International journal of management and economics invention
||Volume||2||Issue||07||Pages-681-689||July-2016|| ISSN (e): 2395-7220
www.rajournals.in

Factors Affecting The Adoption Decision Of High Doses Of Chemical Fertilizer And Pesticide In Agriculture In Rangpur District Of Bangladesh

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Abstract:
Like other developing countries, Bangladesh is struggling to meet the food needs for its population. There are two possible solutions to this problem- import of food products and increasing national food production. In Bangladesh, increase in agricultural production is hindered by various constraints inherent in the sector such as low availability of cultivable land, declining fertility of soil, pest and virus attack problems etc. Chemical fertilizer and pesticide are vital inputs for agricultural production. With the growing popularity of modern agriculture, fertilizer and pesticide consumption in Bangladesh has been increasing over the years. The main objective of this study was to estimate the determinants of adoption decision of high doses of chemical inputs in agriculture. Using the Bivariate probit model, this study has made it possible to identify the key determinants affecting the adoption decision of chemical inputs use. The results indicate that age, education, farming experience, total family income, training, and extension service are the main determinants for the adoption decision of high doses of chemical inputs in agriculture. Farmers' education and total family income are positively related to the adoption of chemical inputs whereas age, farming experience and training are negatively related.
Keywords: Chemical inputs; Adoption decision; Bivariate Probit model; Bangladesh.

1. INTRODUCTION

Bangladesh has achieved a remarkable success in food grain production in the recent past which has made the country nearly self-sufficient in food grain production in normal years. Seed, fertilizer and irrigation technologies known as Green Revolution technologies have been playing major roles in the growth of agricultural production in Bangladesh. The growth of the agriculture sector is vital to ensure food security which is one of the primary goals of the National Agriculture Policy (NAP) of Bangladesh. Agriculture contributes 16.77% to the Gross Domestic Product (GDP) of Bangladesh in fiscal year 2012-13 while crop sector alone contributes 9.49%. In the crop sector, rice is dominant occupying about 75% of total crop land and supplying 70% of calorie intake for the people of Bangladesh (BB, 2011: 40).

Fertilizer is a vital input for agricultural production. It not only plays direct role in increasing production but also enhances efficiency of other inputs like irrigation and seeds. Fertilizer inputs grew from 8.8 kg of nutrients per hectare in 1968 to 238 kg. per hectare in 2009-10 (BER, 210: 19). Pesticide is another vital input for agricultural production. The total pesticide use in Bangladesh grew from 2200 tons in 1982 to 10367 tons in 2003 (MoA, 2012: 49). The production of rice crop, particularly boro demands intensive uses of inputs like chemical fertilizer and pesticide. Chemical fertilizer was introduced into the Bangladesh agriculture in the late 1950s by the public sector. Since then the demand has been growing sharply with the increase in production through high yielding varieties (HYVs). Consumption fertilizer was 1 million tons in 1983-84, which reached to a maximum of about 4.1 million tons in 2007-08 and then decreased to 3.4 million tons in 2009-10 (MoA, 2012: 40).

During the past three decades, unsystematic utilization of chemical fertilizer and pesticide in agriculture has created serious health and environmental problems in many developing countries (WRI, 1998: 45). The World Health Organization (WHO) and the United Nations Environment

Program estimate pesticide poisoning rates of 2-3 per minute, with approximately 20000 workers dying from exposure every year, the majority in developing countries (WRI, 1998: 46; Kishi *et al.*, 1995: 129). From an environmental perspective, chemically-polluted runoff from fields has contaminated surface and ground waters, damaged fisheries, destroyed freshwater ecosystems and created growing 'dead zones' in ocean areas proximate to the mouths of rivers that drain agricultural regions (Pimental and Lehman, 1993: 12; Tardiff, 1992: 21). As in many developing countries, Bangladesh has increased the use of pesticide to increase output per acre. As a consequence of this expansive policy, pesticide use has been more than doubled since 1992. It has been raised from 875179 tons in fiscal year 1981 to 4333800 tons in 2011 (MoA, 2012: 43).

