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 by farming households in the area. Data for the study was 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 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 major policy implication of the study is the strengthening of extension service in the area to significantly boost conservation adoption.

Keywords: Conservation practice, multivariate, selectivity bias, Ghana.

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 (ISSER, 2008) and also employing over 56.0 percent of the total labour force (FAO, 2007).

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 northern regions of 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 (GSS, 2008). 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 increased agricultural production, but to realize this potential requires that 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 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 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 (Faltermeier & Abdulai, 2009). 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.

The paper is organized as follows. The next section briefly reviews studies on conservation adoption to help identify relevant variables in conservation decision making. The model is specified in the third section. Whilst the fourth section describes the data and variables used in the model, the penultimate section presents and discusses the results. The last section then concludes the paper.

Previous Studies on Adoption Decisions

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, socio-economic and institutional factors (Knowler & Bradshaw, 2007).

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 (Ersado, Amacher, & Alwang, 2004; Ervin & Ervin, 1982; Pender & Kerr, 1998). However, as observed by Scherr & Hazell (1994), 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. (2004) find 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 & de Graaff (2007) who conducted their study in an Ethiopian highland watershed find 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 (Baidu-Forson, 1999). Contrary to their expectations Bekele & Drake (2003) find family size to have a significantly negative relation with certain adoption choices. But Amsalu & de Graaff (2007) who did not find statistically significant relationship between family size and adoption of stone terraces find the continued use of the practice was negatively impacted by the size of the family. Pender & Kerr (1998) report evidence of labour market imperfections in one of their study villages by observing significantly more conservation investment occurs in households having more adult males and those with fewer females. But Bekele & Drake (2003), Nkonya et al. (2005) and Amsalu & de Graaff (2007) do 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 (Amsalu & de Graaff, 2007; Bekele & Drake, 2003; Ersado et al., 2004) find positive relation between adoption of conservation measures and farm size, Pender & Kerr (1998) find differential effects of farm size on conservation investment across the three villages they studied in India. Studies in different parts of Ethiopia (including Amsalu & de Graaff, 2007; Bekele & Drake, 2003; Gebremedhin & Swinton, 2003; Shiferaw & Holden, 1998) also find 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 & Kerr (1998) and Lapar & Pandey (1999).

The effects of tenure security on conservation measures adoption and investment have been investigated by various studies. Examples of such studies include Besley (1995) in Ghana, Gebredmehin & Swinton (2003) in Ethiopia, Pender & Kerr (1998) in India, Clay et al. (1995) in Rwanda, and Gavian & Fafchamps (1996) in Niger. Better market access has been observed to increase the adoption probabilities of conservation methods (Ersado et al., 2004; Nkonya et al., 2005; Tiffen et al., 1994). Farmers' access to information, usually measured by contact with extension officers, has been reported to have mixed effects at different places. Bekele & Drake (2003) find 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. (2005), Gebremedhin & Swinton (2003), and Amsalu & de Graaff (2007) do not find any effect of extension contact on the adoption of conservation measures.

The attitudes and behaviour of farmers towards certain technologies tend to influence the discrete choice decisions of their neighbours. This interdependence in farm households' adoption choices is what is referred to as 'neighbourhood effect'. Case (1992) find strong evidence of the influence of neighbours in the adoption of sickle harvesting technology by Indonesian rice farmers. In their study to demonstrate the applicability of Bayesian spatial probit estimation in agricultural economics, Holloway et al. (2002) also find strong evidence of neighbourhood effects in the adoption of high yielding varieties among rice producers in Bangladesh. Both studies come to the conclusion that neighbourhood effects play an important role in the adoption decisions of smallholders, and failure to control for them could lead to biased and unreliable estimates as well as policy conclusions. In this study, the influence of nearby farmers is considered attitudinal since ultimately it leads to a change in attitude towards a given conservation practice.

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 (Bekele & Drake, 2003; Kessler, 2006). Conclusions emanating from most of the studies have tended to be case-specific and in some cases contradictory thereby justifying the proposed study.

