average annual rainfall (1363 ± 311 mm) and high summer temperature (BMDA, 2019). In northwestern Bangladesh, about 800,000 hectares of land of the high barind tract remain fallow after transplanted aman rice cultivation for lack of irrigation facilities that potentially be utilized by chickpea cultivation (ICRISAT, 2017). Chickpea is attractive in this context because of its capability to yield well on residual moisture, its low input requirements and high market price (Saha, 2002). As a legume, Chickpea is a deep rooting crop that has a sound effect on soil fertility, particularly through its capacity to fix aerial nitrogen. Furthermore, it can endure a certain degree of high temperature in comparison to other cool-season legumes (Ali, 2000). Therefore, it has a high potential to uplift the livelihoods of poor farmers in the high barind region of Bangladesh (Socioconsult, 2006).

Despite the most chickpea producing area in Bangladesh, chickpea cultivated land has plummeted to only 924 hectares (2018-19) from 2,810 hectares (1998-99) in Rajshahi. While in 2018-19, the productivity was 1.31 t ha^{-1}, which was not only the highest in the last two decades but also more than the average yield of the country (DAE, 2019). The reason behind raising yield is the adoption of modern chickpea varieties that have higher productivity as well as diseases and drought resistance characteristics. BARI Chola-5 is one of the improved chickpea variety which was developed by the Bangladesh Agricultural Research Institute (BARI) in 1996. The plant of this variety is slightly bushy with 45-50 cm height and 1000 seed weight is about 110-120 grams. Additionally, the yield rate of this variety is 1.8 to 2.0 t ha^{-1} (Digital Herbarium of Crop Plants, 2019). BARI Chola-5 was the most adopted variety followed by BARI Chola-3 and BARI Chola-9 in the barind region in 2014. Besides, the profitability of developed chickpea variety (2.1) was more than the traditional variety (1.9) (Rashid *et al.*, 2014). Again, Saha (2002) found that chickpea was more profitable than boro rice, wheat and linseed in the same region. Notwithstanding, a broad range of works has been done on the adoption of agricultural technology, none of these works focused on the determinants of improved chickpea variety adoption in Bangladesh. Only one founded work explored the determinants of modern chickpea variety adoption but that study was accomplished in Ethiopia.

Verkaart *et al.* (2017) revealed that access to technology transfer, access to improved seed, asset ownership, average rainfall boost the planting decision of improved chickpea whereas, household size, asset ownership, and land ownership positively affect the planting area under improved chickpea. On the other hand, off-farm income and age of household head negatively affect adoption and adoption levels consecutively in Ethiopia. Meanwhile, in the case of potato, modern variety selection decision is positively affected by the gross return from potato. In contrast, the adoption of that variety is negatively related to farmer's age, labour wage, and seed price (Begum *et al.*, 2018). While, Anik and Salam (2015) found that extension services and credit access are the two most significant factors to increase adoption probability and adoption level of modern onion varieties. Moreover, more experienced and educated farmers who performed more crop diversification practices tended to devote a higher share of land to improved onion varieties. On the contrary, more off-farm income and the number of fragmented lands reduced adoption probabilities. Ghimire *et al.* (2015) also assessed almost the same results about the modern rice varieties adoption in Central Nepal. Results disclose that education, extension services, farm size, and seed access positively affect adoption decisions. In addition, technology-specific variables like yield potential and acceptability are significant to explain the adoption behaviour of farmers. In the same way, available credit, farm income, higher profit potentiality, and health costs encouraged farmers to adopt Bt cotton in North Indian (Mal *et al.*, 2013). They also evaluated that, farmers with poor-quality soil were more likely to adopt with a greater proportion of land. Nevertheless, the experience was a barrier to Bt cotton diffusion in North India. Another study was conducted by Miah *et al.* (2004) to know the adoption of improved pulses in Bangladesh. They stated that farmer's age, time spends in agricultural activities as well as the influence of family members, neighbours and DAE personnel affect in favour of adopting BARI Mash 1, 2 and 3, BARI Lentil 4, BARI Mung 4 and 5.

Our work can contribute to these remaining research pools in various ways. At first, we not only identify the factors that affect adoption probability, but also the determinants of the adoption level of improved chickpea variety in farmer's field. Secondly, no literature has not addressed the influence of women and farmer's mobile usage ability on adoption decisions until now, although these might have meaningful effects. In this study, we try to find out the effect of these variables on the adoption and adoption level of improved chickpea variety.