The main aim of this study is to identify the key determinants of adoption decision of using high doses of chemical fertilizer and pesticide in agriculture and to draw the significance of the results and findings.

2. LITERATURE REVIEW

Extended studies have been done on different aspects and issues of adoption decision of chemical inputs use in agriculture. Some literature are synthesized in the following sections.

Thou *et al.*, (2011: 9) examined the factors that influence the decision whether or not to use fertilizer (adoption) and the share of land on which fertilizer is used (intensity) in agricultural production. They found that farm productivity in Senegal has been declining over time. Using pooled cross-section time-series data, and Probit and Tobit models they showed that the probability of using fertilizer increases where household heads have higher literacy, larger families and larger farms, but decreases where they have off-farm income. Fertilizer use is also positively associated with the amount of rainfall and varies by geographical location. The analysis indicates that both the adoption and the intensity of use of fertilizer by farmers have been declining over the study period 1998–2005 (Thuo, *et al.*, 2011: 2-6).

Nkamleua and Adesina (1999: 117) found that low use of chemical inputs has been cited as a major factor limiting productivity growth of agriculture in most of sub-Saharan Africa. A wide range of variables influence adoption of such inputs. Socio-economic factors affect the likelihood of using chemical fertilizer and pesticide in pre-urban lowland agricultural systems in Cameroon. The bivariate probit model is employed to take account of the correlation between the disturbances. Results found that lowland farmers who are more highly educated, those with temporary land rights and those whose fields are more distant from the homestead are more likely to use chemical fertilizer. In the same way, lowland male farmers, those who have contact with extension, those who have temporary land rights or those practicing continuous cropping are more likely to use chemical pesticides (Nkamleu et al., 1996: 117).

Zhou *et al.*, (2010: 89) analyzed the factors influencing the farmers' decisions on fertilizer use and the implications for water quality. The analysis was based on a survey of 349 farm households. It took into consideration both farm and farmer specific characteristics and farmers' subjective evaluations of factors shaping their decisions. Regression models were used to examine the determinants of fertilizer use intensity across farm households and to investigate the factors influencing the overuse of nitrogen. The results suggested that many of these subjective factors have great significance in determining famers' decisions. The results also showed that irrigation, gains in crop yield and higher earning goals are positively correlated with fertilizer use intensity, while farm size, manure application, soil fertility and the distance to fertilizer markets are negatively correlated. Investigation of the overuse problem showed that higher education level significantly reduces the probability of over-fertilization (Zohou, *et al.*, 2010: 89).

Beshir, (2012: 39-49) assessed the determinants of the probability of adoption and intensity of use of inorganic fertilizer in two districts of south Wollo zone, in Ethiopia. The results of the study provided empirical evidence of a positive impact of extension and credit services, age, farm land size, education, livestock, off/non-farm income and gender in enhancing the adoption of inorganic fertilizer. Physical characteristics like distance from farmers' home to markets, roads, credit and input supply played a critical role in the adoption of inorganic fertilizers as proximity to information, sources of input and credit supply and markets save time and reduce transportation costs. Therefore, the results of the study suggested that the probability of adoption and intensity of use of inorganic fertilizers should be enhanced to meet the priority needs of smallholder farmers and to alleviate the food shortage problem in the country in general and in the study area in particular (Bashir *et al.*, 2012: 43).

International journal of management and economics invention
||Volume||2||Issue||07||Pages-681-689||July-2016|| ISSN (e): 2395-7220
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Adelaja *et al.,* (2010: 415-27) used an augmented profit function framework to account for externalities related to chemical use in agriculture. They explained the chemical use choices of farmers in an urban fringe farming environment. It further estimated empirical logit models of reduced insecticide, fungicide, herbicide, and fertilizer usage. Results suggested that the farmers who perceived their regulatory environment to be strict, that have experienced right-to-farm conflicts and that are larger in size were more likely to reduce their chemical use over time, vis-a-vis other farmers. The results also suggested the importance of other farm structural and business climate factors in determining chemical use reduction choices (Rahm *et al*., 1984: 409).

