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Full Research Article

Adoption intensity of soil and water conservation practices by smallholders: evidence from Northern Ghana

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Abstract. Soil and water conservation practices are being promoted in Ghana as a way of sustainably managing the environment to support agricultural production. Despite the important role the adoption of the practices plays in conserving the environment, very few studies have been conducted to analyse the factors influencing their intensive adoption. This study analyses the determinants of intensity of adoption of soil and water conservation practices using data from a cross-section of smallholder producers in Northern Ghana. Count data models are used for the analysis. The empirical results show that access to information, social capital, per capita landholding and wealth play an important role in smallholder producers' decision to intensively adopt soil and water conservation practices.

Keywords. conservation practices, adoption intensity, count data models, underdispersion, Ghana

JEL Codes. Q12, Q18, Q56

1. Introduction

A greater majority of the populations in developing countries depend on the natural environment for their subsistence (Barbier, 2010), and most of these countries, like Ghana, are predominantly agrarian relying heavily on earnings from agriculture exports. However, the agricultural sector has long been identified as a cause of environmental degradation and this trend is expected to continue in the next half century (Millennium Ecosystem Assessment, 2007). As a result, a major challenge confronting these countries is how to maintain the natural resource base while at the same time supporting agricultural production.

The people of Northern Ghana are predominantly peasants depending almost exclusively on renewable natural resources for their livelihoods and survival, but they are confronted with deteriorating soil conditions which tend to put a major strain on their livelihoods (IRG, 2005). While about 69.0 percent of the total land area of Ghana is said to be prone to erosion estimated at a cost of 2.0 percent of GDP (MoFA, 2007) and about 35.0 percent estimated to be vulnerable to desertification (IRG, 2005), the majority of the areas under this

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classification are located in the three northern regions of Ghana (IRG, 2005; MoFA, 2007). The upshot of this is that farmers have devised and continue to devise various ways of managing the scarce natural resources, sometimes with external support such as NGOs offering incentives, so they can continue to produce. Some of the conservation practices promoted are grass stripping, composting, stone and soil bunds construction among others, but the scale of penetration of the individual practices among farmers is believed to be inadequate.

Even though a lot of studies have been conducted on technology adoption in developing countries' context, only a few account for intensity of adoption. While decision to adopt is usually a binary one (i.e. adopt or not adopt), intensity of adoption goes on to look at the extent to which the various techniques are adopted. In analysing the adoption decisions of multiple soil and water conservation practices, count data models are employed in which the number of practices adopted serves as a measure of intensity of adoption (see, for example, Isgin *et al.*, 2008; Lohr and Park, 2002; Sharma *et al.*, 2011).

The objective of this study is to identify the determinants of multiple technologies adoption by smallholder producers in Northern Ghana using data collected from 445 farm households between November 2009 and March 2010 in the three northern (*viz.* Northern, Upper East and Upper West) regions of Ghana.

Most of such studies mentioned above account for *overdispersion*, where the variance of the count-dependent variable is greater than the conditional mean. The current study is somewhat unique in the sense that it accounts for *underdispersion* (i.e. the variance of the count-dependent variable is less than its conditional mean) in analysing intensity of adoption of soil and water conservation practices among smallholder farmers in Northern Ghana. In the presence of underdispersion both over- and equi-dispersion models will yield unreliable estimates.

The rest of the paper is organised as follows. Section 2 presents a brief review of the literature on intensity of adoption. While Section 3 discusses the empirical methods employed, Section 4 describes the survey data and variables used. Section 5 presents and discusses the main results of the study, and concluding remarks are provided in the last section.

2. Intensity of adoption studies

Various options exist for measuring intensity of adoption. Some of these include count data models, Tobit and double hurdle models. For example, Isgin *et al.* (2008), Lohr and Park (2002), Rahelizatovo and Gillespie (2004), Ramirez and Shultz (2000), and Sharma *et al.* (2011) employed count data models to explain intensity of adoption of various technologies.

Studies such as Arslan *et al.* (2013) and Alene *et al.* (2000) have employed the Tobit model to examine intensity of adoption of various technologies. In using this approach, either the proportion of land under the given technologies or the proportion of farmers adopting such technologies is used as the dependent variable. This implies that attention is not paid to how many of the technologies are adopted.