Model and Estimation

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, 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 (Greene, 2008), which is normally given as:

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

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:

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

From (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:

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

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 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 (Amsalu & de Graaff, 2007; Dorfman, 1996; Fuglie & Bosch, 1995), and multinomial logit (Bekele & Drake, 2003; Burton et al., 1999; Ersado et al., 2004) for multiple choice problem 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 (2), in the framework of the simple (univariate) probit model, the probability function of choosing an alternative versus another is given by:

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

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 equation (5) below:

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

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:

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

$$Prob(X_i < x_i) = \int_{-\infty}^{x_1\beta_1} \int_{-\infty}^{x_2\beta_2} \phi_2(z_1, z_2, \rho) dz_1 dz_2 = \Phi_2(z_1, z_2, \rho), \quad (6)$$

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 (2008) 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:

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

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 equation (7) are slightly modified and used to form the log-likelihood function as well (see, e.g., Greene, 2008). 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 (see, e.g., Greene, 2008; Train, 2009).

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, socio-economic and institutional variables, and attitudinal 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.

Results and Discussion

Six binary probit models of soil and water conservation measures were estimated. Preliminary analyses conducted showed that multicollinearity is not a problem in the models as all variables had a variance inflation factor of less than 10 (Chatterjee & Hadi, 2006), except age and square of age of household head. Further tests show the two variables did not pose a serious collinearity problem in the model in which they appear. The results are shown

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

in Tables 2, 3, and 4. A Lagrange multiplier test for heteroscedasticity produced values less than the critical value of 5.991 in all models, implying this is not a problem.

Table 1: Variables definition and descriptive statistics

Variable	Definition	Mean	S.D.
Dependent variables			
Water management practices			
1. Stone bund	Dummy, 1 if adopted and 0 otherwise	0.57	0.50
2. Soil bund	Dummy, 1 if adopted and 0 otherwise	0.56	0.50
3. Grass strip	Dummy, 1 if adopted and 0 otherwise	0.31	0.46
Fertility management practices			
4. Agroforestry	Dummy, 1 if adopted and 0 otherwise	0.15	0.36
5. Cover crop	Dummy, 1 if adopted and 0 otherwise	0.09	0.28
6. Composting	Dummy, 1 if adopted and 0 otherwise	0.13	0.34
Explanatory variables			
*Personal and **h**ousehold **c**haracteristics*			
HH_AGE	Age of household head (in years)	53.24	15.42
HHAGESQ	Square of the age of household head	-	-
HHSEX	Dummy for sex of household head (1 if male, 0 if female)	0.91	0.28
HH_EDU	Years of education of household head	2.27	4.31
AVE_EDU	Average level of education of all household members, excluding infants (in years)	5.95	2.88
HH_SIZE	Household size	7.86	2.71
HOUSE	Index for the type of house/dwelling	4.63	1.47
TLU	Livestock holding (in tropical livestock units)	3.15	3.58
LTPFMP	Length of time household has been using fertility management practices (in years)	1.46	4.22
Farm/plot and cropping characteristics			
SIZEWMP	Area of land under water management practices (in hectares)	1.06	0.92
SIZEFMP	Area of land under fertility management practices (in hectares)	0.15	0.49
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_RE	Dummy for location, 1 if in northern region and 0 otherwise	0.33	0.47
UW_REG	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
MEM_FA	Dummy, farmer association member (1 if member, 0 otherwise)	0.60	0.49
SHL_MDAY	Total self-help labour for 2008 agricultural year (in man-days)	81.72	110.02
DISTFH	Distance of plot 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
Attitudinal variable(s)			
NWM	Number of nearby farmers using water management practices	29.21	24.24