Higher earnings is one of the main objectives of adopting high doses of chemical fertilizer and pesticide in agriculture. However, different factors affect the decision of farmers to adopt high doses of chemical fertilizer and pesticide. From the review of above literature it is found that level of education, family size, off farm income, farm size, extension visit, training of farmer, distance of input market, rainfall, geographical region, soil fertility etc. generally affect the farmers' adoption decision of high doses of chemical fertilizer and pesticide in agriculture.

3. METHODOLOGY

The theoretical analysis of the methods appropriate to the field of present study and empirical model is described below.

3.1. Selection of the Study Area and Data Collection

As Rangpur is agriculture based district, five upazilas of the district are selected purposively for the present study. The selected upazilas are Rangpur Sadar, Gangachara, Badarganj, Kaunia, and Pirgachha. Then from each upazila, one union is selected and thus five unions are selected randomly. After selecting the unions, two villages are selected from each union and thus ten villages are selected randomly for analysis. In the next step, the list of farmers is collected from upazila agriculture office and 350 farmers are selected randomly. The empirical data are collected by personal interviews conducted with the sample farmers. The authors and five trained data collectors conducted the interviews.

3.2. Conceptual Model: The Bivariate Probit Model

Several empirical studies estimated the influence of socio-economic variables on farmers' adoption decision of high doses of chemical inputs in agriculture in Bangladesh and elsewhere. In most cases, Probit or Logit model is applied (Rahm *et al.*, 1984: 408-12; Hossain, 1998: 13-17; Kebede et al., 1990: 35-39); Adesina, 1996: 33-37). In this model, farmers are assumed to make adoption decision based upon an object of utility maximization. When farmer use more fertilizer and pesticide compare to recommended doses, then it is considered as high doses. The high doses of fertilizer and pesticide are calculated using recommended doses providing by the Department of Agriculture Extension (DoAE), government of the people's republic of Bangladesh. The recommended doses of fertilizer are shown in Table 4 in appendix. Let us define the chemical fertilizer by 'f' and pesticide by 'p', where f, p = 1 for the adoption of high doses, and f, p = 0 for non-adoption of high doses. The essential utility function which ranks the preference of the i^{th} farmer is assumed to be a function of farmer-specific attributes, X_i (e.g. age, farm size, etc.) and a disturbance term having a zero mean:

$U_{i1}(X) = \beta_1 X_i + \varepsilon_{i1}$ for the adoption of high doses of chemical fertilizer and pesticide in agriculture and $U_{i0}(X) = \beta_0 X_i + \varepsilon_{i0}$ for the non-adoption of high doses of chemical fertilizer and pesticide in agriculture.

As the utilities are random, the i^{th} farmer will select the alternative 'adoption' if and only if $U_{i1} > U_{i0}$; i.e., the utility derived from adoption is higher than non-adoption. Thus, for the farmer i, the probability of adopting high doses of chemical inputs in agriculture is given by:

$$P(1) = p(U_{i1} > U_{i0})$$

$$P(1) = p(\beta_1 X_i + \varepsilon_{i1} > \beta_0 X_i + \varepsilon_{i0})$$

$$P(1) = p(\varepsilon_{i0} - \varepsilon_{i1} < \beta_1 X_i - \beta_0 X_i)$$

$$P(1) = P(\varepsilon_i < \beta X_i)$$

$$P(1) = \phi(\beta X_i)$$

Where, ∅ is the cumulative distribution function for ∈. The functional form for ∅ will depend on the assumptions made about ∈. A probit model arises from assuming the normal distribution for ∈.

