What Determines Adoption of Fertilizers among Rice-Producing Households in Northern Ghana?

Alexander Nimo Wiredu
University of Hohenheim, Stuttgart, Germany, and
Savanna Agricultural Research Institute, Nyankpala, Ghana

Manfred Zeller
University of Hohenheim, Stuttgart, Germany

Aliou Diagne
Gaston Berger University, Saint-Louis, Senegal

Abstract

Fertilizers remain important in global food production, yet fertilizer application rates in sub-Saharan Africa are far below global average. This study examines determinants of adoption of fertilizers in general and an important fertilizer combination among 820 rice-producing households in northern Ghana. Overall, nearly 67% of rice-producing households use fertilizer. The combination of nitrogen, phosphorus and potassium (NPK), and ammonium (NH4) fertilizers is the most popular with about 44% adoption incidence rate. Results from Cragg's two-step regression models show that different sets of factors affect the probability and intensity of adoption. The sets of factors also vary when fertilizer adoption in general is compared to the combination of NPK and NH4 fertilizers. The decisions also vary when whole farm operation is compared to specific farm enterprise. The factors that are found to be important in determining adoption include participation in a fertilizer subsidy program and expectation about yields. Good agricultural practices including, drilling of seeds, and harrowing of fields are also shown to be important determinants of fertilizer adoption. Effective adoption of the combination of NPK and NH4 fertilizers in particular can be achieved by enhancing access to information that will expose farm households to the benefits of these practices and also of complementary technologies such as improved seeds.

Keywords: fertilizer, adoption, Cragg's model, Ghana
JEL: Q12, Q18

1 Introduction

Fertilizers are applied to meet specific nutritional needs of crops, and to minimize potential environmental hazards of continuous cropping (HERA, 1996; VERMA and SHARMA, 2007). They increase productivity on crop farms (SAUER and TCHALE, 2009), investment returns in crop production systems (OLAGUNJU and SALIMONU, 2010), and ultimately enhance household, national, and global food availability (SPIERTZ, 2010). Fertilizer application is, therefore, critical for sustaining food security and the well-being of the global community.

Strategies that ensure effective use of fertilizers are very important, particularly in sub-Saharan Africa where low soil fertility continuously constrains crop productivity (MUTEGI et al., 2012). The region, in particular, records the lowest rate of fertilizer application of about 10.5 kg/ha compared to global average of about 122.1 kg/ha. The rate is also below that of South Asia (176 kg/ha), Latin America and Caribbean (92.2 kg/ha), Middle East and Northern Africa (79.5 kg/ha), and Europe and Central Asia (38.8 kg/ha) (WORLD BANK, 2012). Increasing adoption of fertilizers should therefore be a core component of agricultural development strategies of the countries in the region.

A recent study in Ghana reports an average rate of application of about 90 kg/ha for nitrogen, phosphorus, potassium (NPK) compound fertilizer for the 2012 cropping season (RAGASA et al., 2013a). A follow-up study identifies determinants of fertilizer adoption in northern Ghana (MARTEY et al., 2014), but does not focus on a specific crop production system in the area. To fill this gap, this study examines the determinants of fertilizer adoption in the rice-production system in northern Ghana. In fact northern Ghana produces around 30% of national rice production (SRID/MOFA, 2011), yet under poor soil conditions (LANGYINTUO and DOGBE, 2005). Recommendations that improve fertilizer adoption will certainly increase rice yields, and rice production in this part of Ghana. Since northern Ghana is located within the savannah agro-ecological zone, the recommendations are also useful in the food security strategies of areas around the globe with similar agro-ecology and crop production systems.

For fertilizers to produce optimum yield response, agronomists recommend initial application of compound fertilizers, and then nitrogen-based fertilizers (VAN ASTEN et al., 2004; MORO et al., 2008). However, existing literature on fertilizer adoption have examined fertilizer use in general without consideration for recommended combinations (ZHOU et al., 2010; FUFA and HASSAN, 2006). In addition to fertilizers use in general, this study identifies the determinant of adoption of the most important fertilizer combination among rice-producing households in northern Ghana. This is an important contribution to the literature on fertilizer adoption. The methodology for achieving this objective is described in the next section. In Section 3, the results of the study are presented, and then discussed in Section 4. The conclusion and recommendations of the study are presented in Section 5 where suggestions for promoting adoption of fertilizers in general and an important fertilizer combination are made.

2 Methodology

2.1 Data and Sampling

This study is based on data collected through semi-structured interviews with representatives of a cross-section of rice-producing households in developed rice valleys of Northern Region of Ghana in 2013. The interviews captured information on the characteristics of the households and their farm-level conditions, their subjective inclinations, and input accessibility.

Sampling started with listing of communities within the valleys together with the directorates of Ministry of Food and Agriculture (MOFA) that operate in the valleys. Out of the list, 82 communities were randomly selected. Within each community, 10 rice-producing households were randomly selected from a list of households provided by the assembly members of the communities. Overall, data on 820 rice-producing households was used for the analysis. The sample is, however, not representative of the rice production system of northern Ghana because it does not capture households operating in undeveloped valleys, upland ecologies, and irrigated ecologies.

2.2 Empirical Procedure

The sample includes rice-producing households who use different types and combinations of fertilizers. Adoption incidence rates of the types and combinations of fertilizers are, therefore, generated as the ratio of the number of adopters to the total sample size. Those who use fertilizer have different rates or intensity of application, which is computed as the total quantity of fertilizer applied per unit area of cultivated land. These decisions are examined for total arable crop area and for area under rice.

The fertilizer adoption decision process is based on the expected profit framework (DIMARA and SKURAS, 2003), where adoption occurs if expected profit from fertilizer use, which is latent and thus not directly observed, exceeds current level of profit (BURNHAM et al., 1999). This decision is assumed to be in two parts, the discrete decision of whether to use or not to use fertilizers, and the continuous decision on the quantities or rates of application. Where adoption is universal least squares regression models produce consistent estimates of the determinants of adoption (ZHOU et al., 2010). The use of probit and Tobit regression models to separately estimate the determinant of the probability and intensity of adoption (FUFA and HASSAN, 2006), may produce misleading recommendations. This is because the latter estimates the joint determinants of probability and intensity of adoption creating a situation of double counting (ADESINA, 1996; WAITHAKA et al., 2007). This property of Tobit models has been contested because the discrete and continuous decisions are not necessarily joint decisions.

