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Smallholder Adoption of Soil and Water Conservation Practices in Northern Ghana

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Abstract: Both governmental and non-governmental organizations are engaged in the promotion of soil and water conservation practices in Northern Ghana, but adoption is believed to be low. This study thus examines the determinants of conservation practices adoption by farming households in the area. Data for the study were collected from 445 households located in 15 communities in Northern Ghana. Univariate, bivariate and multivariate probit models were used to analyse the decision to adopt six conservation practices in the area. Results show that the major determinants of adoption are plot and cropping characteristics such as location; and socio-economic and institutional variables such as number of contacts with extension officers, membership in farmer association and distance to major market. A policy implication of the study is the strengthening of extension service in the area to significantly boost conservation adoption.

Key words: Conservation practice, multivariate, selectivity bias, soil and water conservation, Ghana.

1. Introduction

Ghana's economy continues to be heavily dependent on agriculture and a critical challenge that remains is how to increase agricultural output while at the same time maintaining the natural resource base supporting agricultural production. The agriculture sector is a major contributor to Ghana's gross domestic product (GDP) with its contribution standing at 34.7 percent in 2007 at constant 1993 prices [1] and also employing over 56.0 percent of the total labour force [2].

Northern Ghana, which comprises Northern, Upper East and Upper West regions, is a major food production area and the poorest in the country despite the fact that it is known to abound in so many natural resources. According to the most recent living standards survey, the incidence of poverty in the three regions of Northern Ghana remains as high as 52.0 percent, 70.0 percent, and 88.0 percent respectively in the Northern, Upper East and Upper West regions [3]. The poverty in the area is caused partly by deteriorating soil conditions and inadequate water availability for crop, livestock and other enterprises.

Food production in Ghana is concentrated in the savannah and forest zones with the three northern regions producing a substantial portion of the national output. The three regions have the potential for increasing agricultural production, but to realize this potential requires the deteriorating soil conditions be addressed. Against this background, governmental and non-governmental organizations in Northern Ghana are engaged in promoting soil and water conservation practices, such as grass stripping, composting, stone and soil bunds, among farmers in the area. But

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adoption of the practices among farmers is believed to be low.

In the light of the above, the objective of this paper is to identify factors that motivate farmers to adopt various resource conservation practices so that the adoption process can be enhanced by targeting those factors. Specifically, the paper examines the adoption of six conservation practices *viz*. stone bund, soil bund, grass strip, agroforestry, cover crops and composting using data collected in the 2008/2009 agricultural year from 445 households in Northern Ghana.

The paper makes a contribution to the literature on adoption studies, especially in Northern Ghana. Adoption of innovation or technology can generally be said not to be a random process as farmers usually self-select into treatment [4]. A sound approach thus requires that such selectivity issue is taken into account. The methodological approach in this paper incorporates selectivity and also analyses all six conservation practices simultaneously. The analysis shows that the major determinants of soil and water conservation in the area are the farm/plot and cropping characteristics, and socio-economic and institutional variables.

Empirical studies in developing countries on the adoption of soil and water conservation practices by farmers have considered a broad range of factors. These can be loosely categorised into personal and household attributes, farm/plot and cropping characteristics, and socio-economic and institutional factors [5].

The personal and household attributes include factors like education, age, family size, gender among others. In general, education has been observed to have positive effects on conservation [6-8]. However, as observed by Scherr and Hazell [9], education might offer alternative livelihood opportunities in off-farm activities thereby increasing the opportunity cost of labour and competing with labour use for agricultural production. Ersado et al. [6] found that age has a significantly negative effect on adoption of productivity enhancing technology only as well as sequential adoption of productivity enhancing technology followed by resource conserving technology. Amsalu and de Graaff [10] who conducted their study in an Ethiopian highland watershed found a weakly significant positive relation between age and adoption of stone terraces bringing to the fore the inconsistency of evidence about the relationship between age and innovativeness [11]. Contrary to their expectations, Bekele and Drake [12] found family size, a proxy for own labour use, to have a significantly negative relation with certain adoption choices. But Amsalu and de Graaff [10] who did not find statistically significant relationship between family size and adoption of stone terraces found that the continued use of the practice was negatively impacted by the size of the family. Pender and Kerr [8] reported evidence of labour market imperfections in one of their study villages by observing significantly more conservation investment occurred in households having more adult males and those with fewer females. But Bekele and Drake [12], Nkonya et al. [13] and Amsalu and de Graaff [10] did not find any significant effect of gender of household head on the adoption of conservation practices.