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||Volume||2||Issue||07||Pages-681-689||July-2016|| ISSN (e): 2395-7220
www.rajournals.in

Thus, for a farmer 'i', the probability of the adoption of chemical fertilizer and pesticide, respectively, is given by:

$$\phi_f(\beta X_i) = \int_{-\infty}^{\beta X_i} \frac{1}{\sqrt{2\pi}} \exp(\frac{-t^2}{2})dt$$

$$\phi_p(\beta X_i) = \int_{-\infty}^{\beta X_i} \frac{1}{\sqrt{2\pi}} \exp(\frac{-t^2}{2})dt$$

The two equations can be estimated by individual single equation Probit methods. However, this is inefficient in that it ignores the correlation between the disturbances ϵ_f and ϵ_p of the underlying stochastic utility functions associated with fertilizer and pesticide, respectively (Green, 1992: 25-27). In the present study, the bivariate probit model is employed to avoid insufficiencies of the single variable probit or logit model. The bivariate probit model is based on the joint distribution of two normally distributed variables and is specified as ([12], [9]):

$$f(f,p) = \frac{1}{2\pi\sigma_f\sigma_p\sqrt{1-\rho^2}} e^{-(\varepsilon_f^2+\varepsilon_p^2-2\rho\varepsilon_f\varepsilon_p)/2(1-\rho^2)}$$

$$\varepsilon_f = \frac{e-\mu_f}{\sigma_f}$$

$$\varepsilon_p = \frac{e-\mu_p}{\sigma_p}$$

Where, ρ is the correlation between e and p. the covariance is $\sigma_{fp} = \rho\,\sigma_f\,\sigma_p$. μ_f, μ_p, σ_f, and σ_p are the means and standard deviations of the marginal distributions of f and p, respectively. The distribution of f and p are independent if and only if ρ = 0.

3.3. Empirical Model

A bivariate probit model is developed to test the relationship between socio-economic and farm level characteristics and the adoption of high doses of chemical fertilizer and pesticide in agriculture. Adaption behavior is affected by the acquisition of information (Nkamleu *et al.* 1998: 121). Earlier studies in Sub-Shaharan Africa suggest that adoption behavior is influenced by various individual socioeconomic and farm level characteristics (Hossain, 1988: 17; Nkamleu, 1998: 17-20).

The dependent variable is whether or not the farmer adopts high doses of pesticide and/or fertilizer. For chemical pesticide, this variable is denoted by PEST, and for fertilizer, the variable is denoted by FERT which take on the value of 1 if the farmer use high doses of chemical fertilizer and/or pesticide and 0 other wise. The farmer-specific socio-economic and farm level explanatory variables are age of the farmer (AGE), family size (FS), level of education (EDU), farming experience (FEXP), total non-farm family income (TFI), training of the farmer (TRA), agriculture extension service (EXT), and farm size(FAS).

Table 1: Description of Dependent and Independent Variable

Variables	Category	Description
PEST	Dummy	Pesticides utilization. 1 = adoption of high doses of pesticides, 0 = otherwise.
FERT	Dummy	Fertilizer utilization. 1= adoption of high doses of fertilizer, 0 = otherwise.
AGE	Continuous	Age of the farmers in years
FS	Continuous	Households' family size. No. of total members in the households
EDU	Continuous	Education level of farmers' in years of schooling
FEXP	Continuous	Farmers' experience in year in farming land
TFI	Continuous	Total non-farm income of the farmers' family in a single crop year in BDT. (Bangladeshi currency)
TRA	Dummy	Training status of the farmers'. 1 = yes, 0 = no
EXT	Dummy	Agriculture extension service receiver by the farmer. 1= yes, 0 = no
FAS	Continuous	Farm size. Total cultivable land of the farmer in decimal.