A number of other studies (see, for example, Beshir, 2014; Caviglia-Harris, 2003; Gebremedhin and Swinton, 2003) have considered factors affecting both the decision to adopt and the degree or intensity of adoption of technologies or conservation practices using double hurdle models. These usually involve a first stage probit model and a second stage truncated model to assess the degree (or intensity) of use. Other studies (for example, Mbaga-Semgalawe and Folmer, 2000) use an integrated socio-economic model of adoption to examine a first stage perception of erosion, a second stage adoption of improved soil and water conservation measures, and then a Poisson regression model to analyse a third stage adoption effort (or level of adoption) of improved conservation measures in which selectivity bias is accounted for using the Heckman two-stage approach. Two methodological issues, however, arise from such integrated studies. First, it is not clear whether the use of the Poisson model to analyse the level of adoption decision is appropriate since it is not known whether there is equidispersion in the dependent variable. The second issue relates to the use of the inverse mills ratio as a variable in the Poisson model to account for selectivity. It is argued that such a procedure is inappropriate since the model is nonlinear (Greene, 2006; Terza, 1998).

The use of the number of practices adopted as a measure of adoption intensity is underpinned by a number of assumptions and these are discussed by Lohr and Park (2002), Isgin *et al.* (2008) and Sharma *et al.* (2011). One of the assumptions is that provided a farming household derives a greater utility from the last adopted technology, there is no limit to the number of practices or technologies adopted. Adopting greater number of conservation practices is seen to be better where marginal benefit of adopting is at least equal to the marginal cost. It is acknowledged that conditions that make the marginal benefit of conservation adoption to be greater than the marginal cost will include situations where the risk of environmental degradation is very high (like in the study area) and where farming households can efficiently use the practices.

Another assumption is that the adoption decision of the farming household for any one conservation practice does not rule out the adoption of the other available practices, but as noted by Isgin *et al.* (2008, p.232), the adoption of a given technology might not be independent of another since the effects of certain technologies might be complementary. However, Isgin *et al.* (2008) still believed adoption of most technology components in their sample was independent due to variable needs and conditions of producers, and most especially because only 12.0 percent of the 153 correlation coefficients turned out to be greater than a threshold level of 50.0 percent and statistically significant. Given this observation, there is even a stronger reason in this study to believe the adoption of conservation practices is independent since none of the 15 correlation coefficients is up to the 50.0 percent threshold; indeed, only one is 40.3 percent (refer to Appendix 1). It is also noted that a serious limitation of count data models is that they do not have very sound theoretical basis, and there is very little guidance on the appropriate functional form, but they remain the best when modelling number of technologies adopted.

3. Empirical methods[2]

To investigate factors influencing the intensity of adoption of soil and water conservation practices in the study area, the number of conservation practices adopted by each

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[2] These methods are based on the economic model of utility maximisation by households known as the agricultural household model (proposed by Singh *et al.* (1986)), details of which are presented in Nkegbe, P.K. (2013). Soil conservation and smallholder farmer productivity: an analytical approach. Journal of Management and Productivity 3(2): 92-99.

farming household defines the dependent variable; it is thus a discrete nonnegative integer-valued count variable. Following the studies that have employed count data models to explain the intensity of adoption of various technologies, thus, the number of conservation practices adopted is interpreted as defining the intensity of adoption.

The number of conservation practices at any given y_i which is an integer count variable, can be said to come from a Poisson distribution and can thus be modelled using the basic Poisson model as (Cameron and Trivedi, 1998; Greene, 2008; Maddala, 1983; Winkelmann, 2008):

$$Prob(Y_i = y_i|x_i) \frac{e^{-\lambda_i}\lambda_i^{y_i}}{y_i!}, \lambda_i \in \mathbb{R}^+, y_i = 0,1,2,\ldots \quad (1)$$

From equation (1), the $\lambda_i = E(y_i|x_i) = Var(y_i|x_i)$ and the mean is usually defined $\lambda_i = exp(x_i\beta)$ where x_i is a vector of characteristics specific to household i, and β is a vector of unknown parameters to be estimated. The marginal (or partial) effects in the Poisson model are given by:

$$\frac{\partial E(y_i|x_i)}{\partial x_i} = \lambda_i\beta. \quad (2)$$

This marginal effect, as in other count data models, is interpreted as the unit change in the intensity of adoption variable resulting from a change in the explanatory variable (Cameron and Trivedi, 1998, p.80).

