Journal of Agriculture and Environmental Sciences
March 2014, Vol. 3, No. 1, pp. 23-37
ISSN: 2334-2404 (Print), 2334-2412 (Online)

American Research Institute for Policy Development
42 Monticello Street, New York, NY 12701, USA.
Phone: 1.347.757.4901 Website: www.aripd.org/jaes

Harvesting Technology Adoption among Irrigated Rice Farmers on the Kpong Irrigation Project in Ghana

Justice G. Djokoto[1] and Seth Blackie[1]

Abstract

Farmers have cultivated rice on the Kpong Irrigation Project (KIP) since 1997 using manual methods of harvesting. In order to reduce the drudgery, improve quality and reduce field losses,mechanised harvesting technology was introduced tofarmers on the project. The study examined the factors that influenced the adoption of mechanised harvesting technology among irrigated rice farmers operating on the KIP. From a sample of 99 farmers, 60% of farmers used mechanised harvesting technology. Plot size, gender of farmer, household size and level of formal education influenced adoption of mechanised harvesting technology. Plot size influenced adoption most. Age, source of capital, marital status and experience in cultivating rice did not influence adoption of mechanised harvesting technology. Since increasing plot size in the scheme design may not be possible, adequate information on availability of sublease plots should be made available. Subsequently, in designing irrigated rice schemes, consideration should be given to higher plot sizes than currently obtains at KIP. Persons with higher levels of formal education should be encouraged to go into irrigated rice farming on the KIP facility. Government should improve rural infrastructure to encourage young persons to remain in agriculture in the KIP area.

Keywords: Farmers, Ghana, Harvesting technology adoption, Irrigated rice, Kpong IrrigationProject

[1] Justice G. Djokoto, Department of Agribusiness, Central University College, P. O. Box DS 2310, Dansoman, Accra, Ghana, Tel: 233-28-503-7399, E-mail: dgameli2002@gmail.com

1. Introduction

1.1 Background

Harvesting is one of the terminal field activities involved in rice (*Oryzasativa*) production. Both manual and mechanised methods are employed in harvesting rice. Harvesting of rice include cutting the rice stalk or ripping the panicles, either laying out the paddy-on-stalk or stacking it to dry, bundling and transport (Khan &Salim, 2004). At the Kpong Irrigation Project (KIP) site, the process involves cutting the dry rice stalk with sickles or cutlasses by gangs and threshing. The threshing consists of hitting the grain-bearing stalk on the inside of wooden basins. The threshed grains are then winnowed by raising the grains in bowls and allowing them to fall by gravity. In the process the wind blows the chaff away. All these activities are done manually. The farmers describe this as *manpower.* As at 2012 production year, the cost of *manpower* harvesting per hectare averaged 400 Ghana cedis. Mechanised harvesting technology involves employing a small combine harvester. This harvester slashes the stalks from the hill, threshes and winnows. The products are the paddy rice (which is bagged) and the chaff left on the field. This service is currently being offered at 650 Ghana cedis per hectare. By 2012, seven combine harvesters have been brought in by private investors and three by Ghana's Ministry of Food and Agriculture (Takeshima, 2013).

1.2 Problem Statement

Since the inception of rice production on the KIP in 1997 farmers have relied on manual rice harvesting. This is associated with sizable grain losses, grain damage and additional time to harvest. A combine harvester takes a few hours to harvest one hectare whilst seven people will take two days to harvest the same area (Takeshima*et al.,* 2013). With the migration of labour out of the area to the cities for better employment opportunities, there is shortage of labour during peak rice harvesting and threshing period. This has increased the cost of harvesting and threshing services offered by the harvesting gangs. Also, there are delays in rice harvesting and threshing and thus increasing both quantitative and qualitative field losses. Though some farmers have patronised and continue to patronise the mechanised technology, others continue to use the manual technology. The question that arises is what factors account for the adoption or otherwise of the mechanised technology by the farmers?

1.3 Objectives

The study seeks to identify factors that influence the adoption of mechanised harvesting technology by irrigated rice farmers.

1.4 Relevance

Literature on reviews of technology adoption in agriculture abound. This is evidenced in papers authored by Shaw (1987), Kayizzi-Mugerwa (1998), Place *et al.* (2000), Meskens*et al.* (2001) and Suman*et al*. (2002). Others include Nlerum (2007), Liu (2011), Mazuri*et al.* (2012), Ragasa (2012), Loevinsohn (2013), Truong (2013) and Yadav (2013). However, these have not addressed harvesting technology adoption among irrigated rice farmers. The few studies on mechanised harvesting and irrigated rice production were conducted in Asia. Diagne*et al*. (2009) seemed to be the only study in Africa on the subject found by the authors. Therefore, this study contributes to the literature on the subject specifically for Ghana. Identification of factors that influence mechanised harvesting technology adoption will be useful for policy purposes.