Variable AGE measures the age of the farmers. Grown-up farmers may have preferential access to new information or technologies through extension services or development projects that work in the region. Also with age, farmers accumulate more personal capital and, thus show a greater likelihood of investing in innovations (Nkamleu, 1998: 22). However, it may also be that younger farmers are more likely to adopt new technologies and /or are more likely to be early adopters (Alavalapati, 1995: 11). Young people have more energy, and it's more important for them to invest in the long-term productivity. Therefore, the expected sign of AGE is indeterminate. A large family often has a large number of working members. Generally, an increase in family size is likely to increase the probability of using high doses of chemical inputs to increase agricultural output (Kebede *et al*., 1990: 39; Nkamleu, 1998: 18-20). Educated members are more likely to adopt new technologies and/or more likely to be early adopters (Falusi, 1975: 49; Kebede *et al*., 1990, 38). It is assumed that EDU is positively or negatively related to high doses of PEST and FERT.

With increasing farming experience (FEXP), farmers may evaluate the benefits of chemical inputs or may evaluate the negative impact of chemical inputs on environment. Therefore, we may expect that FEXP is positively or negatively related with the adoption of high doses of chemical inputs in agriculture. TFI measures the total non-farm income of the farmer. Previous studies revealed that farmers often depend upon non-farm income generating activities to support returns from agriculture. Such non-farm income may influence the adoption of technology in agriculture (Kebede *et al*., 1990: 39). It is assumed that TFI is positively related to chemical input use. With training (TRA) and agriculture extension service (EXT) farmers may enable to understand the demerit of chemical inputs and they may try to apply appropriate amount of chemical inputs or even they may use organic inputs instead of chemical inputs. Therefore, we may expect that TRA and EXT are negatively related to the adoption decision of chemical inputs in agriculture.

4. DISCUSSION OF RESULT

4.1. Descriptive Statistics of the Variables

The socio-economic and farm level characteristics of sample farmers are listed in Table 2. The average age of the farmers is 36.67 years whereas the average education is 6.75 years of schooling and average farming experience is around 22.32 years. The average farm size is 131.85 decimal. There is an average of 5.07 members in each household.

Table 2: Descriptive Statistics of Explanatory Variables by Adopter and Non-adopter Groups

Variables	Unit of Measurement	Continuous Variables		Categorical Variables	
		Mean	S.D.	Percentage (%)	
Age of farmers	Years	36.67	19.49	-	-
Households' family size	Person per households	5.07	2.79	-	-
Education of household head	Years of schooling	6.75	3.98	-	-
Farmers' experience	Years	22.32	15.46	-	-
Total non-farm income of the farmer family in a single crop year	BDT. (Bangladeshi currency)	5590.29	1950.73	-	-
Training receive by the farmer	Dummy (1 = yes, 0 = no	-	-	1 = 27	0 = 73
Agriculture extension service receive by the farmer	Dummy (1= yes, 0 = no)	-	-	1= 42	0 = 58
Farm size	Decimal	131.85	90.33	-	-

International journal of management and economics invention
||Volume||2||Issue||07||Pages-681-689||July-2016|| ISSN (e): 2395-7220
www.rajournals.in

Source: Authors' own calculation

The average non-farm household income in a single crop year is found around Tk. 5590.29. Only 42% households have access to agriculture extension service. It is also found that only 27% farmers have training on agriculture.

4.2. Regression Results

The purpose of this study is to explore the factors that influence farmers' decisions to use high doses of fertilizer and pesticide in their farms. To this end, we perform bivariate probit regression analysis (Table 3). The obtained Rho is significant at 1% level. This result indicates that a bivariate probit model is more suitable rather than two univariate probit models. Totally, five variables have significant relation with the decision of whether or not to use high doses of chemical fertilizer and five variables have significant relation with the decision of whether or not to use high doses of pesticide.

From Table 3 is found that the age of farmers is significant at 10% level in both fertilizer and pesticide sub-model. The coefficient of age is negative in both cases indicating that the farmers with more age are less likely to apply high doses of chemical fertilizer and pesticide in their farms. Education of the farmers has a positive relationship to the application decision of high doses of chemical fertilizer and pesticide. The coefficient of EDU is positive and significant at 10% level in case of fertilizer application and at 5% level in the case of pesticides application. Thus, these results indicate that the farmer with higher education is more likely to use chemical fertilizer and pesticide. Experience of farmers has negative relationship to the adoption of high doses of chemical fertilizer and pesticide. The coefficient of FEXP is significant at 5% level in case of chemical fertilizer while it is significant at 10% level in case of pesticide. The negative sign of the variable indicates that farmers with more experience are less likely to apply more chemical fertilizer and pesticide.