Methodology

Data and survey

A farm-level survey was conducted for collecting primary data through a multi-stage sampling technique. At first, district, upazila, and villages were purposively selected to reveal most chickpea growing areas in Bangladesh (i.e. 11 villages of Godagari and Tanore upazila of Rajshahi district). After that, the simple random sampling technique was applied to select samples from the list of farmers of those 11 villages those were collected from Rajshahi regional office, Department of Agricultural Extension (DAE). A total of 180 farmers were interviewed about chickpea production in 2018-19 cropping year, among them, 120 respondents were improved chickpea variety growers and 60 respondents were local chickpea variety growers. For this study, the BARI Chola-5 variety was considered as the improved chickpea variety. The first and second time lengths were from the 11-18 March and 9-18 June of 2019, respectively.

Determining factors affecting adoption and adoption level

In this study, the empirical analysis aims to identify the determinants of improved chickpea variety adoption and adoption level. Among our surveyed chickpea growers, some cultivate improved chickpea variety (adopters), while others cultivate local variety (non-adopters). In addition, the adoption levels are diverse among the adopters. Hence, we have two questions to answer: (i) why are some of the chickpea growers adopting improved variety and some do not? and (ii) why does the adoption level vary among the adopters? In order to answer these questions, we can use a Cragg's Double hurdle model or Heckman selection model. According to Jones (1989), the essential difference between these two models is the source of zero. In the Heckman model, the non-adopters will never adopt under any cases. Alternately, in the double hurdle model, non-adopters stay as a corner solution in a utility-maximizing model. The assumption of Heckman's seems obstructive and inverse mills ration (IMR) of this model is insignificant for these samples. So that, we employ the more flexible two-tier truncated or simply called double-hurdle (DH) model to estimate the improved chickpea variety planting decision.

The most underlying assumption of the model is that adoption and adoption level is supposed to be independent which means two decisions are made in two different stages (Cragg, 1971). At the beginning of a cropping season, farmers may decide to cultivate improved chickpea variety without making exact plans about the quantity of land. After that, they may ascertain the specific amount of land for modern chickpea variety. In agricultural economics, the use of Cragg's model for evaluating adoption and adoption level is common (Verkaart *et al.*, 2017; Mal *et al.*, 2013; Gebregziabher and Holden, 2011; Shiferaw *et al.*, 2008; Teklewold *et al.*, 2006). The first stage or tier 1 of Cragg's two-tier model is a Probit model to find out the determinants of adoption. While, the second stage or tier 2 is a Truncated model, which follows truncated normal distribution for identifying determinants of adoption intensity (Cragg, 1971). If d_i^* is the latent variable indicating the decision to adopt improved chickpea variety, whereas, y_i^* is the latent variable which mentions adoption level decision, and d_i and y_i are their observed counterparts, respectively. Based on the specification by Cragg (1971), the two hurdles can be written as

$$d_i^* = \alpha z_i + v_i \qquad (1)$$
$$y_i^* = \beta x_i + \varepsilon_i \qquad (2)$$

Where,

$$d_i = \begin{cases} 1, & if\ d_i^* > 0 \\ 0, & if\ d_i^* \le 0 \end{cases}$$

And

$$y_i = \begin{cases} y_i^*, & if\ y_i > 0\ and\ \ d_i > 0 \\ 0 & if\ otherwise \end{cases}$$

Where, z_i is the vector of variables explaining whether a farmer adopts improved chickpea variety or not and x_i is the vector of variables that illustrate the level of adoption. Table A.1 in the appendix presents the dependent and explanatory variables used in the double hurdle model. The same set of explanatory variables is used in both stages because the variables illustrating adoption can also define adoption intensity. Equations 1 and 2 are assumed independent, and therefore the error terms are randomly and independently distributed, $v_i \sim$ N (0, 1) and $\varepsilon_i \sim$ N $(0, \sigma_\varepsilon^2)$. The log-likelihood function for this version of Cragg's model assumes the Probit and Truncated regressions to be uncorrelated and is given as

$$L = \prod_{y_i - 0} \left[1 - (z_i\alpha)\Phi(\frac{x_i\beta}{\sigma})\right] \prod_{y_i > 0} \Phi(z_i\alpha)\sigma^{-1}\varphi\left(\frac{y_i - \beta x_i}{\sigma}\right) \qquad (3)$$

Where, Φ and ϕ are the standard normal cumulative distribution function and density function, respectively (Carroll *et. al.*, 2005). The log-likelihood function is estimated by using the maximum likelihood estimation (MLE) technique.