Table 2[3]: Probit models of adoption of stone bund and soil bund

Variable	**Stone bund**				**Soil bund**			
	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	-0.9424*	-0.2921	-0.6937	0.0000	-2.2869**	-0.3893	-2.2385**	0.0000
HH_AGE	-0.0042	-0.0017	-0.0036	-0.0009	0.0552*	0.0213	0.0651**	0.0221
HHAGESQ					-0.0005	-0.0002	-0.0005*	-0.0002
HHSEX	-0.6448**	-0.2264	-0.5544**	-0.888	0.0486	0.0188	0.2329	0.0775
HH_EDU					0.0205	0.0079	0.0238	0.0081
AVE_EDU	0.0460**	0.0179	0.0483**	0.0203				
HH_SIZE	0.0611**	0.0238	0.0451**	0.0190	-0.0839***	-0.0323	-0.0902***	-0.0309
SIZEWMP	0.3611***	0.1409	0.1391**	0.0586	0.6598***	0.2540	0.3966***	0.1357
PER_DEG	0.2543*	0.0992	0.2786**	0.0865	0.0422	0.0162	-0.0455	-0.0056
PETENURE					-0.3496**	-0.1306	-0.4098**	-0.1347
EXNTACT	0.0549***	0.0214	0.0615***	0.0160				
MEM_FA	0.2944**	0.1152	0.2971**	0.1378	0.4844***	0.1870	0.4363**	0.1533
SHL_MDAY					0.0026***	0.0010	0.0022**	0.0009
HOUSE	0.1265***	0.0494	0.0993***	0.0419	0.0508	0.0196	0.0636	0.0218
SOILDEX	-0.0812	-0.0317	-0.0908	-0.0302	0.0570	0.0219	0.1012	0.0332
SLOPEDEX	0.1299	0.0507	0.1236	0.0259	-0.0225	-0.0087	-0.0864	-0.0234
DISTFH	-0.0563*	-0.0220	-0.0538	-0.0211				
NORTH_RE	-0.5143***	-0.2014	-0.4347**	-0.1011	-0.3326*	-0.1292	-0.0818	-0.0535
UW_REG	-1.1277***	-0.4207	-1.0898***	-0.4074	1.0605***	0.3689	1.2383***	0.3507
Observations	445		445		445		445	
Log likelihood	-251.557		-348.786		-202.486		-311.500	
Chi squared	105.942***				206.072***			
AIC	1.198		1.702		0.982		1.539	
BIC	1.336		1.979		1.129		1.824	
$\rho_{(1,2)}$ [a]	0.000		0.996***		0.000		-0.416**	
Predicted prob[b]	71.24 percent				77.75 percent			
Lagrange mul.[c]	$LM = 0.511$		$\chi^2_{(0.95,2)} = 5.991$		$LM = 0.587$		$\chi^2_{(0.95,2)} = 5.991$	

***, **, *, stand for values statistically significant at 0.01, 0.05, and 0.1 levels respectively; [a] is the correlation parameter between the two equations and is used to test for selection effects; [b] denotes proportion of correctly predicted probabilities; and [c] is the Lagrange Multiplier test for heteroscedasticity.

[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.