Table 3: Regression Results of Bivariate Probit Model

Independent Variables	Dependent variables	
	Fertilizer	Pesticides
Constant	0.381	-0.88
	(0.31)	(-0.74)
Age	-0.0063***	-0.0163***
	(-1.75)	(1.68)
FS	0.0030	0.00554
	(0.25)	(0.45)
EDU	0.0022***	0.0001685**
	(1.73)	(2.18)
FEXP	-0.0048**	-0.00947***
	(-1.97)	(1.69)
TFI	0.318***	0.656
	(1.82)	(-0.96)
TRA	-0.297*	-0.3228*

	(2.89)	(-2.59)
EXT	0.035	-0.0079***
	(0.81)	(-1.69)
FAS	-0.635	-0.5134
	(-0.76)	(0.64)
Log-likelihood = -317.29	Rho(ρ) = 0.76***	Sample Size = 350

Source: Author's own calculation. Note: Figure in the bracket corresponding t-values.

* significant at 1%, ** significant at 5%, and *** significant at 10%.

Total non-farm family income of the farmers is an important factor that influences the adoption decision whether a farmer will apply more chemical fertilizer and pesticide or not. Total non-farm family income has positive relationship to the adoption decision of more chemical fertilizer and pesticide. The coefficient of TFI is significant at 10% level in case of chemical fertilizer while it is insignificant in case of pesticide. The positive sign of the variable indicates that farmers with more family income are more likely to apply high doses of chemical fertilizer. The training of the farmers has a negative relationship to the adoption decision of chemical fertilizer and pesticides. The coefficient TRA is negative and significant at 1% level in both cases. Thus, these results indicate that the farmer with training is less likely to use more chemical fertilizer and pesticide. Extension service received by the farmers is insignificant in case of fertilizer application but it is significant at 10% level in case of pesticide. The coefficient of EXT is negative, indicating that, the farmers who receive agriculture extension service are less likely to apply more chemical fertilizer and pesticide.

5. CONCLUSION

The result from this study reveals that the key determinants of using chemical fertilizer and pesticide are age of the farmer, family size, level of education, farming experience, total non-farm family income, training of the farmer, agriculture extension service, and farm size. Among all variables farmers' age, education, farming experience, and training are significant in the case of using both chemical fertilizer and pesticide but total family income is significant in the case of using more chemical fertilizer and agriculture extension service is significant in the case of using more pesticide only. The study found that farmers' education and total family income are positively related to the adoption decision of more chemical inputs whereas age, farming experience, training and agriculture extension service are negatively related to the adoption decision. Unsystematic utilization of chemical fertilizer and pesticide in agriculture create serious health and environmental problems. Therefore, the government and non-government organization should come forward to make awareness of farmers to control the unbalance application of chemical fertilizer and pesticide in agriculture ensuring sustainable environment and safe food for people.

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||Volume||2||Issue||07||Pages-681-689||July-2016|| ISSN (e): 2395-7220
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Appendix

Table 4: Recommended Doses of Fertilizer in Bangladesh

Types of Fertilizer	Types of Soil	Dose (Kg./ha.)	Average Dose (Kg./ha.)
Urea	Medium Fertile Soil	197.60	254.40
	Low Fertile Soil	311.22	
TSP	Medium Fertile Soil	61.75	81.51
	Low Fertile Soil	101.27	
MOP	Medium Fertile Soil	59.28	89.54
	Low Fertile Soil	119.80	
Zinc Sulphate	Medium Fertile Soil	4.94	7.41
	Low Fertile Soil	9.88	
Gypsum	Medium Fertile Soil	28.40	54.96
	Low Fertile Soil	81.51	

Source: Basak, J. K. (2010)