Farm size and slope have been considered under farm/plot and cropping characteristics. Farm size is found to have mixed effects on adoption of soil and water conservation practices. While various studies [6, 10, 12] found positive relation between adoption of conservation measures and farm size, Pender and Kerr [8] found differential effects of farm size on conservation investment across the three villages where they studied in India. Studies in different parts of Ethiopia [10, 12, 14, 15] also found a significantly positive effect of the slope variable on the adoption of soil and water conservation measures. Similar results have been reported elsewhere by Pender and Kerr [8] and Lapar and Pandey [16].

The effects of tenure security on conservation measures adoption and investment have been investigated by various studies. Examples of such studies include Besley [17] in Ghana, Gebredmehin and Swinton [14] in Ethiopia, Pender and Kerr [8] in India, Clay et al. [18] in Rwanda, and Gavian and Fafchamps [19] in Niger. Better market access has been observed to increase the adoption probabilities of conservation methods [6, 13, 20]. Farmers' access to information, usually measured by contact with extension officers, has been reported to have mixed effects at different places. Bekele and Drake [12] found this to have a significant effect on the decision to adopt soil and water conservation practices in the eastern highlands of Ethiopia, but Nkonya et al. [13], Gebremedhin and Swinton [14], and Amsalu and de Graaff [10] did not find any effect of extension contact on the adoption of conservation measures. Farmers' social networks have been observed to facilitate adoption through information flow and group action [21, 22].

From the foregoing discussion, it is clear that different factors determine the adoption of conservation practices in different parts of the world or even in different locations within a given country due to differences in agro-ecological as well as socio-economic setting under which production takes place [12, 23]. Conclusions emanating from most of the studies have tended to be case-specific and in some cases contradictory thereby justifying the proposed study.

2. Methods

In this study, as in other adoption studies, the choice decision of a given household is considered to be discrete so that the choice variable is qualitative in nature. For a rational household, if each conservation practice is seen as a possible adoption option, then such a household will be expected to choose the conservation practice that maximizes their utility. This approach is based on the linear random utility assumption [24], which is normally given as:

$$\begin{cases} U_{i0} = x_i'\beta_{i0} + e_{i0} \\ U_{i1} = x_i'\beta_{i1} + e_{i1} \end{cases} \qquad (1)$$

where U_{ij} is a measure of utility derived by household i from choosing alternative j (with the decision not to use a conservation practice being U_{i0} while using is denoted by U_{i1}); x_i is a vector of characteristics specific to household i as well as attributes associated with alternative j and specific to the i th household, β is a vector of unknown parameters, and e_{ij} is random disturbances associated with the choice of alternative j by household i.

The probability that household i chooses a particular alternative (i.e. $Y_i = 1$) versus another (i.e. $Y_i = 0$) is associated with the probability distribution of the error differences in the expected utilities from the choices and given by:

$$P_i = \text{Prob}(Y_i = 1|x) = \text{Prob}(y_i^* > 0|x) = \text{Prob}[e_i > -x_i'\beta|x] = F(x'\beta) \qquad (2)$$

From Eq. (2), F is the cumulative distribution function of $e_i(= e_{i1} - e_{i0})$ evaluated at $x_i'\beta$, and $y_i^*(= U_{i1} - U_{i0})$ is a latent variable, since it is unobservable, and is linked to y_i, the observed binary variable, through the relation below:

$$y_i = \begin{cases} 1 \text{ if } y_i^* > 0 \\ 0 \text{ otherwise} \end{cases} \qquad (3)$$

The specification of a model to describe the relation between the probability of choosing an alternative and the explanatory variables is dependent on the assumption made regarding the distribution of the error term[1]. Because this is a non-linear model, the effect of the explanatory variable is measured in terms of marginal effect defined as partial change in the probability of the outcome attributable to a change in the variable.