Table 3: Probit models of adoption of cover crops and composting

Variable	**Cover crops**				**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	-3.1502***	-0.8608	-3.1743**	0.0000	-1.4296**	-0.4614	-1.2587*	0.0000
HH_AGE	-0.0066	-0.0004	-0.0065	-0.0004	-0.0006	-0.0001	0.0022	0.0003
HHSEX	-0.1063	-0.0071	-0.1015	-0.0071	0.0300	0.0053	0.1004	0.0135
HH_EDU	-0.0062	-0.0004	-0.0044	-0.0003	0.0026	0.0005	0.0071	0.0015
HH_SIZE	-0.1011*	-0.0062	-0.1092	-0.0080	0.0586*	0.0104	0.0596	0.0127
SIZEFMP	0.6933***	0.0422	0.6599***	0.0485	-0.1130	-0.0201	-0.1780	-0.0378
PER_DEG	0.5329**	0.0324	0.5722	0.0407	-0.1946	-0.0346	-0.2765	-0.0480
PETENURE	0.0299	0.0018	0.0107	0.0012				
LTPFMP	0.1398***	0.0085	0.1370***	0.0101				
EXNTACT	0.0392**	0.0024	0.0407*	0.0025				
MEM_FA					0.4815**	0.0811	0.3762	0.0754
TLU					0.0120	0.0021	0.0065	0.0014
SOILDEX	0.2174	0.0132	0.2155	0.0161	0.0795	0.0142	0.0911	0.0172
SLOPEDEX	0.2615	0.0159	0.2756	0.0194				
DISTFH					-0.0140	-0.0025	-0.0106	-0.0027
DISTFM					-0.1765**	-0.0315	-0.2023**	-0.0429
ROAD					-0.7040***	-0.0956	-0.6598**	-0.1091
NORTH_RE	-0.0721	-0.0043	-0.0869	-0.0029	-0.5453**	-0.0871	-0.3763	-0.0932
UW_REG	0.0818***	0.0051	0.0499	0.0068	0.3168	0.0605	0.2792	0.0392
Observations	445		445		445		445	
Log likelihood	-65.774		-198.547		-154.175		-281.288	
Chi squared	132.821***				39.879***			
AIC	0.359		1.023		0.760		1.399	
BIC	0.487		1.290		0.898		1.675	
$\rho_{(1,2)}$ [a]	0.000		0.348		0.000		-0.455	
Predicted prob[b]	94.16 percent				86.74 percent			
Lagrange mul.[c]	$LM = 0.873$		$\chi^2_{(0.95,2)} = 5.991$		$LM = 0.146$		$\chi^2_{(0.95,2)} = 5.991$	

***, **, *, stand for values statistically significant at 0.01, 0.05, and 0.1 levels respectively; [a] is the correlation parameter between the two equations and is used to test for selection effects; [b] denotes proportion of correctly predicted probabilities; and [c] is the Lagrange Multiplier test for heteroscedasticity.

Table 4: Bivariate probit model for grass strip and agroforestry

Variable	Conventional Model: No Selectivity			Model Corrected for Selectivity Bias		
	Grass strip	***Agroforestry***	Marginal Effect [a]	***Grass strip***	***Agroforestry***	Marginal Effect [a]
	Coefficient			Coefficient		
Constant	-0.3863	-2.5941***	0.0000	-0.3399	-2.4117**	0.0000
HH_AGE	-0.0130**	0.0003	-0.0050	-0.0111*	-0.0005	-0.0046
HHSEX	-0.0333	-0.0181	-0.0086	0.0379	-0.0111	0.0179
HH_EDU	-0.0071	0.0256	-0.0083	-0.0037	0.0310	-0.0077
HH_SIZE	0.0299	-0.0219	0.0161	0.0269	-0.0271	0.0168
NWM	0.0120***		0.0046	0.0117***		0.0050
SIZEWMP	0.3582***		0.1354	0.2514***		0.1072
SIZEFMP		1.3441***	-0.2930		1.2901***	-0.2552
PER_DEG	-0.0807	-0.0291	-0.0241	-0.0914	0.0002	-0.0383
PETENURE	-0.2726	-0.0244	-0.0916	-0.2748	0.0184	-0.1211
EXNTACT	0.0413***	0.0472	0.0053	0.0397**	0.0489	0.0075
SHL_MDAY	0.0023**	0.0027***	0.0003	0.0024**	0.0027***	0.0005
HOUSE		0.0502	-0.0109		0.0292	-0.0383
TLU	-0.0430**		-0.0163	-0.0437**		-0.0186
SOILDEX	0.1633	0.2429*	0.0088	0.1603	0.2007	0.0285
SLOPEDEX	0.0388	0.1228	-0.0121	0.0349	0.1277	-0.0100
NORTH_RE	-0.4250**	0.5286	-0.2964	-0.3665	0.5243	-0.2612
UW_REG	-1.7235***	-1.1929***	-0.4291	-1.7406***	-1.2106***	-0.5037
$\boldsymbol{\rho}_{(1,2)}$ [b]		0.659***			0.6016***	
$\boldsymbol{\rho}_{(1,3)}$					0.2189	
$\boldsymbol{\rho}_{(3,2)}$					0.5750	
AIC		1.451			2.072	
Log likelihood		-290.864			-413.120	

***, **, *, 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 $P[y_1|y_2=1]$, but for a dummy the value is a difference; [b] is the correlation parameter between two equations and is also used to test for selection effects here.

