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UNDERSTANDING SOIL CONSERVATION DECISION OF FARMERS IN THE GEDEB WATERSHED, ETHIOPIA

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ABSTRACT

The aim of this study was to investigate the main factors that influence smallholders' adoption decision of soil conservation measures in the Gedeb watershed. Data from 498 household heads who live in the three districts of the watershed were analysed using the binary logistic regression model. We find that farmers need adequate cash to invest in soil conservation measures. Moreover, farmers would be more encouraged to implement soil conservation measures when they have larger areas of cropland. We explore the possibility that when farmers presume that they have fertile land, they exploit their land more. This hints at the need for extension advice about the benefit of sustainable use of farmers' cropland so that they can maintain their land and pass it on to the future generation. Farmers' awareness about the benefit of land management practices and recognition of the problem erosion is causing on their crop land are central to their decision to adopt soil conservation measures. Furthermore, to adopt these measures, farmers have to be convinced about the effectiveness of these measures. Thus, awareness creation and demonstration of the effectiveness of these measures is essential. Because of the transboundary nature of the problem, policy makers in downstream countries that are suffering from the off-site impact (e.g. Sudan) would benefit from the information provided and support efforts in the implementation of soil conservation measures. Copyright © 2013 John Wiley & Sons, Ltd.

KEY WORDS: soil erosion; soil conservation measures; logistic regression model; Gedeb watershed; Ethiopia

INTRODUCTION

Soil erosion is by far the greatest cause of land degradation in Ethiopia (Dubale, 2001). Annually, Ethiopia looses over 1·5 billion tons of topsoil from the highlands by soil erosion (Taddese, 2001) resulting in low and declining agricultural productivity (Sonneveld, 2002). The Country's inherently fragile soils, undulating terrain, highly erosive rainfall and the environmentally destructive farming methods that many farmers practice coupled with high population density make it highly vulnerable to soil erosion (Grepperud, 1996; Dubale, 2001; World Bank, 2008; GMP, 2009). In Ethiopia, soil erosion is greatest on cultivated land, where the average annual loss is 42 t ha^{-1}, compared with 5 t ha^{-1} from pasture land; as a result, nearly half the soil loss comes from land under cultivation (Hurni, 1993).

According to Sonneveld (2002), the on-site cost of soil erosion on Ethiopia's economy is estimated at US $1 billion per year. The problem is transboundary in nature particularly in the upper Blue Nile basin where soil and excessive runoff that leave the boundary of individual farms cause off-site or off-farm impacts to reservoirs, irrigation schemes and waterways downstream within and across political borders (Pagiola, 1999). The Gezira Irrigation Scheme in Sudan is a case in point where soil erosion from the highlands of Ethiopia mainly the upper Blue Nile basin is causing sedimentation and siltation of irrigation canals and waterways resulting in average annual sediment removal of 16·5 million m^3 and associated cost of US $12 million per year (Gismalla, 2009).

Recognizing land degradation as a major environmental and socio-economic problem, the Government of Ethiopia and non-governmental organizations have supported several efforts since the 1970s to promote soil conservation and environmental rehabilitation. Recently, the government has designed and implemented a comprehensive Sustainable Land Management Project that focuses on a compromise between top-down and bottom-up approaches to watershed management activities (MoFED, 2006). Moreover, the Eastern Nile Watershed Project is one of the many areas of cooperation agreed by the Eastern Nile countries, having a strong element of upstream and downstream interaction of transboundary nature and with the objective of, among others, reducing soil erosion, sediment transport and siltation of infrastructure along the River (World Bank, 2001; Geoffrey and Kahsay, 2005).

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However, many of these watershed management practices such as soil conservation programmes in the past were ineffective in either triggering voluntary adoption of conservation practices among farmers outside the Project area or conserving the structures constructed (e.g. Bekele, 1997; Shiferaw and Holden, 1998; Admassie, 2000). Furthermore, a recent case-study conducted by the Global Mountain Programme – Sustainable Agriculture and Rural Development also revealed that there is a noticeable prevalence of natural resources degradation in the highlands of the Ethiopia particularly in Amhara and Tigray regions (GMP, 2009). Some scholars (e.g. Erenstein, 2003; Bolliger *et al*., 2006; Giller *et al*., 2009) argue that low or no uptake of conservation agriculture in general and soil conservation in particular signify the incompatibility of these technologies for resource poor smallholder farmers in most sub-Saharan African and Latin American countries, for example, in Brazil. Similarly, Erenstein (2002) and Knowler and Bradshaw (2007) suggest that conservation agriculture and soil conservation are no panacea for soil degradation unless they are tailored to local conditions because these technologies are site specific and depend on bio-physical and socio-economic environment. The objective of our study was to investigate the main factors that influence farmers decision to adopt soil conservation measures in the three (Gozamn, Machakel and Senan) districts of the Gedeb watershed in the upper Blue Nile basin. Although some studies have been conducted in the Ethiopian highlands to identify factors that affect the adoption of soil conservation measures (e.g. Shiferaw and Holden, 1998; Shiferaw and Holden, 1999; Bewket and Sterk, 2002; Gebremedhin and Swinton, 2003; Bekele and Drake, 2003; Asrat *et al*., 2004; Bewket, 2007; Anley *et al*., 2007; Amsalu and de Graaff, 2007; Holden *et al*., 2009), no study has been conducted in the Gedeb watershed where soil erosion is causing off-site damage to reservoirs and irrigation schemes across political borders.