To account for this potential flaw two-step models, Cragg's and Heckman's two-step models, are used to estimate the probability and intensity of adoption separately (MAL et al., 2012; YIRGA and HASSAN, 2013). Among the two-step models, Heckman`s model in addition to addressing separability problem also addresses the problem of selectivity bias by imposing an exclusivity condition in the first step (HECKMAN, 1979). For rice-producing households, the discrete decision to use fertilizers and the decision on the rate of fertilizer application may be joint or separate. Where the decisions are separate, the intensity of adoption may be characterized by selectivity bias. This study, therefore, conducts thorough diagnosis of separability and selectivity in fertilizer adoption decision.

In order to confirm separability in the adoption decision, likelihood ratio test is conducted. To do this probit, truncated, and Tobit adoption models, shown in Equations 1, 2, and 3, are estimated.

$$z = Prob(z|z^* > 0) = x\gamma + \varepsilon \tag{1}$$

$$y = E(y|y^* > 0) = x\beta + \mu \tag{2}$$

$$Y = (x\gamma + \varepsilon) + (x\beta + \mu) = x\alpha + \omega \tag{3}$$

In the first model above, z, identifies fertilizer adopters with $z = 1$ and non-adopters with $z = 0$, z_i^* represents the latent variable for the probability of adoption, x a set of explanatory variables in the model, γ the set of coefficients of the explanatory variables, and ε the error term. In the second model y represents adoption intensity, y_i^* is the latent variable of adoption intensity, β is the set of coefficients for the explanatory variables, and μ is the error term. The Tobit model combines the first two models to obtain the joint coefficient, α, which explain both the probability and intensity of adoption. In the third model ω is the error term.

From the three models, the log likelihood ratios are obtained and used to compute the likelihood ratio test statistic, L, as follows,

$$L = 2(LR_{Probit} + LR_{Truncated} - LR_{Tobit}) \quad (4)$$

In Equation 4, the LRs are the log likelihood ratios of the three models. The estimated L should be greater than the chi^2 distribution with degrees of freedom equal to the number of independent variables (including the intercept) in the models to justify the use of any of the two-step models. DOUGHERTY (2002) published statistical tables which include chi^2 distribution tables.

The Tobit model provides a consistent estimate of the determinants of fertilizer adoption if the L is less than the critical value (MAL et al., 2012). Otherwise the two step models are appropriate. As mentioned earlier, there is the opportunity to select between Cragg's and Heckman's two step models. Heckman's two-step model also accounts for selectivity bias and is described below.

The first step of Heckman's model also involves the estimation of a probit regression model shown in Equation 1. Using q to represent adoption intensity in the second stage, q_i^* as the latent variable of adoption intensity, δ as the set of coefficients estimates, and φ as the error term, the second step of the model is a truncated regression expressed as follows:

$$q = E(q|q^* > 0) = x\delta + \lambda(x\gamma) + \varphi \quad (5)$$

The second term on the right hand side of Equation 5 is the inverse Mills ratio which corrects for selection bias in the truncated regression model. A significant lambda suggests that the intensity of adoption depends on the initial discrete decision to adopt fertilizers (MARCHENKO and GENTON, 2012), a condition which is not considered in the Cragg's model.

In the absence of selectivity bias, Cragg's model provides a relatively simple approach for estimating the two-step model. In this case, the second stage of the model is also a truncated regression without the inverse Mills ratio. This is specified as,

$$q = E(q|q^* > 0) = x\delta + \varphi \quad (6)$$

In general, determinants of fertilizer adoption can be classified into household-level factors, farm-level factors (YIRGA and HASSAN, 2013), subjective factors (ZHOU et al., 2010), environmental factors (KALIBA et al., 2000), access factors (CAVANE, 2011), and risk factors (KALIBA et al., 2000). These guided the choice of explanatory variables for the model.

The variables examined in the model include dummy variables that describe nativity, engagement in off-farm activities, access to extension, participation in fertilizer subsidy program, access to external markets, purchase of seeds of improved rice varieties, harrowing, dibbling of seeds, herbicide use, and expectation of high yields from fertilizer application. Without careful examination, the listed agronomic practices namely, harrowing, dibbling, and herbicide use, can be perceived to have simultaneous relationships with adoption. Regardless of the need for fertilizers, the farm households are expected to undertake these practices. The most compelling factors the prevent farmers from undertaking such practices are financial and labor constraints. The practices on the other hand ease the application of fertilizers and also improve yield response, the agronomic practices, therefore, influence fertilizer adoption decisions and not the other way round. Continuous variables such as average age of economically active persons in a household, proportion of male members of a household, proportion of educated members of a household, and labor-land ratio in man-days/ha are also examined in the models. In order to satisfy the exclusivity condition of Heckman's model, nativity is assumed to only determine the discrete decision of adoption but have no effect on intensity of adoption.

A potential bias of the specified adoption models is endogeneity of the variable, participation in fertilizer subsidy program. This error is corrected by the estimation of a separate probit model of participation in the subsidy program on pure exogenous variables, including an instrument (ABADIE et al., 2002). Experience during the field visit, which, showed that some communities, regardless of their location, are more pro-active and aggressive, in terms of their negotiation for government interventions, presents a mean for instrumenting. A dummy variable which identifies these communities is likely to be correlated to both participation and adoption. The number of households in these communities on the other hand does not have any obvious link to adoption, and more appropriate as an instrument. With this instrument the predicted probability of participation in subsidy program is estimated and used in the adoption models.