Even though the basic Poisson model is attractive for use in empirical studies, it has a major shortcoming of assuming equality between the variance of the count-dependent variable and its conditional mean, known as the equidispersion condition (Cameron and Trivedi, 1998; Greene, 2007a; Greene, 2007b; Winkelmann, 2008). But in most empirical studies the count-dependent variable has been observed to exhibit overdispersion, implying the variance is greater than the conditional mean, due largely to the preponderance of zero observations of the dependent variable in such data sets. As a result, most empirical applications (including, Gale, 1998; Isgin *et al.*, 2008; Kim *et al.*, 2005; Lohr and Park, 2002; Rahelizatovo and Gillespie, 2004) have employed a negative binomial model, which is suitable for modelling overdispersion.

However, an initial inspection of the count-dependent (i.e. the intensity of adoption) variable in this study as a crude guide shows the variance is less than the mean, a result that is most likely emanating from the fact that only about 12.0 percent of the observations on the dependent variable is zero (see Table 1). This implies that the model(s) to be used should be capable of handling underdispersion, and this is what makes the current study different from other previous studies. To model the apparent underdispersion, the gamma model is employed since the flexibility in that model allows for handling under- or overdispersion, besides equidispersion (Cameron and Trivedi, 1998; Greene, 2007b; Winkelmann, 2008).[3]

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[3] It is noted that the generalised Poisson model could also be used, but it has the shortcoming of the range of the

The gamma count model is derived from the gamma distributed renewals proposed by Winkelmann (1995), and has been discussed by Cameron and Trivedi (1998), Greene (2007b), and Winkelmann (2008). If waiting times between any two events are distributed as continuous, two parameter gamma variate, then the density for inter-arrival times can be stated as (Greene, 2007b; Winkelmann, 2008):

$$f(\tau|\alpha,\lambda_i)=\frac{\lambda_i^{\alpha}}{\Gamma(\alpha)}\tau^{\alpha-1}e^{-\lambda_i\tau},\tau\geq 0,\alpha>0,\lambda_i>0 \quad (3)$$

with α being a shape parameter and $\lambda_i=e^{x_i'\beta}$ being a location parameter.

Using a Laplace transformation of a gamma distribution (as detailed in Winkelmann 2008, p.56) with parameters λ_i and αj and arrival time of the jth event being $Q_j = \tau_1 + \tau_2 +\ldots+ \tau_j$ the density function of Q_j can be written as:

$$f_j(Q_j|\alpha,\lambda_i)=\frac{\lambda_i^{\alpha j}}{\Gamma(\alpha j)}Q_j^{\alpha-1}e^{-\lambda_i Q_j},Q_j\geq 0,\alpha>0,\lambda_i>0 \quad (4)$$

To derive the count data distribution, the cumulative distribution function below must be evaluated:

$$F_j(T|\alpha,\lambda_i)=\int_0^T\frac{\lambda_i^{\alpha j}}{\Gamma(\alpha j)}u^{\alpha j-1}e^{-\lambda_i u}\,du,\alpha>0,\lambda_i>0$$

$$=\frac{1}{\Gamma(\alpha j)}\int_0^{\lambda_i T}u^{\alpha j-1}e^{-u}\,du, j=0,1,2,\ldots$$

$$= G(\alpha j,\lambda_i T) \quad (5)$$

It is noted that the integral above is an incomplete gamma function normally approximated numerically (Greene, 2007b). If j events occur in a fixed (0,T) then it gives the two-parameter distribution function:

$$Prob(j\ events) = G(\alpha j,\lambda_i T) - G(\alpha(j+\mathrm{i}),\lambda_i T) \quad (6')$$

where $G(0,\lambda_i T) = 1$

If the period is normalized to $T = 1$ the distribution for the counts of events, especially in a cross-sectional framework, is given by:

random variable being dependent on an unknown parameter, thereby violating one of the standard conditions for consistency and asymptotic normality of maximum likelihood estimation procedure (Cameron and Trivedi, 1998).