A number of studies have observed that the adoption choice by farm households is multivariate in nature and so the appropriate modelling procedure should not be binary, but must instead take into account the interactions and possible simultaneity of the adoption decisions. As a result methods such as the bivariate or multivariate probit [10, 25, 26], and

[1] The two mostly assumed distributions in the literature are the normal and logistic corresponding to probit and logit models respectively.

multinomial logit [6, 12, 27] for multiple choice problems have been used in the analysis of farmer adoption decisions. In the light of this, the analysis here is pursued at the univariate, bivariate and to some extent the multivariate levels to account for possible contemporaneous correlation or correlated disturbances among the models as well as selectivity effects.

If the error term in the utility model is assumed to be normally distributed, the analysis can be carried out using a probit model. Following from Eq. (2), in the framework of the simple (univariate) probit model, the probability function of choosing an alternative versus another is given by:

$$P_i = \text{Prob}[Y_i = 1|X] = \int_{-\infty}^{x_i'\beta} \phi(t)dt = \Phi(x_i'\beta) \quad (4)$$

with $\phi(\cdot) = (2\pi)^{-0.5}\exp(-t^2/2)$ and $\Phi(\cdot)$ being the density and cumulative distribution functions respectively of a standard normal random variable.

In the bivariate probit model, the assumption of correlated normally distributed error terms in a two-equation system leads to Eq. (5) below:

$$\begin{cases} y_1^* = x_1'\beta_1 + e_1, Y_1 = 1 \text{ if } y_1^* > 0, \textit{and } 0 \textit{ otherwise} \\ y_2^* = x_2'\beta_2 + e_2, Y_2 = 1 \text{ if } y_2^* > 0, \textit{and } 0 \textit{ otherwise} \end{cases} \quad (5)$$

where e_i is the normally distributed error term, $E[e_1|x_1, x_2] = E[e_2|x_1, x_2] = 0$, $Var[e_1|x_1, x_2] = Var[e_2|x_1, x_2] = 1$, and $Cov[e_1, e_2|x_1, x_2] = \rho$. The bivariate normal cumulative distribution function is given by:

$$\text{Prob}(X_i < x_i) = \int_{-\infty}^{x_1\beta_1}\int_{-\infty}^{x_2\beta_2} \phi_2(z_1, z_2, \rho)dz_1dz_2 = \Phi_2(z_1, z_2, \rho) \quad (6)$$

with the probability density function being $\phi(z_1, z_2, \rho) = \frac{e^{-0.5(z_1^2 + z_2^2 - 2\rho z_1 z_2)/(1-\rho^2)}}{2\pi(1-\rho^2)^{0.5}}$. To simplify this to allow for constructing the log-likelihood function, Greene [24] uses the notation $q_{ij} = 2y_{ij} - 1$ so that $q_{ij} = 1$ or -1, respectively, if $y_{ij} = 1$ or 0, for $j = 1, 2$ and $i = 1, \ldots, N$; $z_{ij} = x_{ij}'\beta_j$ and $w_{ij} = q_{ij}z_{ij}$, $j = 1, 2$; and $\rho_{i^*} = q_{i1}q_{i2}\rho$. The probabilities that enter the log-likelihood function then become:

$$\text{Prob}(Y_1 = y_{i1}, Y_2 = y_{i2}|x_1, x_2) = \Phi_2(w_{i1}, w_{i2}, \rho_{i^*}) \quad (7)$$

The subscript 2 in the probability density ϕ_2 and cumulative distribution Φ_2 functions signifies the underlying bivariate normal distribution. In the sample selectivity framework, the probabilities in Eq. (7) are slightly modified and used to form the log-likelihood function as well (e.g., [24]), a procedure employed in this study. The multivariate probit framework extends the bivariate model above to include three or more outcome variables.