The two studies conducted in the upper Blue Nile basin (Bewket and Sterk, 2002; Bewket, 2007) used qualitative methods to explore adoption factors; this study seeks to show quantitative relationship, applying a logistic regression model, between smallholders' adoption decision and various socio-economic factors. Because the complex nature of inter-relationship between the different socio-economic factors requires some degree of quantification of data and analysis (Cassell and Symon, 1994), we employ quantitative methods. Investigating quantitative relationship is believed to help policy makers and development planners of both upstream and downstream countries understand the role of each factor influencing smallholders' adoption decisions.

The working definition of 'adoption' we employed in this study is the one given by Rogers (1983:21), 'a decision to make full use of an innovation as the best course of action.' We made a distinction between adopters and non-adopters on the basis of the existence of soil conservation structures on individuals' farm land for the past 5 years (2004–2008) from the time of data collection (July 2009).

METHODOLOGY

Study Area

The Gedeb watershed is one of the watersheds of the upper Blue Nile basin in Ethiopia (see Figure 1). The watershed has a total area of 871 km^2 and a population of 495 000 (CSA, 2007) living in four districts: Gozamn, Senan, Machakel and Debre Elias. The annual rainfall ranges from 920 to 1650 mm and temperature between 7·5 and 22·5 °C. The soil types of the watershed varies from Humic Nitosols (clay-loam texture) to Chromic Luvisols (sandy-loam texture) (MoA, 2000). Agriculture is the most important economic activity for more than 80 per cent of the households living in the watershed. Major crops grown in the area include **tef** (*Eragrostis tef*), wheat, barley, potato and **senar/engedo** (*Avena sativa*). This case-study was carried out in three of the four districts – Senan, Gozamn and Machakel – because they adequately represent the watershed and its different altitudes. The elevation of the Gedeb watershed ranges from 1500 to 4000 metres above sea-level (m asl). Senan is highland (>3500 m asl) and Machakel lowland (1500 m asl), whereas Gozamn is intermediate (2000–2500 m asl) (MoA, 2000). The three locations are found at different slope gradients: Senan district is between 15 and 50 per cent, whereas Gozamn and Machakel districts are between 8 and 15 per cent slope gradient on average.[1]

Similar to most part of the highlands of Ethiopia Gedeb watershed is highly degraded by soil erosion. According to Emrie (2008), the estimated soil loss in the watershed ranges between 0·01 and 140 tons per hectare per year depending on elevation, with the mean soil loss throughout the watershed being 9·1 t ha yr^{-1}. The severe erosion in the upper catchments of the Blue Nile basin results in sedimentation of the Gezira irrigation (Ahmed *et al*., 2004).

Data and Sample Size

The data for this analysis were obtained both from primary and secondary sources. The primary data were part of a household survey conducted for a similar study by the first author in July 2009 using simple random sampling technique. The sample used for this study was from 250 adopters and 248 non-adopters. Table I depicts the sample size for each district. The secondary information was gathered from relevant published articles and reports. The three main soil conservation measures considered for this study were soil bunds, stone bunds and **fanya juu** bunds. Soil and stone bunds are ridges and ditches made of soil or stone, constructed across the slope along the contour. **Fanya juu** is a type of terrace adopted from Kenya

[1]The information about the slope of the area was obtained from the officials of Senan District Agricultural and Rural Development Office.