3 Results

3.1 Type and Combinations of Fertilizers Adopted

Computed fertilizer adoption incidence rates and intensities of application are presented in Table 1. Overall, about 72% of the sampled rice-producing households apply fertilizer on their arable crop fields at a rate of 109 kg/ha. For rice fields, about 68% of the households apply fertilizers at an average rate of about 145 kg/ha. Compound (NPK) fertilizer is most popular, followed by ammonium (NH_4) fertilizer, and then urea fertilizer. For the combinations, NPK and NH4 fertilizer is most popular, and is applied at a rate of about 128 kg/ha on all arable crop fields and about 136 kg/ha on rice fields. The next popular combination is NPK and urea $CO(NH_2)_2$, applied by about 5% of the households on their entire arable crops and about 3% on their rice fields at average rates of about 81 kg/ha and about 90 kg/ha, respectively. The combination of NH4 and urea is applied by about 3% of the farmers on all arable crops and 1% on their rice farms at average rates of about 97 kg/ha and about 101 kg/ha, respectively. There are households who use only compound fertilizers, ammonium, and urea on their lands.

Table 1. Fertilizers used by sampled households

Fertilizer types	All farms			Rice farm		
	Adopters (%)	Quantity (kg/ha)		Adopters (%)	Quantity (kg/ha)	
All fertilizers	71.95	109.39	(111.75)	68.17	128.65	(106.28)
Compound (NPK)	68.78	78.66	(68.32)	61.59	83.73	(95.63)
Ammonium (NH4)	55.49	49.29	(52.70)	48.54	53.22	(73.70)
Urea (CO(NH2)2)	6.95	4.18	(19.03)	6.10	6.72	(29.99)
Compound only	14.51	17.11	(46.87)	15.00	19.21	(52.49)
Ammonium only	2.68	3.59	(24.58)	2.44	4.75	(28.40)
Urea only	16.71	1.41	(9.10)	3.41	2.18	(13.78)
Combination of NPK-NH4	52.07	127.95	(105.12)	44.39	136.30	(153.52)
Combination of NPK-urea	4.63	81.82	(68.06)	2.93	89.98	(101.01)
Combination of NH4-urea	3.17	97.04	(131.13)	1.46	100.53	(133.49)

Figures in parenthesis are standard deviation.

Source: computation by author based on survey data

3.2 Determinants of Fertilizer Adoption

Since the combination of NPK and NH4 fertilizers is most common, this study examines the factors that affect adoption of the combination and that of fertilizer use in general. Four different adoption scenarios are examined. The first involves estimation of adoption of fertilizers in general on all arable crop fields. The second is adoption of fertilizers in general on rice fields. The third considers adoption of the combination of NPK and NH4 fertilizers on all arable crop fields. Adoption of NPK and NH4 fertilizer combination on rice fields is considered in the fourth scenario.

The model in Appendix 1 is used to correct for endogeneity in participation in the fertilizer subsidy program. Therefore, the subsidy variable in the adoption models is the predicted probability of participation in the subsidy program and, therefore, considered as exogenous. The results of the separability tests are presented in Appendix 2. In all cases, the likelihood ratio test statistics show that the decisions to adopt fertilizers are in two steps. The two-step regression models are therefore considered in examining the determinants of fertilizer adoption. The estimated lambdas from the Heckman two-step models are insignificant, indicating the absence of selectivity bias (Appendix 3 and 4). As described in the empirical model, the Cragg's two step model in this case presents a simple and straight forward estimate of the determinants of the probability and intensity of fertilizer adoption. Subsequent presentations in this section, therefore, focus on the results from the Cragg's model.

A quick look at the results shows that different sets of factors affect the probability and intensity of adopting fertilizers in general. Moreover, the set of factors that affect adoption of fertilizers in general on all arable crop fields differ from the set of factors that affect adoption on rice field (Table 2). The same trend is observed for adoption of NPK and NH4 fertilizer combination (Table 3). For the same field category, the results also show that the set of factors that affect adoption of fertilizers in general differ from the set of factors that influence adoption of NPK and NH4 fertilizer combination. In some cases, the same factor may have different effects on the probability and intensity of adoption.

More specifically, Table 2 shows the results of Cragg's model for adoption of fertilizers in general on all arable crop fields in the first part, and for rice fields in the second part. For all the arable crop fields participation in off-farm income generating activities for instance, is shown to have negative effect on the probability of adoption. Labor-land ratio on the other hand increases both the probability and the intensity of adopting fertilizers in general. The two decisions on all arable crop fields are also positively related to harrowing of fields. Taking each decision separately, the results show that the probability of adoption is increased by participation in fertilizer subsidy program and expectation of high yield from fertilizer application, and is decreased by use of improved seeds. The intensity of adoption is increased by proportion of educated persons in the households and dibbling of seeds (Table 2).

For rice fields, the probability and intensity of adopting fertilizers in general are both shown to be increased by participation in fertilizer subsidy program, and decreased by participation in off-farm income generation activities. The probability of adoption, separately, is increased by expectation of high yields from fertilizer application, labor-land ratio and harrowing of fields, and decreased by use of improved seeds (Table 2).

Table 3 presents the results of Cragg's model for adoption of NPK and NH4 fertilizer combination on all crop fields and then on rice fields. Per the results, the probability and intensity of adopting the fertilizer combination on all arable crop fields are both increased by the number of arable crop cultivated, labor-land ratio, and harrowing. The probability of adopting the combination on all arable crop fields is increased by participation in fertilizer subsidy program and expectation of high yields from fertilizer application, and decreased by off-farm income generating activities and use of improved seeds. The intensity of adopting the fertilizer combination on all arable crop fields is shown to be increased by dibbling of seeds.