Maximum likelihood methods are employed in estimating the univariate and bivariate probit models, but the *M*-variate integrals involved in the multivariate probit model makes it rather difficult to estimate and so simulation-based techniques are normally used (e.g., [24, 28]).

2.1 Data and Variables

The data for the study came from a survey of 445 households in the three northern regions of Ghana. The survey was conducted between November 2009 and March 2010, and covered production activities for the 2008/2009 agricultural year. A multi-stage sampling procedure was used and it involved first identifying a district from each of the regions. Five communities were then randomly selected from each of the districts, and finally 30 households randomly selected from each community[2].

Each conservation measure practised by the farmers in Northern Ghana is assumed to define one equation in the univariate probit models estimated and thus constitute the set of binary dependent variables. All six measures *viz.*, stone bund, soil bund, grass strip, agroforestry, cover crops, and composting are considered in this study. Following the literature, as shown earlier, the variables hypothesized to explain the probability of adopting a specific conservation measure have been broadly categorised into personal and household characteristics, farm or plot and cropping characteristics, and socio-economic and

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[2] For the purpose of this study, six households were dropped from an original sample of 451 due to incomplete responses.

institutional variables. Both the dependent and explanatory variables together with their descriptive statistics are shown in Table 1. The location variable for the Upper East region is not included in the models since it is used as the base case.

3. Results and Discussion

Six binary probit models of soil and water conservation measures were estimated. Preliminary analyses conducted showed that multicollinearity was not a problem in the models as all variables had a variance inflation factor of less than 10 [29]. To account for potential heteroscedasticity in the univariate models, robust standard errors were estimated. Except in the grass strip model, a Lagrange multiplier (LM) specification test for normality of the error term produced values less than the critical value of 5.991 in all models (Table 2 for some of the results), implying the use of probit models to examine adoption decisions of the sampled households is reasonably justified.

Each model was estimated first without correcting for selectivity bias and then correcting for it in a

Table 1 Variables definition and descriptive statistics.

Variable	Definition	Mean	S.D.
Dependent variables			
Water management practices			
Stone bund	Dummy, 1 if adopted and 0 otherwise	0.57	0.50
Soil bund	Dummy, 1 if adopted and 0 otherwise	0.56	0.50
Grass strip	Dummy, 1 if adopted and 0 otherwise	0.31	0.46
Fertility management practices			
Agroforestry	Dummy, 1 if adopted and 0 otherwise	0.15	0.36
Cover crop	Dummy, 1 if adopted and 0 otherwise	0.09	0.28
Composting	Dummy, 1 if adopted and 0 otherwise	0.13	0.34
Explanatory variables			
Personal and household characteristics			
HHAGE	Age of household head (in years)	53.24	15.42
HHGEND	Dummy for gender of household head (1 if male, 0 if female)	0.91	0.28
AVEDU	Average level of education of all adult household members (in years)	5.95	2.88
OWNLAB	Total household own labour for agricultural production in 2008/09 agricultural year (in man-days)	291.58	298.57
HOUSE	Index for the type of house/dwelling (3-12)	4.63	1.47
TLU	Livestock holding (in tropical livestock units)	3.15	3.58
Farm/plot and cropping characteristics			
FSIZE	Area of land under cultivation (in hectares)	1.95	1.08
PER_DEG	Average index for perception of degradation on plots (highest = 4)	2.06	0.51
SOILDEX	Average index for major soil type on plots (1 = most fertile)	2.24	0.68
SLOPEDEX	Average index for type of slope on plot (1 = flat)	1.72	0.56
NORTH	Dummy for location, 1 if in northern region and 0 otherwise	0.33	0.47
UWEST	Dummy for location, 1 if in upper west region and 0 otherwise	0.33	0.47
Socio-economic and institutional variables			
PETENURE	Dummy, perception of tenure security (1 if secure, 0 if insecure)	0.74	0.44
EXNTACT	Contacts with extension officers in the 2008/09 agricultural year	2.53	4.51
TRACON	Dummy, participation in conservation training (1 if yes, 0 otherwise)	0.60	0.49
POFFY	Proportion of income from off-farm activities	29.44	28.98
MEMFA	Dummy, membership in farmer association (1 if member, 0 otherwise)	0.60	0.48
SHLAB	Total self-help labour for agricultural production in 2008/09 (in man-days)	40.86	55.01
DISTFH	Average distance of plots from homestead (in km)	1.58	2.04
DISTFM	Distance of homestead to the nearest major market (in km)	0.87	1.24
ROAD	Condition of road to the major market (1 if good, 0 otherwise)	0.19	0.40