$Prob(j\ events) = G(\alpha j,\lambda_i) - G(\alpha j+\alpha,\lambda_i)$. (6)

In the model, α is the dispersion parameter with $\alpha<1$ and $\alpha>1$ denoting over- and underdispersion, respectively, while $\alpha=1$ reduces the model to the basic Poisson model hence equidispersion. The conditional mean and variance functions are

$$E(y_i|x_i)=\sum_{j=1}^{\infty} jG(\alpha j,\lambda_i) \text{ and } Var(y_i|x_i)=\sum_{j=1}^{\infty} j^2[G(\alpha j,\lambda_i)-G(\alpha j+\alpha,\lambda_i)]-E(y_i|x_i)^2,$$

respectively.

As noted by Greene (2007b), because the conditional mean has no closed form, an approximation usually used is $E(y_i|x_i) \approx \lambda_i/\alpha$ so that it readily reduces to the Poisson model if $\alpha=1$. This then leads to the marginal effects function:

$$\frac{\partial E(y_i|x_i)}{\partial x_i}=\frac{\lambda_i}{\alpha}\beta\cdot \tag{7}$$

Finally, the model that is estimated is of the form:

$$Prob(Y_i=y_i|x_i)=f(x_i^p,x_i^{fc},x_i^{si}) \tag{8}$$

where:

Y_i = number of conservation practices (count) adopted by household i;

x_i^p = personal and household characteristics;

x_i^{fc} = farm/plot and cropping characteristics; and

x_i^{si} = socio-economic and institutional variables.

The variables are explained in the following section.

4. Survey data and variables

The data for the study are obtained from a survey of 445 households in the three northern regions of Ghana. The survey covered production activities for 2008/2009 agricultural year and was undertaken between November 2009 and March 2010. The households were drawn using a multi-stage sampling procedure which involved identifying a district in each of the regions, randomly selecting 5 communities from each district and finally randomly selecting 30 households from each community.[4] The households are smallholder producers growing cereals like maize, millet, sorghum and rice; and other crops like groundnut, cowpea and soy bean under rainfed conditions. These crops are produced mainly for home consumption, but surpluses are marketed to meet other household needs.

[4] Six households were dropped from an original sample of 451 due to incomplete responses. Detailed explanation of the sampling approach can be found in Nkegbe, P. K. (2011). Resource Conservation Practices: Adoption and Productive Efficiency among Smallholders in Northern Ghana. Unpublished PhD dissertation, Department of Agricultural and Food Economics, University of Reading.

Farmers in this study were asked which conservation practices they adopted. The responses formed the basis for the construction of the dependent variable. The soil and water conservation practices examined are stone bund, soil bund, grass strip, agroforestry, cover crops, and composting. The numbers of conservation practices adopted by the sample are shown in Table 1.

Table 1. Distribution of counts of conservation practices adopted

Practice counts	Frequency	Percent
0	53	11.9
1	156	35.1
2	114	25.6
3	74	16.6
4	41	9.2
5	7	1.6
Total	445	100.0

From Table 1, 11.9 percent of the sampled households did not adopt any of the soil and water conservation practices and thus have a zero count while only 1.6 percent of the sample adopted five of the conservation practices, with no household adopting all six. The majority of households (35.1 percent) adopted one practice and the average number of practices adopted among the sample was 1.81 (see also Table 3). The types of conservation practices adopted by the households are also shown in Table 2. While the most adopted practice is stone bund, the least adopted is cover crops with 56.6 percent and 8.8 percent of the households, respectively, adopting each of them.

The variables hypothesised to influence the probability of the intensity of adoption of conservation practices have been classified as personal and household characteristics, farm or plot and cropping characteristics, and socio-economic and institutional variables. Sixteen variables, excluding the UEAST (Upper East Region) variable since that region is used as the reference location in this study, were included in the count data models. Table 3 presents the definition and descriptive statistics of the variables.