Table 2. Cragg's models of fertilizer adoption in general

Variables	All plots				Rice plots			
	Step 1		Step 2		Step 1		Step 2	
	Coef.	Std. err.	Coef.	Std. err.	Coef.	Std. err.	Coef.	Std. err.
Subsidy	2.288***	0.258	-0.047	0.175	2.944***	0.287	0.839***	0.194
Extension	-0.150	0.105	0.088	0.074	-0.089	0.113	0.018	0.079
Age of active persons	-0.003	0.010	-0.008	0.007	-0.010	0.011	-0.003	0.008
Proportion of males	-0.220	0.314	0.059	0.221	0.384	0.342	0.002	0.238
Proportion of educated	-0.075	0.202	0.248*	0.147	0.074	0.217	-0.236	0.158
Number of arable crops	0.071	0.046	-0.035	0.032	-0.006	0.050	0.038	0.034
Off farm activities	-0.427***	0.117	0.172**	0.079	-0.454***	0.124	-0.173**	0.088
Expectation of high yield	0.476***	0.170	0.009	0.152	0.470***	0.171	-0.100	0.154
Labor-land ratio	0.032*	0.019	0.077***	0.013	0.034*	0.021	0.001	0.014
Nativity	0.013	0.121			0.140	0.129		
Access to market	-0.081	0.215	0.030	0.141	0.309	0.269	-0.081	0.146
Improved seeds	-0.345***	0.112	0.081	0.078	-0.298**	0.123	0.053	0.083
Harrowing of filed	0.255**	0.109	0.123*	0.072	0.461***	0.123	0.071	0.078
Dibbling of seeds	0.161	0.121	0.277***	0.079	0.120	0.135	0.105	0.087
Herbicides application	0.130	0.118	0.080	0.084	0.136	0.125	-0.076	0.090
Tropical livestock units	0.006	0.006	0.000	0.003	0.005	0.007	0.001	0.004
Constant	-1.226***	0.458	4.233***	0.324	-1.287***	0.491	4.393***	0.345
N				820				820
Wald chi^2				129.760***				170.610***
Log likelihood				-981.344				-1099.094
Sigma				0.698***				0.833***

*10% significant, **5% significant, ***1% significant

Source: computation by author based on survey data

Table 3. Cragg's models of adoption of NPK and NH4 fertilizer combination

Variables	All plots				Rice plots			
	Step 1		Step 2		Step 1		Step 2	
	Coef.	Std. err.	Coef.	Std. err.	Coef.	Std. err.	Coef.	Std. err.
Subsidy	2.908***	0.301	0.001	0.167	2.996***	0.282	0.825***	0.199
Extension	0.028	0.116	0.068	0.069	-0.137	0.112	-0.001	0.081
Age of active persons	-0.013	0.012	-0.005	0.007	-0.016	0.011	-0.002	0.008
Proportion of males	-0.189	0.355	-0.073	0.205	0.462	0.337	-0.055	0.242
Proportion of educated	0.080	0.224	0.189	0.138	0.003	0.214	-0.169	0.163
Number of arable crops	0.119**	0.055	-0.077***	0.029	-0.034	0.049	0.037	0.035
Off farm activities	-0.470***	0.130	0.045	0.076	-0.449***	0.123	-0.196**	0.089
Expectation of high yield	0.618***	0.174	0.128	0.139	0.498***	0.171	-0.157	0.162
Labor-land ratio	0.048**	0.022	0.076***	0.012	0.024	0.020	0.007	0.014
Nativity	0.154	0.134			0.156	0.127		
Access to market	0.164	0.274	-0.102	0.130	0.090	0.251	-0.080	0.153
Improved seeds	-0.394***	0.127	0.060	0.073	-0.332***	0.120	0.060	0.085
Harrowing of filed	0.326***	0.127	0.157**	0.068	0.413***	0.119	0.019	0.080
Dibbling of seeds	0.173	0.143	0.284***	0.075	0.053	0.130	0.145*	0.089
Herbicides application	0.174	0.131	-0.030	0.079	0.096	0.124	-0.074	0.092
Tropical livestock units	0.006	0.007	0.001	0.003	0.004	0.007	0.001	0.004
Constant	-1.299***	0.516	4.306***	0.298	-1.038**	0.482	4.427***	0.351
N				820				820
Wald chi^2				173.440***				173.710***
Log likelihood				-1038.881				-1087.605
Sigma				0.744***				0.833***

*10% significant, **5% significant, ***1% significant

Source: computation by author based on survey data

On rice fields, the probability and intensity of adopting NPK and NH4 fertilizer combination are shown to be increased by participation in the fertilizer subsidy program, and decreased by participation in off-farm income generating activities. Considering the two decisions separately, the results show that the probability of adopting the fertilizer combination on rice fields is increased by expectation of high yield from fertilizer application, labor-land ratio and harrowing of fields, and decreased by dibbling of seeds. The intensity of adoption on the other hand is only increased by dibbling of seeds.

4 Discussions

4.1 Fertilizer Adoption and Decision-Making Processes

This study shows that rice-producing households use different types and combinations of fertilizers, with the combination of NPK and NH4 dominating. The estimated fertilizer adoption incidence rate confirms findings by RAGASA et al. (2013a) who report a 68% fertilizer adoption incidence rate in Ghana. Even with the fertilizer subsidy program, more than 30% of rice-producing households in the study area do not apply fertilizer. Among the adopters, the rates of application are below the recommended rates of application of 240 kg/ha for NPK and 120 kg/ha for NH4 (RAGASA et al., 2013a). Further interactions with the households in the study area revealed that some are not fully convinced about the benefits of fertilizers. For adopters, there is inadequate knowledge about the recommended rates and methods of application.

It is clear that additional strategies, aside the subsidy program, are required to enhance the use of fertilizer at the recommended rates and combinations. Obviously, education on fertilizers has not been exhaustive enough, in terms of coverage and content. There is, therefore, a need to upscale the promotion of fertilizers. Relevant agencies including extension service providers should be adequately resourced and trained for effective delivery of information on fertilizers.

The results of this study also show that the set of factors affecting adoption of fertilizers in general differ from those affecting adoption of the combination of NPK and NH4 fertilizers. Moreover, for the same fertilizer combination the set of factors that influence adoption differ for total land area and for specific crop area. There is a need for separate discussions to guide the development of strategies to address objectives of interventions aimed at promoting fertilizers in general or specific types of fertilizers. For example, in order to promote adoption of fertilizers in general, policy makers may have to encourage participation in the fertilizer subsidy program, which has broad objectives. In addition to the subsidy program, promotion of specific fertilizer combination can be achieved through effective extension services which deal directly with individuals and are, therefore, able to treat specific and more detailed technics such as application of the combination of NPK and NH4 fertilizers.