Table 2 [3]Probit models of adoption of stone bund and composting.

Variable	Stone bund				Composting			
	Independent model: No. selectivity		Model corrected for selectivity bias		Independent model: No. selectivity		Model corrected for selectivity bias	
	Coefficient	Marginal effect	Coefficient	Marginal effect	Coefficient	Marginal effect	Coefficient	Marginal effect
Constant	-0.8754	-0.2794**	-0.5096	0.0000	-1.3216**	-0.4111*	-1.3249*	0.0000
HHAGE	0.0017	0.0007	0.0037	0.0013	0.0044	0.0008	0.0048	0.0009
HHGEND	-0.3912	-0.1453*	-0.3983	-0.1444	0.0885	0.0144	0.1111	0.0215
AVEDU	0.0334	0.0131	0.0561**	0.0203**	-0.0526*	-0.0090*	-0.0501*	-0.0097*
OWNLAB	-0.0001	-0.42E-4	0.0002	0.0001	-0.0010***	-0.0002***	-0.0010**	-0.0002**
FSIZE	0.0094	0.0037	-0.1068	-0.0387	0.2058**	0.0351**	0.2149*	0.0417*
PER_DEG	0.2780**	0.1087**	0.2423	0.0879	-0.1539	-0.0263	-0.1507	-0.0292
EXNTACT	0.0441*	0.0173*	0.0222	0.0081	0.0312**	0.0053**	0.0333	0.0065
TRACON	0.5012***	0.1957***	0.4294*	0.1556*	-0.0482	-0.0083	-0.0423	-0.0082
POFFY	0.0015	0.0006	0.0019	0.0007	0.0053*	0.0009*	0.0048	0.0009
MEMFA	0.3016**	0.1181**	0.2947*	0.1068*	0.4510**	0.0729**	0.4348*	0.0843*
HOUSE	0.1009**	0.0394**	0.0823	0.0299				
TLU					0.0074	0.0013	0.0052	0.0010
SOILDEX	-0.0284	-0.0111	-0.0510	-0.0185	0.0859	0.0147	0.0749	0.0145
SLOPEDEX	0.1001	0.0391	0.0634	0.0230				
DISTFH	-0.0322	-0.0126	-0.0356	-0.0129	-0.0209	-0.0036	-0.0186	-0.0036
DISTFM					-0.1535**	-0.0262**	-0.1670*	-0.0324*
ROAD					-0.6831**	-0.0891***	-0.6685**	-0.1296**
NORTH	-0.4554**	-0.1787***	-0.1397	-0.0506	-0.6455**	-0.0967***	-0.6614**	-0.1282**
UWEST	-1.2924***	-0.4818***	-1.2223***	-0.4432***	0.1118	0.0196	0.0799	0.0155
ρ [a]	-		-0.047		-		0.977	
Log likelihood	-261.821		-345.932		-148.425		-274.324	
Chi squared	105.942***				51.379***			
AIC	1.253		1.708		0.748		1.390	
BIC	1.410		2.021		0.914		1.713	
Predicted prob [b]	70.79 percent				86.74 percent			
Lagrange mul. [c]	$LM = 4.489\chi^2_{(0.95,2)} = 5.991$				$LM = 3.641\chi^2_{(0.95,2)} = 5.991$			