1.5 Organisation

The remainder of the paper is sectioned into four. Review of literature is presented in section two. The research area, data and model are detailed in section three. The results of data analysis are presented and discussed in section four. The study concludes in section five with recommendations.

2. Literature

Recent studies on rice on the KIP showed that the average land area was 1.57 ha based on 70 farmers sampled in 2011 (Nimoh*et al.,* 2012). KIP (2013) have also indicated that the average farm size is one hectare whilst Takeshima*et al*. (2013) reported 0.96 ha from a field survey in 2012. Tinsley (2009) noted that the 1 ha area they found was inadequate for full time rice cultivation and implied that individuals will have to divide their time between working in the scheme and working rainfed upland areas outside the scheme. Takeshima*et al.* (2013) found that 48% of farmers on KIP used combine harvesters in 2012.

As noted in section 1.4, there is a dearth of literature on adoption of mechanised harvesting technology among irrigated rice farmers. The rest of literature review thus focuses on the scanty documentation available. Mechanised harvesting of rice was adopted in high rice producing Vietnam. To increase output and save labour, Chi (2010) reported that 1.8% of the total rice was harvested by mechanised technology in 2006. This number rose to 13.9% in 2007. By 2008, the adoption of the technology reached 20.7%. In terms of number of farmers, less than 10% of farmers used rice harvesters and dryers in 2006. In the case of Senegal, Diagne*et al*. (2009) estimated the true population of irrigated rice farmers in the River Valley that have been exposed to the mechanised threshing as 86%.

Mechanisation generally saves labour and should increase area under cultivation in agricultural production. By the aid of a probit estimation, Diagne*et al*. (2009) showed a positive relationship between area of land and adoption of mechanised harvesting technology for irrigated rice farmers in the Senegal Valley. Tuong (2008) also reported a positive relationship. However, the coefficient was not statistically significant. Chi (2010) noted that in the case of Vietnam, the coefficient of -0.271 was statistically significant.

One would expect that older farmers will embrace labour saving methods as their physical energy declines with age. However, Tuong (2008) reported a negative and statistically significant coefficient of 0.0627 and marginal effect of 0.9736. This implied that as farmers grow older, they have a lower propensity to adopt mechanised harvesting technology.

There is a gender dimension to mechanised harvesting technology adoption. In a participatory rural appraisal involving staff from the 13 provinces of Vietnam and a survey of 250 farmers, Chi (2010) specified male as 1 and female as 0. In a probit model, Chi (2010) reported a statistically significant coefficient of -0.880. This implied that females embraced harvesting technology more than males. Since most rural economies around the world are male dominated, this result may seem unusual. Incidentally, Chi (2010) did not provide a reason for this finding.

Credit plays a role in technology adoption. Takeshima*et al.* (2013) reported 57% of rice farmers benefited from credit. Interestingly, 52% of this was from wife/sister, traders or market women. A minute 5% took credit from Agricultural Development Bank and the Dangme Rural Bank Limited in the study area.

Knowledge is important in technology adoption. The ability to acquire this knowledge may be correlated to the level of formal education. Tuong (2008), Chi (2008) and Chi (2010) reported positive relationship between level of education and mechanised harvesting technology adoption. While the finding of Chi (2008) was from the perspective of local authority managers, those of Tuong (2008) and Chi (2010) were from the perspective of farmers. Whilst Tuong (2008) posted a marginal coefficient of 1.0563, Chi (2010) posted a statistically significant coefficient of 0.170. Clearly, low level of formal education is a barrier to mechanised harvesting technology adoption.

Farmers with more experience in farming are more likely to be aware of successes, failures and gaps in farming. It is therefore not surprising that Diagne*et al.* (2009) demonstrated a positive and statistically significant relationship between mechanised harvesting technology adoption and length of experience in farming among irrigated rice farmers in the Senegal Valley. Earlier, Tuong (2008) reported a positive but statistically insignificant coefficient of 0.0153 for Vietnam.