This study also shows that regardless of the measure of adoption, rice-producing households make an initial decision of choice (i.e., whether to use fertilizers on rice fields) before deciding on the amount of fertilizer to apply. The distinction of these decisions provides additional evidence to support the two-step analysis of agricultural technology adoption (YIRGA and HASSAN, 2013; MAL et al., 2012).

4.2 Factors Affecting the Adoption of Fertilizers in General

Considering adoption of fertilizers in general on all plots, rice-producing households who participate in the subsidy program are more likely to apply fertilizers in general. The subsidy program has no effect on the intensity of fertilizer adoption in general on all plots. This particular finding contradicts MASON et al. (2013) who find a significant effect of participation in a fertilizer subsidy program on the rate of fertilizer application on maize in Zambia. This contradiction may be due to the fact that MASON et al. (2013) considers only maize while this part of the study examines all arable crop fields.

Unlike arable crop fields, the probability and intensity of adoption of fertilizers in general on rice plots are increased by the fertilizer subsidy program. This actually confirms the assertion made earlier that the effect of the subsidy program can be identified when specific crops are examined, as with MASON et al. (2013). This suggests that evaluating the effect of interventions on overall farm activities of households can cloud the effects. Indeed, in northern Ghana most farm households do not apply fertilizers to root crops and legumes. Due to data limitation, adoption decisions on all the different crop fields have not been examined.

The type of knowledge about technologies also shapes perceptions, expectations, and eventually adoption decisions (ODOEMENEM and OBINNE, 2010; HSUA et al., 2007). As hypothesized, rice-producing households who expect high yields from fertilizers application are more likely to adopt fertilizers. These expectations, however, do not influence the application rate of fertilizers. Exposure to additional evidence on the benefits of fertilizers can strengthen their expectations, which can then inform their decisions on rate of fertilizer application.

Agricultural mechanization in Ghana and Africa as a whole is not only low, but has been declining in the past three decades (MREMA et al., 2008), necessitating the use of manual labor. Meanwhile, resource poor farm households are unable to pay for the cost of hired labor, and therefore rely on family labor for farm operations (BENJAMIN, 2006). This assertion is also true for this study as large households who have high labor-land ratios are likely to adopt and apply high rates of fertilizers in general on all their arable crop fields. For resource poor households, lack of adequate finance can limit the use of fertilizer (MUGISHA et al., 2004).

The use of technologies as a package yields higher returns. To experience such returns from fertilizers, access to complementary technologies is a necessary condition for adoption (DOSS and MORRIS, 2000). This study, however, shows that rice-producing households who use seeds of improved crop varieties are not likely to use fertilizers in general on all arable crop fields. Meanwhile adoption is shown to be increased by dibbling and harrowing on all arable crop fields. Observation during the field interviews showed that the households expect high yields from the use of improved varieties and may not find the need for fertilizers. However, controlling weeds by harrowing and by use of herbicides eases fertilizers application, and also prevent loss of nutrients to competitive weeds. This argument also applies for dibbling of seeds.

This study shows that households who are engaged in off-farm income generating activities are not likely to adopt fertilizers in general for their arable crop fields. Yet, for the adopters, participation in off-farm income activities increases the intensity of application. Due to time constraints the farm households who are engaged in off-farm income generating activities may have difficulty in considering fertilizers, particularly for their entire field. However, for the adopters, the extra income from off-farm income generating activities provides the opportunity to increase the rate of fertilizer application. This is possible because the two adoption decisions are not jointly made.

4.3 Factors Affecting the Adoption of NPK and NH4 Fertilizer Combination

Agronomists recommend the application of compound fertilizers and then ammonium or urea fertilizers (MORO et al., 2008). Urea fertilizer is, however, highly volatile and can easily be lost after application (GIOACCHINI et al., 2002), which may explain its low adoption rate. The combination of compound and ammonium fertilizers is thus an obvious option for rice-producing households in the study area.

The results in this part of the study also confirm earlier observation that there may be clouding of information when the effect of an intervention is examined on the total farm operation of households. For the NPK and NH4 fertilizer combination, participation in the subsidy program is shown to be positively related to the probability of adoption on all arable crop fields. Participation in the program is actually shown to increase both probability and intensity of adoption when rice fields are specifically considered. It is possible that the subsidy program which halves the price of NPK and NH4 (YAWSON et al., 2010) may have influenced the decisions of the rice-producing households to focus more on crops that have high fertilizer response, have high nutrient requirements, or are of high economic values. This will, however, require further investigation.

Complementary technologies are again shown to be important in the decision to use the combination of NPK and NH4 fertilizers. Harrowing of rice fields influences both discrete and continuous decisions, and dibbling of seeds influences the continuous decision only. It appears that rice-producing households who use this combination are already convinced about the benefits. However, the use of improved seeds rather reduces the probability of using the fertilizer combination. The results suggest the need to also educate farm households on the yield response of improved varieties to fertilizers and the NPK and NH4 fertilizer combination in particular. This will enable them to obtain the highest response from the improved variety plus fertilizer technology package.

Resource considerations are necessary when farmers decide to use the combination of NPK and NH4 fertilizers. As a technology package, the combination of NPK and NH4 fertilizers has relatively high resource, particularly labor, requirements (MUGISHA et al., 2004; SAKA et al., 2005). Access to adequate labor resources is, therefore, necessary to motivate adoption of the fertilizer combination. Participation in off-farm income activities, again, limits the availability of the households and has, therefore, been shown to have negative effect on the probability of adoption on rice fields.

5 Conclusion and Recommendations

5.1 Conclusion

The results of this study support that of RAGASA et al. (2013b) which report significant increases in the fertilizer adoption incidence rate since 1990s. Despite this increase in the incidence there is still fertilizer adoption gap in Ghana. The observed increase is due to a set of factors, including the fertilizer subsidy program. If possible, strategies to further enhance adoption of fertilizers should consider all the relevant factors included in the recommendations of this study. With different measures of adoption, this study provides recommendations for the promotion of both fertilizers in general and the combination of compound and ammonium fertilizers.