The Probit mechanism can be absent ($d_i^* > 0$) from the double-hurdle model when the decisions about adoption and level of adoption are made simultaneously. In this case, the hurdle model is reduced to the Tobit model and $\Phi(z_i\alpha) = 1$ in the log-likelihood function presented in Equation 3. The Tobit model arises if $\alpha = \beta/\sigma$ and $x = z$ (Martínez-Espiñeira, 2006). We compare these two models through a standard likelihood ratio test because the determinants in both hurdles are the same (Buraimo *et al.*, 2010). The test statistics can be computed as Greene (2000):

$$\Gamma = -2[lnL_T - (lnL_P + lnL_{TR})] \sim \chi_k^2 \qquad (4)$$

Where, L_T, L_P and L_{TR} are log-likelihoods of the Tobit, Probit, and Truncated regression models, respectively. The null hypothesis is rejected ($\Gamma < \chi^2_k$) which proclaims the supremacy of the Cragg's model over the Tobit model. Hence, the sample farmers decide about adoption and level of adoption in different stages.

Results and Discussion

Summary statistics of explanatory variables

The summary statistics of independent variables used in the econometric analysis are shown in Table 1. The table reveals that the differences between adopters and non-adopters are significant for all explanatory variables except experience and off-farm income. In the case of formal education, the adopters passed more years of formal school than non-adopters did. In the family of adopters, the women are more likely to have the ability to visualize their decision about agriculture such as which crops and varieties should be grown in next season along with taking a loan for agricultural purposes. Less proportion of adopters depends on agriculture as their primary occupation. Compared to non-adopters, the adopters get more training and have more information sources that help them to know about new agricultural technologies. Additionally, a higher proportion of adopters are capable to use mobile phone facilities. Moreover, the number of farmers related to any local organization is about three times higher in the adopter group. These organizations mainly provide different services to their members, for instance, deposit and credit facilities. The value of the crop diversification index reflects that the adopters used to cultivate various types of crops, which may motivate them to adopt improved variety. The adopters have two times credit accessibility than the non-adopters. Again, the adopters have a bigger farm than non-adopters according to farm size. The statistics of village location disclose that the adopter's houses are nearer to the main road, while non-adopters lived in the villages far away from the main road (Table 1).

Table 1. Summary statistics of explanatory variables for adopters and non-adopters.

Items	Adopter	Non-adopter	Mean difference
	(N=120)	(N=60)	(N=180)
Education	7.13 (3.65)	5.93 (3.16)	1.20(0.55)**
Farming experience	14.30 (8.82)	15.80 (9.03)	1.50(1.40)
Women's decision	0.62 (0.49)	0.43 (0.49)	0.18(0.08)**
Main occupation	0.80 (0.40)	0.88 (0.32)	0.08(0.06)*
Off-farm income	0.23 (0.42)	0.25 (0.44)	0.02(0.07)
Mobile usage ability	0.89 (0.78)	0.68 (0.72)	0.21(0.12)*
Training	2.09 (1.47)	1.22 (0.88)	0.88(0.21)***
Organization membership	0.40 (0.49)	0.12 (0.32)	0.28(0.07)***
Information sources	3.31 (1.33)	2.12 (1.14)	1.19(0.20)***
Crop diversification index	0.73 (0.07)	0.69 (0.08)	0.04(0.01)***
Credit access	0.68 (0.47)	0.33 (0.48)	0.35(0.07)***
Farm size	6.48 (2.82)	4.16 (1.76)	2.31(0.40)***
Village location	1.70 (0.66)	1.52 (0.77)	0.18(0.11)*

*Note: Figures in parentheses are standard deviations. *, **, and *** imply that mean differences between the adopters and non-adopters are significant at the 10%, 5%, and 1% confidence levels, respectively.*

Determinants of adoption and adoption level

Table 2 represents the factors that influence the adoption decision of improved chickpea variety. The adoption probabilities are ascertained through the first stage of Cragg's double-hurdle model, which is the Probit model. Whereas, the Truncated regression model identifies the factors that affect the adoption level of modern chickpea variety. The adoption probability decision of farmers is positively influenced by women's decision-making ability about agriculture, training, organization membership, information sources, crop diversification index, credit access, farm size, and village location. On the contrary, farmers with more off-farm income tend to adopt less. While the farmer's education, mobile usage ability, main occupation are insignificant in the Probit model. Besides, the farming experience of farmers is insignificant in both stages of the model. The results of the Truncated regression model reveal that farmer's education, main occupation as agriculture, off-farm income, mobile usage ability, organization membership, information sources, crop diversification index and village location positively affect the adoption level of improved chickpea variety (Table 2).