3. Methodology

3.1 Study area

The study was conducted among rice farmers operating on the KIP located at Asutuare on the west bank of the Volta River in the Greater Accra Region of Ghana. Established by the Ghana Government in 1994 to take advantage of the Kpong Hydroelectric Dam (KHD) in Akuse, it covers an area of 1,870 ha under flood irrigation system specifically for rice (KIP, 2013). The total irrigable area is 3,070 ha. Unlike other government irrigation projects facing financial difficulties due to high cost of lifting water, water flows by gravity from the KHD to the KIP site. The total length of main canals is 38.8km with water discharge of $7.2m^3s^{-1}$.

3.2 Data

From the population of farmers operating on the KIP, 115 of them were randomly selected. A structured questionnaire was designed and administered to elicit information on harvesting technology, farm and farmer characteristics between April and June in the year 2013. However, complete data was available for only 99 farmers. The reference time for the data collection was 2012 production year.

3.3 Model

Technology adoption can be viewed from three perspectives. First, whether or not the technology is adopted (Mzoughi, 2011). Secondly, the extent to which the technology is adopted (*See* Nelson and Phelps, 1966; Benhabib and Spiegel, 2005) and thirdly, how long it takes to adopt (duration analysis) (*See* Kallas *et al.,* 2009). The problem in this study is neither about the extent of adoption nor how long it takes farmers to adopt. Rather, it is about whether farmers adopted mechanised harvesting technology or not. This therefore informed the derivation of the model that follows.

Let the utility of the irrigated rice farmer be represented by U. Then, the utility gained by adopting mechanised harvesting technology T will be $U_i(T)$. If T=1, farmer adopts mechanised harvesting technology and T=0, otherwise.

Therefore, a farmer adopts mechanised harvesting technology if:

$$U_i(1) > U_i(0) \quad \text{.......... 1}$$

And no adoption takes place when

$$U_i(1) \leq U_i(0) \quad \text{.......... 2}$$

Therefore,

$$U_i^*(T) = U_i(1) - U_i(0) \quad \text{.......... 3}$$

Considering that the decision to adopt depends on some factors such as farm and farmer characteristics, then,

$$U_i^*(T)=X_i\beta+\varepsilon_i \quad \text{.......... 4}$$

where T=1 if $U_i^*(T)$ >0 and T = 0 otherwise. ε_i is assumed to be continually distributed and has symmetry around zero.

Thus the probability of adopting technology:

$$\Pr(T_i=1)=\Pr(U_i^*>0)=\Pr(\varepsilon_i>X_i\beta)=1-F(-X_i\beta)=F(X_i\beta) \quad \text{.......... 5}$$

If the probability of adoption is P_i, then probability of non-adoption is 1-P_i. Thus, the log odd is:

$$L_i=\ln\left(\frac{P_i}{1-P_i}\right) \quad \text{.......... 6}$$

Replacing the left hand side of equation 4 with equation 6 results in

$$L_i=\ln\left(\frac{P_i}{1-P_i}\right)=\Sigma_{k=1}^{K} Z_k\beta_{k-1}+\varepsilon_i \quad \text{.......... 7}$$

where P_i is the probability of adoption by farmer *i*, *k* are the variables hypothesised to explain adoption and β are parameters to be estimated. The estimable econometric model is:

$$L_i=\ln\left(\frac{P_i}{1-P_i}\right)=\beta_0+\beta_1 PLOTSIZE_i+\beta_2 AGE_i+\beta_3 SEX_i+\beta_4 CREDIT_i+\beta_5 HHS_i+\beta_6 EDUCATION_i+\beta_7 MS_i$$
$$+\beta_8 EXPERIENCE_i+\varepsilon_i \quad \text{.......... 8}$$

where *HHS* is household size and *MS* is marital status. The other variables carry the usual meaning of the words. Additional variable definitions and *a priori* expectations of the sign of the coefficients are presented in Table 1. Equation 8 was estimated as a binomial logit model.

4. Results and Discussions

4.1 Descriptive Statistics

About two thirds (59.6%) of farmers on KIP employed mechanised harvesting technology in 2012 production year (Table 1). This is higher than 10% reported for Vietnam (Chi, 2010) and constitutes two thirds of that reported for Senegal (Diagne*et al.*, 2009). The bulk of farmers sampled are males (85.9%). More than 62% of the sample is aged 40 years and below. This point to a relatively young population engaged in rice farming on the KIP. The entire sample is formally educated at varying levels. Ten percent of the number has tertiary education. Close to 80% of the sample are married and living with their spouses. More than 50 percent (53%) of the sample relies on credit for rice production. This is similar to 57% reported by Takeshima*et al.* (2013).