Table 2. Distribution of adoption of conservation practices by households

Practice	Frequency	Percent
Stone bund	252	56.6
Soil bund	248	55.7
Grass strip	140	31.5
Agroforestry	67	15.1
Cover crops	39	8.8
Composting	59	13.3

The personal and household characteristics considered here include age of household head, gender of head, average education of household members, own labour use, per capita landholding, wealth (house type) and number of plots cultivated. Age could have positive or negative effect on the decision to intensively adopt conservation practices. Because conservation practices in the study area mostly do not involve construction of permanent structures on the land, it is not likely there will be gender dimensions to adoption as land is mostly owned by males and the presence of permanent structures is interpreted as laying claim to the land. Thus it would have been more difficult for females to adopt conservation practices if construction of permanent structures were involved. The effect of average level of education of adult household members on adoption is mixed. While it could have positive effect on adoption of conservation practices, it might offer alternative livelihood opportunities in off-farm activities thereby increasing the opportunity cost of labour and competing with labour use for agricultural production (Scherr and Hazell, 1994). Own labour use is proxied by household size as in most adoption studies. The effect of household per capita landholding, which is used to capture the effect of population pressure (Lapar and Pandey, 1999), could go either way. It could either provide evidence supporting the Malthusian view of negative effect of population pressure on natural resource conditions, or provide evidence in support of the Boserupian hypothesis that population pressure induces households to embark on agricultural intensification thereby adopting land enhancement technologies which ultimately leads to improved natural resource conditions. Given the high poverty levels in the study area, wealthy farming households are expected to have higher probability of adopting soil and water conservation practices. Housing type is used to proxy the effects of wealth on adoption. Number of plots operated by the households is expected to positively impact the intensity of adoption of soil and water conservation practices, as conditions on different plots may require the use of different conservation practices.

Perception of degradation, type of soil, slope and location are the factors considered under farm/plot and cropping characteristics. It is expected that the more farm households perceive their fields to be degraded - in the form of erosion on plots - the more likely they will adopt practices to minimize the adverse effects of degradation on their farming activities (Mbaga-Semgalawe and Folmer, 2000). This variable is an index with 1 being less degraded and 4 being highly degraded, and where a farmer cultivates more than one plot an average index is used. Also, farm households will adopt fertility enhancing practices, especially in Northern Ghana where the soils are less fertile, to reduce soil infertility induced yield losses. The variable on major soil type is also an index ranging from 1 to 4, with 1 being most fertile. It is expected that the steeper the slope the more likely farm households will adopt conservation practices. A very steep slope is given an index of 4 with a flat topography taking 1. For this variable also, an average index is taken for farmers with more than one plot. The Upper East Region is the most degraded of the three regions and so households in that region should be more likely to intensively adopt soil and water conservation practices than those in the Northern and Upper West Regions.

Finally, the socio-economic and institutional variables hypothesised to affect adoption decisions of farm households are related to access to information and social networks.[5]

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[5] Security of tenure, an important institutional variable, has generally been reported to have positive effects on

Table 3. Variables definition and descriptive statistics

Variable	Definition	Mean	S.D.
Dependent Variable			
NUMCON	Number of conservation practices adopted (counts)	1.81	1.21
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
HH_SIZE	Household size	7.86	2.72
ADLAND	Landholding per economically active member of household (in hectares)	0.52	0.41
HOUSE	Index for the type of house/dwelling (3-12)	4.63	1.47
NOPLOTS	Number of plots cultivated by the household	2.58	1.48
Farm/Plot and Cropping Characteristics			
PER_DEG	Average index for perception of degradation on all plots (highest = 4)	2.06	0.51
SOILDEX	Average index for major soil type on all plots (1 = most fertile)	2.24	0.68
SLOPEDEX	Average index for type of slope on plots (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			
EXNTACT	Number of contacts with extension officers in the 2008/09 agricultural year	2.53	4.51
MEMFA	Dummy for membership in farmer association (1 if member, 0 otherwise)	0.60	0.49
SHLAB	Total self-help labour for 2008/09 agricultural year (in man-days)	40.86	55.01
DISTFH	Distance of plot from homestead (in km)	1.58	2.04

Farm households' access to information, which is expected to have positive effect on adoption intensity, is proxied by contacts with extension (public or private) staff. Farmers' social networks generally will facilitate adoption through information flow and group action, especially involving engagement in mutual labour sharing arrangements. Effects of social capital in this study are measured by membership in farmer association and total man-days of mutually shared labour received in the 2008/09 agricultural production year. Distance between homestead and plot can affect adoption of conservation practices in either way depending on the type of practice. For example, adoption of composting will be less likely for plots that are very far away from the house as preparation of the compost might require the use of bulky kitchen waste and dung from compound kraals.