Farmer's education level does not affect the adoption probability rather than positively influences the decision of adoption level of improved chickpea variety (Table 2). Most of the studies have proved that the education of farmers and adoption intensity of new agricultural technology has a positive association (Begum *et* *al.*, 2018; Ricker-Gilbert and Jones, 2015; Bezu *et al.*, 2014; Mariano *et al.*, 2012). Education makes farmers more compatible to accumulate information and knowledge about new agricultural practices. Therefore, educated farmers quickly understand specific varietal characteristics that push them to cultivate more improved chickpea variety.

The adoption probability increases considerably when women of the farm families (mainly farmer's spouses) can make decisions about agriculture (Table 2). Nonetheless, it has no impact on the adoption rate because women are not concern about the quantity of land and reluctant to give the specified decisions about the proportion of land under different varieties. Some researchers have noticed a positive association between the influences of family members and improved variety adoption (Miah *et al.*, 2004). Meanwhile, others have found a negative correlation between male-headed households and modern technology adoption (Verkaart *et al.*, 2017; Ogada *et al.*, 2010).

When farmers occupy agriculture as their primary occupation, it has a highly significant and positive impact on the adoption intensity (Table 2). Those farmers are more conscious to adopt any new agricultural technology but once they adopt and comprehend its benefits, they tend to adopt more of that technology to gain more profit.

The farmers with off-farm income are 16% lesser probable to adopt improved chickpea than the farmers with no off-farm earnings (Table 2). One study divulged a negative correlation between off-farm activities and adoption decisions (Ghimire *et al.*, 2015). The farmers who have off-farm income sources are indolent to adopt improved chickpea variety due to the devotion of non-agricultural activities that provide them with more profit. However, the adoption level is tended to high among those kinds of farmers likewise the outcomes of other researches (Mal *et al.*, 2013; Knowler and Bradshaw, 2007). When those types of farmers adopt the improved variety, they adopt more than others because they try to make a better amount of yield with less effort.

Mobile usage ability reflects the ability of farmers to use mobile money transfer services and the internet by which they stay connected with the input dealers, extension officers, and other information sources. This variable has a positive relationship with the adoption rate (Table 2). By using mobile effectively, farmers can swiftly receive agricultural information that may influence the adoption level of modern chickpea. Alternately, the number of training received by farmers only influences the adoption probability. The adoption possibilities increase on an average of 6% if the farmers are provided one more training (Table 2). This result is consistent with the works of Gauchan *et al.* (2012) and Mariano *et al.* (2012). The sample farmers mainly accomplish training about specific agricultural practices that motivates them to adopt improved variety.

Table 2. Determinants of adoption probability and adoption level identified by the Cragg's double-hurdle model.

Variables	Probit		Truncated
	Coef. (S.E.)	Marginal effect (S.E.)	Coef. (S.E.)
Education[a]	0.02 (0.04)	0.004 (0.008)	0.81* (0.47)
Farming experience[a]	-0.02 (0.02)	-0.004 (0.004)	0.07 (0.22)
Women's decision	0.79*** (0.31)	0.153*** (0.056)	-1.82 (3.47)
Main occupation	-0.73 (0.55)	-0.140 (0.104)	16.19*** (5.69)
Off-farm income	-0.83* (0.49)	-0.162* (0.921)	18.69*** (5.39)
Mobile usage ability	-0.31 (0.23)	-0.059 (0.044)	4.63* (2.51)
Training[a]	0.32*** (0.11)	0.062*** (0.020)	-0.69 (1.10)
Organization membership	0.80** (0.34)	0.155** (0.064)	7.88** (3.29)
Information sources[a]	0.32*** (0.11)	0.063*** (0.019)	2.80** (1.20)
Crop diversification index[a]	3.45* (1.80)	0.667* (0.336)	44.58** (22.34)
Credit access	0.59** (0.26)	0.113** (0.049)	-1.39 (3.44)
Farm size[a]	0.29*** (0.07)	0.057*** (0.012)	-0.14 (0.56)
Village location	0.40** (0.20)	0.077** (0.036)	5.62** (2.50)
Constant	-5.29*** (1.51)		5.62 (19.15)
Log-likelihood	-569.21		
Wald chi2(13)	54.63		
Prob>chi2	0.00		

*Note A: The Probit model and the Truncated regression model are tier-1 and tier-2 of Cragg's double-hurdle, respectively. Figures in parentheses are standard errors. *, **, and *** indicate significance at 10%, 5%, and 1% confidence level, respectively.*

Note B: These (a) variables were also tested in a nonlinear way but this did not improve the results of the model.