***, **, *, stand for values statistically significant at 0.01, 0.05, and 0.1 levels respectively; [a] is the correlation parameter between the two equations (i.e. each equation of interest and the selection equation) and is used to test for selection effects; [b] denotes proportion of correctly predicted probabilities; and [c] is the Lagrange multiplier test for normality of the error term.

second estimation. The first two columns of each model in Table 2 present results of the models estimated independently of the selection equation for stone bund and composting while the second two columns show results of the models estimated jointly with the selection equation[4]. Selectivity effects in non-linear models are measured using the correlation parameter between the error terms of the two equations, ρ [24]. As observed earlier, it is necessary to correct selectivity bias since farmers' adoption decisions can generally be said not to be a random process as they usually self-select into treatment.

To cater for a possible contemporaneous correlation, all six models, for all the practices, were jointly estimated and the results (not shown here) show the soil bund, grass strip, agroforestry and cover crops, models should be jointly estimated since various combinations of those equations are correlated; the stone bund and composting models are not correlated with the other models and so are efficiently estimated

[3] Results for the adoption model (defined for a household using at least one conservation practice, and 0 otherwise) used as the selection equation are not shown in the tables.

[4] Results of the other four models are not shown here, but could be accessed from authors.

as independent models. However, selectivity bias should be accounted for in the grass strip and agroforestry equations only as a result of the correlation parameter between the selection equation (of adoption of any one conservation practice) and each of the selected equations for the two practices, ρ, being statistically significant. Results of the independent and multivariate adoption models are shown in Tables 2 and 3.

From the above thus, the models that have been chosen for discussion are the independent adoption models, i.e. the models without correction for selectivity bias, for stone bund and composting (first two columns of models in Table 2) and the multivariate probit adoption model with sample selectivity correction for grass strip and agroforestry (Table 3). A number of the variables hypothesized to explain farmers' decision to adopt conservation measures are significant and shed more light on farmer adoption of conservation practices in northern Ghana.

Personal and household characteristics play a marginal role in the adoption decisions of farmers. The average education of household members, own labour use and wealth proxied by dwelling type are the significant determinants in this category, even though their effects remain mixed across the models. In particular, average level of education of household members and level of use of own labour on the farm have negative and significant effects on the decision to adopt composting. Even though education has been widely observed to positively impact adoption of technology (e.g., [6, 8, 30]), it is likely the case that offers alternative livelihood opportunities in off-farm activities among the sample thereby competing with labour use for agricultural production as observed by Scherr and Hazell [9]. The availability of labour within the household is expected to promote the adoption of labour intensive practices like composting, especially where such labour is used on the farm. It is thus unclear why the own labour variable has a negative, even though marginal, effect on adoption of composting. But this is consistent with the finding of Bekele and Drake [12]. Household wealth, with type of house and total livestock unit as its proxies, impacts adoption of conservation practices in Northern Ghana positively, with the effect being significant only in the stone bund adoption model. The presence of wealth effects in the adoption of conservation practices points to imperfections or failures in the credit market in the study area, a situation that is pervasive in developing countries. Generally, the findings here are consistent with that of Wossink and van Wenum [31] who found farmer characteristics only explained marginally the participation decision of Dutch arable farmers in biodiversity conservation programmes.

The farm and cropping characteristics play an important role in the choice of conservation practices in the study area. As expected, perceiving serious degradation problem on a parcel increases the probability of adopting stone bunds by almost 11.0 percent as depicted by the marginal effect of the perception variable. This finding is consistent with that of Mbaga-Semgalawe and Folmer [32] in Tanzania, and Pender and Kerr [8] in India who observed that the more their sampled farmers perceived erosion problem on their fields the more likely they applied soil and water conservation practices. Households with large farms have higher probability of adopting composting and cover crops, a finding which agrees with that of Amsalu and de Graaff [10], Bekele and Drake [12], Ersado et al. [6] among others who found positive relation between adoption of conservation measures and farm size. Strong and significant differential effects of location show up in the adoption of the six soil and water conservation practices in the study area, perhaps pointing to differences in characteristics of the three northern regions.