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conservation investment in southern Ghana (Abdulai *et al.*, 2011a; Besley, 1995; Goldstein and Udry, 2008). But this might not be the case for Northern Ghana as the predominant type of ownership remains communal and rather complex (Abdulai *et al.*, 2011a), as against the increasingly individualised type of ownership in the south. As a result, including a variable to capture tenure security might amount to a misspecification, thus no provision is made for security of tenure.

5. Results and discussion

From the results in Table 4, extension contacts in the previous production season, membership in farmer association, engagement in mutual labour sharing, wealth, number of plots cultivated, index for soil type and slope are positive and significant determinants, while landholding per economically active member of household and being located in the Upper West Region are negative and significant determinants of the intensity of adoption decision across both models. The results can therefore be said to be reasonably uniform across the two (i.e. Poisson and gamma) count data models.

However, a number of formal tests of dispersion confirmed the existence of underdispersion by the crude check. First, results in Table 4 indicate two of the statistics developed by Cameron & Trivedi (1990), and discussed by Greene (2007b), for testing for dispersion in the Poisson count data model, $g(\mu_i)$ and $g(\mu_i^2)$ are -8.307 and -8.162, respectively. The two statistics have limiting chi-squared distributions with one degree of freedom under the null hypothesis of equidispersion, thereby giving a critical value of 3.841 at the 0.05 level. Clearly, the absolute values of both statistics exceed the critical value. The equidispersion assumption is therefore rejected, and the fact that both values are negative indicates underdispersion and not overdispersion.

As a result, the gamma model is used to model farmers' intensity of adoption of soil and water conservation practices in Northern Ghana. As shown in Table 4, the results of the gamma count model confirm that there is underdispersion in the data since the dispersion parameter is greater than one and statistically significant. The rest of the discussion of the results is thus based on the chosen gamma count data model.

Three factors under the category personal and household characteristics are statistically significant determinants of the decision to intensively use soil and water conservation practices. The results show that larger landholding per economically active member of the household reduces intensity of adoption; as this variable increases by one additional unit, households in the sample decrease the number of soil and water conservation practices adopted by about 0.4 (as shown by the marginal effect of the variable). This observation can be explained in two ways. First, it is likely that households with larger per capita landholding are labour constrained and so are not able to mobilize the required labour for implementing soil and water conservation practices. However, this point seems not to be in operation in the study area as the evidence suggests household labour use on farm does not have any effect on the intensity of adoption of conservation practices. The second point, which appears more plausible for the area, is the explanation that as pressure increases on land reflecting in smaller landholding per economically active member of household, adoption of conservation practices becomes more intensive thereby providing more evidence for the Boserupian thesis of population-induced agricultural intensification, as reported by Pender *et al.* (2004) and Tiffen *et al.* (1994). Household wealth, proxied by type of house, impacts intensity of adoption positively. The existence of wealth effects in the intensive adoption of the conservation practices points to imperfections or failures in the credit market in the study area, a situation that is pervasive in developing countries. Consistent with expectations, an additional plot cultivated by the sampled households would lead to the adoption of over 0.1 more soil and water conservation practices. The result on number of plots is similar to the one obtained by Deininger and Jin