This study also proposes improvements to the methodologies of adoption studies in general. The study actually shows that the discrete decision to use fertilizers and the decision on the rate of application are not the same. They are influenced by different sets of factors. Estimating the probability of adoption alone does not provide a true understanding of the factors that affect the entire decision process. On the other hand, assuming that the two decisions are jointly made can be misleading. It is, therefore, important for studies on fertilizer adoption, as well as studies on adoption of agricultural technologies in general, to include a test for separability of the two decisions in order to apply appropriate estimation procedure(s). Otherwise, the sets of factors that influence the two decisions may not be adequately captured. Moreover, the study shows that the decisions vary for the whole farm operations and specific farm enterprise. In fact the decisions are also expected to even vary across enterprises. Future studies can therefore endeavor to examine such differences in order to make specific recommendations for such enterprises.

Another important outcome of this study is the difference between the adoption of fertilizers in general and the adoption of specific combinations of fertilizers, like the combination of NPK and NH4 fertilizers. Using fertilizer adoption in general oversimplifies the adoption situation, clouding details. There is also the tendency to overestimate or underestimate the effects of some factors on adoption. For example, the results show that the number of arable crops cultivated is not important in determining adoption of fertilizers in general. However, for adoption of NPK and NH4 fertilizer combination, the number of arable crops cultivated is shown to be important, at least for the entire arable crop fields.

5.2 Recommendations

Regardless of the type of fertilizer considered, the fertilizer subsidy program of Ghana increases the probability of adoption. The effect on the intensity of adoption is observed on specific crop fields. As mentioned earlier, instead of a cross board evaluation of such intervention it is important to examine the effects by farm enterprise.

Positive expectations about fertilizers are important in the adoption decision process for both the combination of NPK and NH4 fertilizers and fertilizers in general. Adequate evidence on the benefits of the NPK and NH4 combination and fertilizers in general, the response of improved varieties, together with complementary technologies can increase adoption incidence and application rates. Strengthening the extension agencies to educate farmers in this regard remain relevant.

References

ABADIE, A., J. ANGRIST and G. IMBENS (2002): Instrumental Variables Estimates of the Effect of Subsidized Training on the Quantiles of Trainee Earnings. In: Econometrica 70 (1): 91-117.

ADESINA, A.A. (1996): Factors affecting the adoption of fertilizers by rice farmers in Cote d'Ivoire. In: Nutrient Cycling in Agroecosystems 46 (1): 29-39. URL: http://link.springer.com/article/10.1007%2FBF00210222.

BENJAMIN, C. and A. KIMHI (2006): Farm work, off-farm work, and hired farm labour: estimating a discrete-choice model of French farm couples' labour decisions. In: European Review of Agricultural Economics 33 (2): 149-171.

BURNHAM, A.J., J.F. MACGREGOR and R. VIVEROS (1999): Latent variable multivariate regression modelling. In: Chemometrics and Intelligent Laboratory Systems 48 (2): 167-180.

CAVANE, E. (2011): Farmers' Attitude and Adoption of Improved Maize Varieties and Chemical Fertilizers in Mozambique. In: Indian Research Journal of Extension Education 11 (1): 1-6.

DIMARA, E. and D. SKURA (2003): Adoption of agricultural innovations as a two-stage partial observability process. In: Agricultural Economics 28 (3): 187-196.

DOSS, C.R. and M.L. MORRIS (2000): How does gender affect the adoption of agricultural innovations? The case of improved maize technology in Ghana. In: Agricultural Economics 25 (1): 27-39.

DOUGHERTY, C. (2002): Introduction to econometrics. Second edition. Oxford University Press Inc., New York, USA.

FUFA, B. and R.M. HASSAN (2006): Determinants of fertilizer use on maize in Eastern Ethiopia: A weighted endogenous sampling analysis of the extent and intensity of adoption. In: Agrekon 45 (1): 38-49. URL: http://ageconsearch.umn.edu/bitstream/31734/1/45010038.pdf.

GIOACCHINI, P., A. NASTRI, C. MARZADORI, C. GIOVANNINI, L.V. ANTISARI and C. GESSA (2002): Influence of urease and nitrification inhibitors on N losses from soils fertilized with urea. In: Biology and Fertility of Soils 36 (6): 129-135.

HECKMAN, J.J. (1979): The Common Structure of Statistical models of Truncated, Sample Selection and Limited Dependent Variables and a Simple Estimator for Such Models. In: Annals of Economic and Social Measurement 5 (4): 475-492.

HERA, C. (1996): The role of inorganic fertilizers and their management practices. In: Fertilizer Research 43 (1-3): 63-81.

HSUA, M., T.L. JUB, C. YENC and C. CHANGA (2007): Knowledge sharing behavior in virtual communities: The relationship between trust, self-efficacy, and outcome expectations. In: International Journal of Human-Computer Studies 65 (2): 153-169.

KALIBA, A.R.M., H. VERKUIJL and W. MWANGI (2000): Factors Affecting Adoption of Improved Maize Seeds and Use of Inorganic Fertilizer for Maize Production in the Intermediate and Lowland Zones of Tanzania. In: Journal of Agricultural and Applied Economics 32 (1): 35-47.

LANGYINTUO, A.S. and W. DOGBE (2005): Characterizing the Constraints for the Adoption of a Callopogonium mucunoides Improved Fallow in Rice Production Systems in Northern Ghana. In: Agricultural Ecosystems & Environment 110 (1-2): 78-90.

MAL, P., A.R. ANIK, S. BAUER and P.M. SCHMITZ (2012): Bt Cotton Adoption: A Double-hurdle Approach for North Indian Farmers. In: AgBioForum 15 (3): 294-302.

MARCHENKO, Y.V. and M.G. GENTON (2012): A Heckman Selection-t Model. In: Journal of the American Statistical Association 107 (497): 304-317.