Each model was estimated first without correcting for selectivity bias and then correcting for it in a second estimation. The first two columns of each model in Tables 2 and 3 present results of the models estimated independently of the selection equation, except that of grass strip and agroforestry not shown here, while the second two columns show results of the model estimated jointly with the selection equation. Selectivity effects in nonlinear models are measured using the correlation parameter between the error terms of the two equations, ρ, (Greene, 2008). As observed earlier, it is necessary to correct for selectivity bias since farmers' adoption decisions can generally be said not to be a random process as they usually self-select into treatment.

From the results in Tables 2 and 3, the data present evidence of selectivity in the stone bund and soil bund models only, since ρ is statistically significant in only those two models. The selectivity correction models are thus appropriate for those two practices, since without correcting for selectivity the estimates in those models will biased, whilst for the cover crops and composting models the independent models are appropriate as ρ is not significant. To cater for a possible contemporaneous correlation, six models, for all the practices, were jointly estimated but the results (not shown here) show only the grass strip and agroforestry models should be jointly estimated and should not be corrected for selectivity bias (Table 4).

From the above thus, the models that have been chosen for discussion are the sample selectivity correction models for stone bund and soil bund adoption models (in Table 2); the independent adoption models, i.e. the models without correction for selectivity bias, for cover crops and composting (in Table 3); and the bivariate probit adoption model without sample selectivity correction for grass strip and agroforestry (in Table 4). 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 age of the household head, household size and wealth proxied by livestock and dwelling type are the significant determinants in this category, even though their effects remain mixed. In particular, the bigger the herd of livestock in the household the less willing such a household is in adopting grass strips. This could be explained by the fact that grass is required for feeding the animals, especially during the long dry season. Again, household size while reducing the probability of adopting soil bund and cover crops consistent with the finding of Bekele & Drake (2003), increases the probability of adopting stone bund and composting. This could be attributed to the fact that stone bunds and composting are more labour intensive and are only within the reach of households that are well endowed in terms of labour. Generally, the findings here are consistent with that of Wossink & van Wenum (2003) who find 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, the probability of undertaking stone bund, soil bund and grass strip on plot increases as water management becomes the priority (as shown by the significance of the *SIZEWMP* variable). But adoption of agroforestry, cover crops and composting increases when the priority is to manage soil fertility. Adoption of any of the conservation practices is less likely for farmers located in Northern region compared to those in the Upper East, probably because environmental conditions in the former might not be as severe as in the latter. The probability of adopting soil bund and cover crops is higher for farmers in the Upper West region than those in the Upper East.

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 in the previous year remains a 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. In particular, the two variables signifying social capital, that is membership in farmer association (*MEM_FA*) and use of self-help labour (*SHL_MDAY*), positively affect adoption of conservation measures. 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 Baidu-Forson, 1999; Bekele & Drake, 2003; Lapar & Pandey, 1999). 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 & Swinton (2003) in Ethiopia. This is not surprising as nearness to major markets guarantees market participation as a result of decreasing transactions cost (Lapar & Pandey, 1999) 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.

The only variable which is a proxy for social attitude of farmers, *NWM*, has a positively significant effect on the probability of adoption. The probability of adopting grass strip increases significantly as more neighbouring farmers use practices aimed at water management. This agrees with the result of Rahelizatovo (2002) who finds positive attitude of farmers increased the likelihood of adopting best management practices in the dairy industry.

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 (2009) examined adoption of soil bund and dibbling by rice farmers in only 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 is 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 measures 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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