Table 4. Results of count data models

Variable	Poisson		Gamma Count	
	Coefficient	Marginal Effect	Coefficient	Marginal Effect
Constant	-0.2088 (0.3273)	-0.3777 (0.6293)	0.0142 (0.2232)	0.0291 (0.4785)
HHAGE	-0.0033 (0.0025)	-0.0060 (0.0049)	-0.0029 (0.0019)	-0.0059 (0.0041)
HHGEND	-0.0732 (0.1432)	-0.1324 (0.2752)	-0.0655 (0.0992)	-0.1343 (0.2132)
AVEDU	-0.0023 (0.0134)	-0.0042 (0.0256)	-0.0019 (0.0100)	-0.0039 (0.0214)
HH_SIZE	0.0079 (0.0160)	0.0142 (0.0307)	0.0068 (0.0112)	0.0138 (0.0240)
ADLAND	-0.2125* (0.1254)	-0.3845 (0.2484)	-0.1913* (0.1083)	-0.3922* (0.2356)
PER_DEGR	0.0579 (0.0740)	0.1048 (0.1428)	0.0496 (0.0513)	0.1018 (0.1106)
EXNTACT	0.0247*** (0.0063)	0.0447*** (0.0142)	0.0220*** (0.0033)	0.0453*** (0.0087)
MEMFA	0.3002*** (0.0827)	0.5431*** (0.1820)	0.2616*** (0.0585)	0.5365*** (0.1397)
SHLAB	0.0029*** (0.0007)	0.0052*** (0.0016)	0.0026*** (0.0005)	0.0053*** (0.0012)
HOUSE	0.0506** (0.0250)	0.0915* (0.0502)	0.0445*** (0.0172)	0.0913** (0.0384)
NOPLOTS	0.0633 (0.0406)	0.1145 (0.0800)	0.0558** (0.0297)	0.1145* (0.0647)
SOILDEX	0.0848 (0.0543)	0.1534 (0.1071)	0.0757** (0.0370)	0.1553* (0.0814)
SLOPEDEX	0.0867 (0.0649)	0.1569 (0.1271)	0.0766** (0.0388)	0.1570* (0.0850)
DISTFH	0.0144 (0.0179)	0.0262 (0.0345)	0.0129 (0.0120)	0.0264 (0.0259)
NORTH	-0.0683 (0.1065)	-0.1236 (0.2050)	-0.0525 (0.0753)	-0.1077 (0.1622)
UWEST	-0.4859*** (0.1187)	-0.8790*** (0.2705)	-0.4326*** (0.0908)	-0.8870*** (0.2182)
$G(\mu_i)$[a]	-8.307			
$G(\mu_i^2)$	-8.162			
Alpha[b]			1.937***	
Log likelihood	-659.359		-636.570	
Chi squared	87.768***		45.578***	
AIC	3.040		2.942	
BIC	3.196		3.107	

***, **, *, stand for values statistically significant at 0.01, 0.05, and 0.1 levels respectively; figures in parentheses are standard errors; [a] $g(\bullet)$ are dispersion tests values in Poisson model; [b] is the dispersion parameter for gamma count data model.

(2006) who reported that fragmentation, for which number of plots was used as a proxy, had a positive effect on investment in land improvements in Ethiopia.

Under the farm or plot and cropping characteristics category, three variables are statistically significant. The intensity of use of soil and water conservation practices and perception of soil fertility are positively and significantly correlated. Perceiving a problem of soil infertility, *ceteris paribus*, results in the adoption of about 0.2 more conservation practices. This contrasts the finding of Bekele and Drake (2003) who observed that farmers in their sample in Ethiopia were inclined to conserve more fertile plots. Similarly, and in consonance with the findings of Amsalu and de Graaff (2007), Bekele and Drake (2003) among others, the slope variable has a significantly positive effect on intensity of adoption of soil and water conservation practices. This implies that as households perceive their plots to be steeply sloped, the higher the probability of them adopting soil and water conservation practices more intensively.

While location variables, NORTH and UWEST, have a negative effect on intensity of use of conservation practices, only the latter's effect is statistically significant. Being located in the Upper West Region could bring about almost 0.9 decrease in the number of conservation practices adopted. Sharma *et al.* (2011) and Isgin *et al.* (2008) who also employed count data models found evidence of regional effects in the adoption intensity of pest control measures among their sample of UK cereal farmers and precision farming technology among US farmers, respectively.

A number of socio-economic and institutional variables have statistically significant effect on the adoption intensity decisions of households. Obtaining technical advice from extension officers in the previous production season has a positive effect on adoption intensity, a result that highlights the importance of extension service in promoting sustainable agricultural production practices in developing countries. This result is consistent with that of Kim *et al.* (2005) who reported positive effect of contact with extension staff on the intensity of adoption of best management practices among beef cattle producers in Louisiana, and that of Lohr and Park (2002), also in the US, reporting positive effects of both number of personal information sources and secondary information outlets on the intensity of adoption of insect management portfolios.