The mean plot size of the sample is 1.126 ha. This is lower than 1.57 reported by Nimoh*et al*. (2012) and within the 1 ha indicated by Tinsley (2009), KIP (2013) and Takeshima*et al*. (2013). Tinsley (2009) noted that this small plot size is inadequate for full time rice production. This could push farmers to find opportunities to farm rice under rainfed conditions. The result also creates opportunities for diversification of livelihood into non-farm activities. The farmers have a high average household size of 11 persons. This will be available for deployment in farm operations including harvesting. On the average, each farmer has been cultivating rice for about two years and two months. This is quite low considering that KIP has been operating since 1997. There is the possibility of attrition by farmers. Also, new entrants may have pulled down the average.

Table 1. Variable definitions

	Frequency	Percentage (%)	Mean	Standard Deviation	Expected sign
Use of Mechanised harvester	59	59.6	N.A.	N.A.	N.A.
Plot size measured in hectares	N.A.	N.A.	1.125 ha	0.337	+
Age (years)			N.A.	N.A.	-
1.00: 20 years and below	0	0			
2.00: 21-30 years	20	20.2			
3.00: 31-40 years	41	41.4			
4.00: 41-50 years	29	29.3			
5.00: 51-60 years	9	9.1			
Gender			N.A.	N.A.	+
1.00: Male	85	85.9			
2.00: Female	14	14.1			
Sources of capital			N.A.	N.A.	-
1.00: Savings	16	16.2			
2.00: Family and friends	30	30.3			
3.00: Bank credit	53	53.5			
Household size in numbers			11.04	4.486	+
Education			N.A.	N.A.	+
1.00: Primary	32	32.3			
2.00: Junior High School	31	30.3			
3.00: Senior High School	27	27.3			
4.00: Tertiary	10	10.1			
Marital Status			N.A.	N.A.	-
1.00: Married	78	78.8			
2.00: Single	13	13.1			
3.00: Divorced	2	2.0			
4.00: Separated	6	6.1			
Experience in rice cultivation in years	N.A.	N.A.	2.16 years	0.804	+,-

4.2 Factors of adoption

Table 2 shows the estimated binomial logit model. The likelihood ratio (LR) is significant at 0.00%. This suggests that the goodness-of-fit of the model is adequate. The pseudo R^2 of 0.4084 is low relative to linear regression models.

However, Hosmer and Lemeshow (2000) have noted that low pseudo R^2 values in logistic regression are the norm. Thus the model is appropriate for inferences to be drawn from it.

Table 2. Results of binomial logit estimation[1,2,3]

Variables	Regression Coefficients	Marginal Effects
Plot size	5.7137**	0.7305**
	(2.8365)	(0.3404)
Age	-0.1118	-0.0143
	(0.3791)	(0.0484)
Gender	1.8210**	0.2328**
	(0.8513)	(0.0987)
Source of capital	0.0440	0.0056
	(0.4950)	(0.0632)
Household size	-0.2440***	-0.03120***
	(0.08024)	(0.0083)
Education	1.0725***	0.1371
	(0.3950)	(0.0431)
Marital Status	-0.3810	-0.0487
	(0.4331)	(0.0546)
Experience in rice	0.4191	0.05358
cultivation	(0.4808)	(0.0606)
Constant	-7.2016**	
	(3.5888)	
Observations	99	
LR Chi^2 (df=8)	54.55***	
Pseudo R^2	0.4084	
Loglikelihood	-39.5136	

1. Dependent variable is adoption and non-adoption of mechanised harvesting technology. 2. Numbers in brackets are standard errors. *,**,*** are levels of significance of 10%, 5% and 1% respectively.

The signs of the coefficients conform to the *a priori* expectations. In respect of the statistical significance of the coefficients, four out of the eight coefficients are statistically significant at least at 5% level. The coefficient for plot size is 5.7137 and statistically significant at 5%. The marginal effect of 0.7305 is also significant at 5%.

The latter implies that when plot size is increased by 1%, probability of adoption will increase by 0.7305. This result is plausible as with mechanised harvesting technology, farmers can cultivate larger plot size *ceteris paribus.* Indeed, it would take a fraction of a day to accomplish harvesting with combines unlike two days with *manpower* using seven persons (Tinsley, 2009). Since the plot sizes are fixed, the option available for increasing plot size is to sublease. Takeshima*et al*. (2013) did indicate that the practice exists on KIP. They reported that up 33% of rice area cultivated is under sublease whilst 23% of registered farmers on the scheme have ever leased out land. The positive and statistically significant relationship between plot size and adoption of mechanised harvesting agrees with the finding of Daigne*et al.* (2009) for Senegal. Though Tuong (2008) found a positive relation, the coefficient was statistically insignificant. Chi (2010) however, provided a contrary conclusion of negative and statistically significant relationship.