MARTEY, E., A.N. WIREDU, P.M. ETWIRE, M. FOSU, S.S.J. BUAH, J. BIDZAKIN, B.D.K. AHIABOR and F. KUSI (2014): Fertilizer Adoption and Use Intensity among Smallholder Farmers in Northern Ghana: A Case Study of the AGRA Soil Health Project. In: Sustainable Agriculture Research 3 (1): 24-36.

MASON, N.M., T.S. JAYNE and R. MOFYA-MUKUKA (2013): Zambia's input subsidy programs. In: Agricultural Economics 44 (6): 613-628.

MORO, B.M., I.R. NUHU and W. TOSHIYUKI (2008): Determining Optimum Rates of Mineral Fertilizers for Economic Rice Grain Yields under the "Sawah" System in Ghana. In: West African Journal of Applied Ecology 12 (1): 19-31.

MREMA, G.C., D. BAKER and D. KAHAN (2008): Agricultural mechanization in sub-Saharan Africa time for a new look. Agricultural Management, Marketing and Finance Occasional Paper. Food and Agriculture Organization of the United Nations, Rome.

MUGISHA, J., O. OGWAL, W. EKERE and V. EKIYAR (2004): Adoption of IMP Groundnut Production Technologies in Eastern Uganda. In: African Crop Science Journal 12 (4): 383-391.

MUTEGI, E.M., J.B. KUNG'U, M. MUNA, P. PIETER and D.N. MUGENDI (2012): Complementary effects of organic and mineral fertilizers on maize production in the smallholder farms of Meru South District, Kenya. In: Agricultural Sciences 3 (2): 221-229. URL: http://dx.doi.org/10.4236/as.2012.32026.

ODOEMENEM, I.U. and C.P.O. OBINNE (2010): Assessing the factors influencing the utilization of improved cereal crop production technologies by smallscale farmers in Nigeria. In: Indian Journal of Science and Technology 3 (1): 180-183.

OLAGUNJU, F.I. and K.K. SALIMONU (2010): Effect of Adoption Pattern of Fertilizer Technology on Small Scale Farmer's Productivity in Boluwaduro Local Government. In: World Rural Observations 2 (3): 23-33. URL: http://www.sciencepub.net/rural/rural0203/.

RAGASA, C., A. DANKYI, P. ACHEAMPONG, A.N. WIREDU, A. CHAPOTO, M. ASAMOAH and R. TRIPP (2013a): Patterns of Adoption of Improved Rice Technologies in Ghana. Working paper 35. International Food Policy Research Institute (IFPRI), Washington, D.C.

– (2013b): Patterns of Adoption of Improved Rice Technologies in Ghana. Working paper 36. International Food Policy Research Institute (IFPRI), Washington, D.C.

SAKA, J.O., V.O. OKORUWA, B.O. LAWAL and S. AJIJOLA (2005): Adoption of Improved Rice Varieties among Small-Holder Farmers in South-Western Nigeria. In: World Journal of Agricultural Sciences 1 (1): 42-49.

SAUER, J. and H. TCHALE (2009): The Economics of Soil Fertility Management in Malawi. In: Review of Agricultural Economics 31 (3): 535-560. DOI:10.1111/j.1467-9353.2009.01452.x.

SRID/MOFA (Statistics, Research and Information Directorate of Ministry of Food and Agriculture) (2011): Production Estimates. Accra, Ghana.

SPIERTZ, J.H.J. (2010): Nitrogen, sustainable agriculture and food security. A review. In: Agronomy for Sustainable Development 30 (1): 43-55. DOI: 10.1051/agro:2008064.

VAN ASTEN, P.J.A., S.E. BARRO, M.C.S. WOPEREIS and T. DEFOER (2004): Using Farmer Knowledge to Combat Low Productive Spots in Rice Fields of a Sahelian Irrigation Scheme. In: Land Degradation and Development 15 (4): 383-396.

VERMA, S. and P.K. SHARMA (2007): Effect of long-term manuring and fertilizers on carbon pools, soil structure, and sustainability under different cropping systems in wet-temperate zone of northwest Himalayas. In: Biology and Fertility Soils 44 (1): 235-240.

WAITHAKA, M.M., P.K. THORNTON, K.D. SHEPHERD and N.N. NDIWA (2007): Factors affecting the use of fertilizers and manure by smallholders: the case of Vihiga, western Kenya. In: Nutrient Cycling in Agroecosystems 78 (3): 211-224.

WORLD BANK (2012): World Development Indicators. Washington, D.C.

YAWSON, D.O., F.A. ARMAH, E.K.A. AFRIFA and S.K.N. DADZIE (2010): Ghana's Fertilizer Subsidy Policy: Early Field Lessons from Farmers in the Central Region. In: Journal of Sustainable Development in Africa 12 (3): 191-203.

YIRGA, C. and R.M. HASSAN (2013): Determinants of Inorganic Fertiliser Use in the Mixed Crop-Livestock Farming Systems of Central Highlands of Ethiopia. In: African Crop Science Journal 21 (3): 669-68.

ZHOU, Y., H. YANG, H. MOSLER and K.C. ABBASPOUR (2010): Factors affecting farmers' decisions on fertilizer use: A case study for the Chaobai watershed in Northern China. In: Consilience: The Journal of Sustainable Development 4 (1): 80-102.

Contact author:
Alexander Nimo Wiredu
Chair of Rural Development Theory and Policy, Institute of Agricultural Economics and Social Sciences in Tropics and Subtropics, University of Hohenheim, Stuttgart, Germany
e-mail: anwiredu@yahoo.com

Appendix

Appendix 1. Determinants of participation in fertilizer subsidy program (An endogenous correction model)