Organization membership and information sources are the two important influencers that positively affect both the adoption probability and adoption level (Table 2). The information sources provide veritable knowledge about the improved variety and its production technique that ensure farmers about the certain benefits of new technology (Ghimire *et al.*, 2015; Mal *et al.*, 2013). Besides, membership in an organization facilitates interaction with other farmers that stimulates the interest to grow modern chickpea variety (Table 2). Wossen *et al.* (2017) also found coherent results in their work.

Farmer's probability of deciding in favour of improved chickpea variety is accelerated when the sample farmers follow diversified crop production practices (Table 2). The farmers adopt developed chickpea variety with more proportion of the total chickpea cultivated land when they have a higher crop diversification index. The practice of growing more diversified crops may encourage farmers to adopt improved variety (Anik and Salam, 2015). In order to cultivate chickpea, the budget limitation is one of the constraints for the farmers of the high barind region after costly rice production. Access to formal credit can help at that time to adopt developed chickpea variety (Table 2). Mal *et al.* (2013) and Mazid *et al.* (2009) also documented in their papers about the positive relationship between credit and modern varieties adoption. Although chickpea cultivation needs less capital than other concurrent crops, the credit access assures the resource-poor farmers about the financial need at the harvesting time of the production season.

The variable of farm size positively affects the adoption possibility of improved chickpea variety (Table 2). If the farm size is expanded by an extra one acre, the adoption probability enhances about 6%. Since the large farmers are more capable to experiment with new varieties due to their higher risk-taking ability and better financial resources, they may adopt new technologies faster than the way of small farmers (Gauchan *et al.*, 2012; Mariano *et al.*, 2012; Langyintuo and Mungoma, 2008). In rural Bangladesh, where farm size is generally small and agriculture does not fully commercialize, farmer's priority is rice as the staple food after which legumes and other cash crops come. Consequently, adoption becomes more difficult in relatively small farms.

The sample farmers who live in the nearer villages to highway and market tend to adopt improved chickpea variety with more land (Table 2). This variable is considered as a proxy variable of farmer's access to input and output markets. The households far from the markets are less likely to adopt the improved variety because of their poor access to new seed, high search cost and time, and high transaction cost for selling surplus produce. Some shreds of evidence are found out a negative correlation between distance to market and area under improved variety cultivation (Ghimire *et al.*, 2015; Ricker-Gilbert and Jones, 2015).

Conclusion

This article is an attempt to reveal the influential factors of improved chickpea variety adoption and adoption level in the high barind drought-prone area of Bangladesh. The empirical findings reflect that organization membership, information sources, crop diversification practices, and location play a crucial role to increase not only the adoption possibility but also the adoption rate of improved chickpea variety. Furthermore, training, credit accessibility and farm size have affirmative effects only on the adoption probability. Intensive and need-based training should be provided to farmers about specific production techniques and modern technologies to ameliorate the improved chickpea variety adoption scenario. Women in the studied community also have an impact on the adoption possibility, which is a good indicator of women empowerment. Agricultural knowledge of farm family's women should be enriched by various training so that they can make specified agricultural decisions for the betterment of farm families. Along with that, farmers with off-farm income are less likely to adopt but the adoption intensity tends to be more among those types of farmers. Meanwhile, education, primary occupation as agriculture and mobile usage capability of farmers affect in favour of the planting area of improved chickpea. Therefore, education should be mandatory to all people in the rural area as well as appropriate programs are needed to educate the adult farmers.

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Appendix

Table A.1 Description of explanatory variables used in the econometric analysis.

Dependent variable	Description and measurement
Adoption of improved chickpea variety	Dummy, if yes=1, otherwise=0
Adoption level of improved chickpea variety	Percentage of land under improved variety among total land under chickpea
Explanatory variable	Description and measurement
Education	Passed year(s) of formal schooling by farmers
Farming experience	Farming experience of farmers (years)
Women's decision	Dummy, if the woman of the farm family can make decisions about agriculture=1; otherwise=0
Main occupation	Dummy, agriculture=1; otherwise=0
Off-farm income	Dummy, if yes=1; otherwise=0
Mobile usage ability	Having mobile money transfer account and can use the mobile internet =2; having mobile money transfer account or can use the mobile internet =1; none of this=0
Training	Number of training received by farmers
Organization membership	Dummy, having any organization membership=1; otherwise=0
Information sources	Number of information sources farmers have
Crop diversification index	Crop diversification index (CDI) $CDI = 1 - HI$; Here, HI =Herfindahl index; HI is calculated from the primary data
Credit access	Dummy, farmers have formal credit access=1; otherwise=0
Farm size	Farm size in acres
Village location	Villages that are located beside the main road=3, villages that are located after the "3" categorized villages =2, villages that are located after the "2" categorized villages=1