The sign of the coefficient and marginal effect of age is negative. It seems that younger farmers have a higher propensity to adopt mechanised harvesting technology. This cannot be confirmed since the magnitude is insignificant statistically. The result of the relationship of age and adoption diverges with the findings of Tuong (2008).

The magnitude of both the coefficient and marginal effect of the gender variable is statistically significant. This implies that mechanised harvesting technology adoption on the KIP can be distinguished based on gender. Technically, males adopt the technology more than females. This is to be expected as more males than females are engaged in irrigated rice cultivation on KIP (Table 1). Chi (2010) reported the contrary that women adopted mechanised harvesting technology than men in Vietnam.

Credit was contrasted with other sources such as savings, and family and friends. The statistically insignificant coefficient and marginal effect suggests that sources other than credit are equally important as financing sources. This is interesting as 54% of respondents used credit as financing source. Takishama*et al*. (2013) also reported 57% of farmers taking out credit of which 52% received credit from relatives and traders. This study did not investigate the sources of the credit.

An important dimension to credit is the amount. This was however, not investigated in this study. One can guess that the few who do not take credit contribute significant amounts of savings and the family and friends sources of capital. There is also the possibility that credit may be used to augment capital rather than as the sole source of capital. Indeed, lenders would want to see the personal contribution of borrowers to capital as a level of commitment to a project as a consideration for the lender to lend money to the borrower.

Household size is negatively related to probability of adoption of mechanised harvesting technology. Farmers heading large households will prefer to deploy their households for harvesting rather than paying money to combine harvester machinery operators. Indeed, they will avoid paying GHC 650. Where *manpower* is used, cash outlay for the service is lower than mechanised harvesting. This may be an incentive to continue to use *manpower*. Large household size is thus a disincentive to mechanised harvesting technology adoption.

Education varied within levels of attainment. Curiously, all the sampled farmers had some level of formal education. This is possible with simple random sampling. Nevertheless, the coefficient and marginal effect are statistically significant at 1%. This finding concurs with the conclusions of Tuong (2008), Chi (2008) and Chi (2010). Although skills for rice production may be more relevant than mere formal education, levels of formal education distinguished mechanical harvest technology adopters from non-adopters.

Marital status did not statistically distinguish adopters from non-adopters. This may be explained by the seeming communal relationships that exist in rural areas. Recalling that larger households did not adopt harvesting technology, single persons or unmarried people would still have household’s support when it comes to work. Also, the unmarried may have lower financial burden that may free resources to pay for technology. The interplay of these forces may have balanced hence the statistically insignificant effect.

Experience in farming is statistically insignificant. This implies that experience does not distinguish adopters from non-adopters of harvesting technology on the KIP. This may be attributable to the low mean experience in farming.

The standard deviation which is a measure of spread shows that there is minimal variability (0.8044) hence the results. The positive sign and statistically insignificant coefficient agrees with the findings of Tuong (2008). Whilst the finding of Diagne*et al.* (2009) agrees on the positive sign, there is a divergence on significance of the coefficients.

5. Conclusions and Recommendations

The study examined the factors that influence the adoption of mechanised technology among irrigated rice farmers operating on the KIP. From a sample of 99 farmers, 60% of farmers used mechanised harvesting technology by the year 2012. Plot size, gender, household size and education influenced adoption of mechanised harvesting technology. Plot size influenced adoption most. Age, source of capital, marital status and experience in cultivating rice did not influence adoption of mechanised harvesting technology.

Since increasing plot size in the current design of the scheme may not be possible, adequate information on availability of sublease plots should be made available. Subsequently, irrigated rice schemes should consider higher plots sizes than currently obtains at KIP. The relatively young population that is adopting mechanised harvesting technology is a basis for introduction of additional labour saving technologies on the scheme.

More women need to be encouraged to go into irrigated rice production. In as much as extension support is required for farmers on KIP, attracting formally educated persons into rice production even on part time basis will promote mechanised harvest technology adoption and thereby increase rice production. This may reduce the need to deploy several agricultural extension staff as formally educated farmers will be able to read new developments and may be more likely to learn new skills faster than non-educated or less educated farmers.

To keep the young people in farming in the KIP area, there is the need for improved rural infrastructure.

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