	Coef.	Std. Err.	z	P>z	[95% Conf. Interval]	
Number of participants in the community	0.2598	0.0252	10.3200	0.0000	0.2105	0.3092
Age of active persons	-0.0123	0.0106	-1.1600	0.2470	-0.0331	0.0085
Total labor	0.0005	0.0005	1.0700	0.2870	-0.0004	0.0014
Proportion of male	0.0074	0.3241	0.0200	0.9820	-0.6279	0.6427
Proportion of educated	-0.2085	0.2149	-0.9700	0.3320	-0.6297	0.2126
Proportion of economically active	-0.5465	0.2657	-2.0600	0.0400	-1.0673	-0.0256
Off farm activities	0.6339	0.1072	5.9100	0.0000	0.4237	0.8440
Expectation of high yield	0.4380	0.1801	2.4300	0.0150	0.0850	0.7909
Own land	0.8688	0.1650	5.2700	0.0000	0.5454	1.1921
Number of crops	-0.0032	0.0461	-0.0700	0.9450	-0.0936	0.0873
Extension	0.3762	0.0990	3.8000	0.0000	0.1821	0.5703
Neighboring	0.1792	0.1116	1.6100	0.1080	-0.0395	0.3980
Sell rice	-0.0115	0.1795	-0.0600	0.9490	-0.3633	0.3403
Improved seeds	0.1465	0.1116	1.3100	0.1890	-0.0722	0.3652
_cons	-2.2309	0.5272	-4.2300	0.0000	-3.2641	-1.1976
N						820
LR chi2 (18)						212.790
Prob>chi2						0.000
Pseudo R2						0.187
Log likelihood						-461.362

Source: computation by author based on survey data

Appendix 2. Likelihood ratio test

Models	Likelihood ratios			Likelihood ratio statistics
	Probit	Truncated	Tobit	
Adoption of fertilizers in general				
All plots	-376.300	-494.657	-1515.715	1289.516***
Rice plots	-408.218	-690.876	-1583.760	969.332***
Adoption of NPK-NH4 combination				
All plots	-503.763	-665.210	-1587.429	836.912***
Rice plots	-495.455	-663.762	-1564.954	811.474***

***1% significant

Source: computation by author based on survey data

Appendix 3. Heckman's model of fertilizer adoption in general

Variables	All plots				Rice plots			
	Step 1		Step 2		Step 1		Step 2	
	Coef.	Std. err.	Coef.	Std. err.	Coef.	Std. err.	Coef.	Std. err.
Subsidy	3.051***	0.316	-0.487	0.535	2.944***	0.287	1.053*	0.657
Extension	-0.032	0.124	0.089	0.076	-0.089	0.113	0.012	0.082
Age of active persons	-0.010	0.012	-0.006	0.007	-0.010	0.011	-0.004	0.008
Proportion of males	-0.069	0.384	0.067	0.227	0.384	0.342	0.029	0.252
Proportion of educated	-0.044	0.236	0.254*	0.151	0.074	0.217	-0.231	0.159
Number of arable crops	0.117**	0.059	-0.050	0.037	-0.006	0.050	0.037	0.034
Off farm activities	-0.479***	0.137	0.239**	0.112	-0.454***	0.124	-0.204*	0.127
Expectation of high yield	0.599***	0.188	-0.110	0.205	0.470***	0.171	-0.059	0.197
Labor-land ratio	0.050**	0.024	0.072***	0.015	0.034*	0.021	0.003	0.015
Nativity	0.100	0.141			0.140	0.129		
Access to market	0.100	0.292	0.027	0.146	0.309	0.269	-0.068	0.152
Improved seeds	-0.429***	0.137	0.135	0.102	-0.298**	0.123	0.034	0.101
Harrowing of filed	0.372***	0.135	0.074	0.094	0.461***	0.123	0.101	0.119
Dibbling of seeds	0.184	0.152	0.250***	0.087	0.120	0.135	0.113	0.090
Herbicides application	0.162	0.140	0.059	0.090	0.136	0.125	-0.066	0.096
Tropical livestock units	0.006	0.007	0.000	0.003	0.005	0.007	0.001	0.004
Constant	-1.536***	0.560	4.727***	0.657	-1.287***	0.491	4.176***	0.725
N				697				820
Wald chi^2				87.170***				14.550
Sigma				0.730				0.840
Lambda				-0.343				0.168

*10% significant, **5% significant, ***1% significant

Source: computation by author based on survey data

Appendix 4. Heckman's adoption models for NPK-NH4 fertilizers combination

Variables	All plots				Rice plots			
	Step 1		Step 2		Step 1		Step 2	
	Coef.	Std. err.	Coef.	Std. err.	Coef.	Std. err.	Coef.	Std. err.
Subsidy	1.915***	0.248	-0.153	0.831	2.180***	0.251	-0.723	1.291
Extension	-0.120	0.104	0.123	0.090	-0.176*	0.105	0.115	0.151
Age of active persons	-0.008	0.010	0.000	0.008	-0.011	0.010	0.008	0.013
Proportion of males	-0.162	0.310	0.138	0.234	-0.008	0.312	0.349	0.343
Proportion of educated	-0.053	0.200	0.234	0.149	-0.102	0.203	-0.167	0.231
Number of arable crops	0.079*	0.045	-0.036	0.045	-0.089*	0.046	0.184***	0.074
Off farm activities	-0.278**	0.114	0.150	0.143	-0.335***	0.114	0.157	0.230
Expectation of high yield	0.457***	0.171	0.020	0.275	0.342**	0.174	-0.428	0.312
Labor-land ratio	0.011	0.018	0.095***	0.014	0.000	0.018	0.020	0.020
Nativity	0.143	0.120			0.172	0.121		
Access to market	0.090	0.214	-0.039	0.138	0.090	0.214	-0.061	0.213
Improved seeds	-0.231**	0.111	0.104	0.124	-0.190*	0.112	0.232	0.164
Harrowing of filed	0.350***	0.107	0.050	0.157	0.407***	0.107	-0.289	0.244
Dibbling of seeds	0.203*	0.119	0.233**	0.116	0.185	0.118	0.058	0.162
Herbicides application	-0.061	0.116	0.138*	0.086	-0.081	0.117	0.044	0.134
Tropical livestock units	0.004	0.006	0.000	0.003	0.003	0.005	-0.002	0.005
Constant	-1.137***	0.452	4.075***	1.091	-0.774*	0.455	5.205***	1.228
N				820				820
Wald chi^2				106.380***				17.170
Sigma				0.670				1.101
Lambda				-0.111				-0.995

*10% significant, **5% significant, ***1% significant

Source: computation by author based on survey data