A number of socio-economic and institutional variables are significant determinants of the probability to adopt conservation measures in the study area. Number of contacts with extension officers

Table 3 Multivariate probit model for soil bund, grass strip, agroforestry and cover crops.

Variable	Soil bund		Models corrected for selectivity bias				Cover crops	
			Grass strip		Agroforestry			
	Coefficient	Marginal effect[a]	Coefficient	Marginal effect[b]	Coefficient	Marginal effect[c]	Coefficient	Marginal effect[d]
Constant	-1.0705*	0.0000	0.3120	0.0000	-2.5515***	0.0000	-2.9752***	0.0000
HHAGE	0.0035	0.0090	-0.0061	-0.0035	-0.0065	0.0011	-0.0128	-0.0039
HHGEND	0.0119	-0.0074	0.3591	-0.1277	-0.0308	-0.0382	-0.0554	-0.0108
AVEDU	0.0038	0.0029	-0.0126	-0.0004	-0.0089	-0.0176	0.0392	0.0154
OWNLAB	-0.0002	-0.0001***	0.0001	0.24E-4	0.0001	0.45E-4***	-0.45E-5	-0.36E-4
FSIZE	0.0779	0.0240***	-0.1059	-0.0517	0.1015	0.0655***	0.0113**	0.0102***
PER_DEG	-0.0067	-0.0121	-0.0441	-0.0121	0.1799	-0.0434	0.4627	0.1377
PETENURE	-0.3859**	-0.0922***	-0.2870	-0.1073***	0.2040	0.0960**	0.2064	0.0224
EXNTACT			0.0372*	0.0142***	0.0515	0.0059	0.0450*	0.0105***
TRACON			-0.0455	-0.0185	-0.0803	-0.0216		
POFFY			-0.18E-4	-0.0007			-0.0031	-0.0012***
MEMFA	0.5146***	0.1473***						
SHLAB	0.0068***	0.0016***	0.0060***	0.0018***	0.0041**	0.0006		
HOUSE	0.0560	0.0158***			0.0607	0.0278***		
TLU			-0.0145	-0.0058				
SOILDEX	0.0287	0.0065	0.1691	0.0686	0.2222*	0.0265	0.2042	0.0361***
SLOPEDEX	0.0603	0.0207	0.0322	0.0419	0.0756	-0.0608	0.2550	0.0864
NORTH	-0.1023	-0.0132	-0.3157	-0.1904	0.5789*	0.2332***	0.1932	-0.0559
UWEST	0.9223***	0.3247	-1.7302***	-0.5711***	-1.4172***	-0.3623***	-0.4701	0.0099
$\boldsymbol{\rho}_{(SO,GR)}$[e]	0.216**							
$\boldsymbol{\rho}_{(SO,AG)}$	0.205							
$\boldsymbol{\rho}_{(GR,AG)}$	0.549***							
$\boldsymbol{\rho}_{(SO,CC)}$	-0.030							
$\boldsymbol{\rho}_{(GR,CC)}$	0.148							
$\boldsymbol{\rho}_{(AG,CC)}$	0.681***							
$\boldsymbol{\rho}_{(GR,SEL)}$	0.828***							
$\boldsymbol{\rho}_{(AG,SEL)}$	0.774**							
Log likelihood	-674.597							
AIC	3.338							
BIC	3.964							

***, **, *, stand for values statistically significant at 0.01, 0.05, and 0.1 levels respectively; [a] is marginal effects at mean values of all variables on $P[y_1|y_2 = 1,...y_4 = 1, x]$, but for a dummy the value is a difference; [b] is marginal effects at mean values of all variables on $P[y_2|y_1 = 1, y_3 = 1, y_4 = 1, y_{sel} = 1, x]$; [c] is marginal effects at mean values of all variables on $P[y_3|y_1 = 1, y_2 = 1, y_4 = 1, y_{sel} = 1, x]$; [d] is marginal effects at mean values of all variables on $P[y_4|y_1 = 1, y_2 = 1, y_3 = 1, y_{sel} = 1, x]$; [e] is the correlation parameter between two equations and is also used to test for selection effects with SEL=selection (adoption) equation.