Membership in farmer organization and engagement in mutual labour sharing arrangements, representing social capital, both have positive effect on intensity of adoption and are statistically significant at the 0.01 level. While total self-help labour marginally increases intensity of adoption, the farmer association membership variable increases the number of conservation practices adopted by over 0.5. These results, besides confirming the findings in adoption studies like Abdulai *et al.* (2011b), Bandiera and Rasul (2006), Caviglia-Harris (2003), and Munasib and Jordan (2011) reporting positive effect of social networks on adoption, are consistent with that of Ramirez and Shultz (2000) who found belonging to a farmer organization positively affected the intensity of adoption of integrated pest management technologies among their sample from Costa Rica. As farmers belong to associations they learn from others, and especially the influential individuals within their group, even if they do not have direct contact with extension staff. Thus they will have access to information which enhances intensity of adoption.

6. Concluding remarks

Soil and water conservation practices have been promoted in Ghana, especially in the northern parts, as a way of sustainably managing the environment to support agricultural production. Despite the important role that the adoption of the practices plays in conserving the environment, very few studies have been conducted to analyse the factors influencing their intensity of adoption. In this study, thus, the determinants of intensity of adoption of soil and water conservation practices in Ghana are examined using data from a cross-section of 445 smallholder producers in Northern Ghana.

The empirical results confirm the important role access to information plays in stimulating and sustaining adoption of soil and water conservation practices since the number of contacts with extension officers remains a positive and significant determinant in both models. This implies that adoption could be enhanced if the capacity of extension staff in soil and water conservation practices is built and their outreach further increased.

Further, the importance of wealth (with type of house used as its proxy variable) in the intensity of use of conservation practices highlights the need to increase smallholders' access to credit as a way of both promoting and intensifying the adoption of conservation practices.

Social capital, in the form of belonging to farmer association and engagement in mutual labour sharing arrangements, is important in the decision to intensively adopt soil and water conservation practices. It is thus important that this strength of social capital is harnessed in the formulation of rural development policies to improve, or at worse maintain, the condition of the environment for sustainable production. For example, since access to information is considered vital to the decision to intensively adopt conservation practices, a rural development policy that promotes formation of strong and vibrant farmer associations will strengthen farmer-to-farmer knowledge sharing.

The presence of location effects in the intensity of adoption decision of smallholders in Northern Ghana implies that different strategies should be employed for different regions if policy makers aim at promoting widespread diffusion of soil and water conservation practices. Also, regional differences in terms of geography should be factored into any promotional strategies since different practices appear useful to different locations. The results show the Upper West Region must particularly be targeted since intensity of use decreases for households located in that region relative to those located in the Upper East.

On the methodological front, the study yields almost uniform results across the Poisson and gamma count data models, and this demonstrates the robustness of the estimates obtained.

It is important to point out that the current study could suffer a couple of limitations. First, one of the assumptions underpinning the study is that employing more measures means greater intensity of adoption, implying that a producer with several uniform plots might adopt the same practice on all plots whilst another with a single plot with different conditions might adopt more than one practice, in which case the former will be considered adopting less than the latter. Again, the count data on adoption considers whether the producer had one of the practices applied on a plot in the specific production year, but some measures could have been established on the plot from previous production season(s), so that adoption could potentially pose an endogeneity problem.[6] In the light of these, thus, such issues should be taken into account in looking at the results of the study and may provide hints for further research in this field.

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Appendix 1. Spearman's correlation coefficients between adoption methods

Methods	Stone bund	Soil bund	Grass strip	Agroforestry	Cover crops	Composting
Stone bund	1.0000					
Soil bund	-0.0131	1.0000				
Grass strip	0.1633***	0.0777	1.0000			
Agroforestry	0.1529***	0.0463	0.3508***	1.0000		
Cover crops	0.1269***	-0.0438	0.0981***	0.4028***	1.0000	
Composting	-0.0322	0.1083***	0.0063	-0.0534	-0.0040	1.0000

*** stands for values statistically significant at the 0.01 level.