in the previous year are a positively significant determinant of the adoption decision in all the models in which it appears. This is because extension officers remain the main source of information on improved production methods. Participation of any household member in demonstration or training on the use of conservation practices also increases the probability of adopting stone bund. In particular, the two variables signifying social capital, which is membership in farmer association (MEMFA) and use of self-help labour (SHLAB), positively affect adoption of conservation practices. Farmers in the area constitute themselves into worker groups and take turns to work on members' farms without members making any payment. This kind of labour is what is referred to as "self-help" labour. The findings on the variables in this category are consistent with previous studies from elsewhere (including [11, 12, 16]). Distance of homestead to the nearest major market has an inverse relation with the probability of adoption of composting by households, and it is consistent with the finding of Gebremedhin and Swinton [14] in Ethiopia. This is not surprising as nearness to major markets guarantees market participation as a result of decreasing transactions cost [16] thereby encouraging the production of market crops. However, the negative sign on the *ROAD* variable, a dummy for road quality remains unclear. This is because it is expected that good roads will increase market participation and hence adoption.

Higher share of household income derived from engaging in off-farm activities is associated with higher probability of adopting compost technology, albeit its effect is only marginal in terms of both magnitude and statistical significance. This result on the proportion of household income derived from off-farm activities contrasts that of other studies (such as, [10, 32, 33]) reporting a negative effect of participation in non-farm work on adoption of soil and water conservation practices. A plausible explanation for the finding here is that households engaging in off-farm economic activities are likely able to raise resources required to engage hired labour for the purpose of compost preparation, a situation which also points to a possible presence of credit market imperfections. The effects of tenure security on the soil and water conservation practices adoption decisions of households in northern Ghana tend to be mixed. It exerts a negative effect on the probability to adopt soil bund and grass strip even though its effect is not significant on the latter practice. This is in contrast to the results of other studies [17, 34-36] in Southern Ghana which found positive and significant effect of tenure security on investment in various land enhancement measures. At the same time, however, the effect of this variable on agroforestry and cover crops adoption is positive but not statistically significant. This mixed and especially negative effect of the variable on adoption in the study area remains unclear. But the possibility exists that the effect of the complex land tenure system as a whole is being confused with security of specific tenure regimes (e.g., [19]).

4. Conclusions

This study is unique in the sense that it studies multivariate conservation adoption decisions of farm households in the three regions of Northern Ghana; a previous study by Faltermeier and Abdulai [4] examined adoption of soil bund and dibbling by rice farmers only in the Northern region. The results in this study demonstrate the need to study local incentives and determinants of conservation adoption since these differ greatly under different agro-ecological and socio-economic settings. It also makes the point that in analysing adoption decisions of households care should be taken in lumping different practices as their adoption maybe influenced by different variables. It is further shown in the current study that use of binary models does not always prove adequate in the analysis of household conservation decisions.

An unclear result in the study is the fact that good road network reduces the probability of adopting composting. What this might imply for policy is that good roads alone might not be enough to ensure the adoption of conservation practices. Besides developing infrastructure in the underprivileged parts of the country, policies should also aim to improve market incentives for producers. A major policy implication of the study is that extension service in the area should be strengthened to ensure efficient delivery. This way, adoption of conservation practices will be greatly enhanced.

The role of tenure rights on conservation adoption in northern Ghana remains unclear and even tends to negatively affect adoption of soil bunds. This could be as a result of lack of well defined tenure rights in the area. Ongoing projects aimed at clarifying the land tenure system are thus laudable. It will also be insightful for future research efforts to be focused in this regard.

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