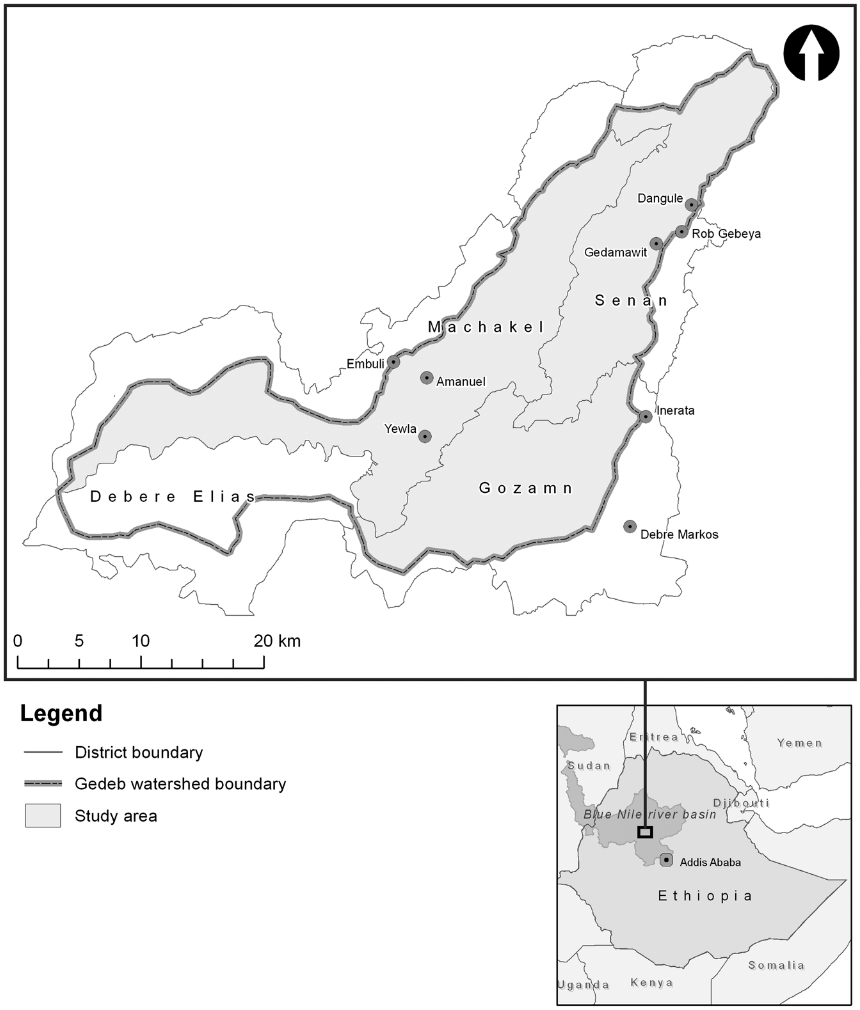

Figure 1. Gedeb watershed.

(Desta *et al*., 2000). Soil, stone and **fanya juu** bunds are the most widely used soil conservation measures in the study area.

Binary Logit Model

The application of a linear regression model when the dependent variable is binary has some fundamental problems such as non-normality of the error term, hetroscadasticity of the error term, possibility of the outcome lying outside the 0–1 range and generally low coefficient of determination (see Pindyck and Rubinfeld, 1991; Scott Long, 1997; Gujarati, 2003). The logit and probit models guarantee that the estimated probabilities will lie between the logical limit of 0 and 1. These two binary outcome models also have an s-shaped relationship between the independent variables and the probability of an event, thus addressing one of the problems with functional form in the linear probability model (Pindyck and Rubinfeld, 1991). Given the similarity between the two models and the comparative mathematical simplicity of the logit model, this study applied the logistic regression model for the analysis of the determinants of farmers' adoption decision. The parameter estimates of a logistic regression can be interpreted easily in terms of odds ratio. The odds ratio shows the strength of association between a predictor and the outcome of interest. When all other predictors are held constant, the odds ratio refers to the change in the odds of the response variable given a unit change in predictor (Peng *et al*., 2002). The dependent variable in our model was the

Table I. Number of household heads interviewed in the study districts of the Gedeb watershed

Location/Site	Non-adopters	Adopters	Total
Gozamn	78	92	170
Machakel	77	67	144
Senan	93	91	184
Total	248	250	498

logarithm of the odds that a given household adopts soil conservation measures specified as (Gujarati, 1995):

$$P_i = E(Y = 1|X_i) = \frac{1}{1 + \ell^{-(\beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \cdots + \beta_k X_{ki})}} \quad (1)$$

Equation (1) can be rewritten as

$$P_i = \frac{1}{1 + \ell^{-Z_i}} \quad (2)$$

Thus, the odds ratio in favour of adoption is given by

$$\frac{P_i}{1 - P_i} = \frac{1 + \ell^{Z_i}}{1 + \ell^{-Z_i}} = \ell^{Z_i} \quad (3)$$

Where:

P_i is the probability of adoption by the *i*th farmer
$1 - P_i = \frac{1}{1+\ell^{Z_i}}$ is the probability of non-adoption by the *i*th farmer
Z_i is a function of k explanatory variables expressed as

$$Z_i = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \cdots + \beta_k X_{ki}$$

β_0 is the intercept and $\beta_1, \beta_2, \ldots, \beta_k$ are the coefficients of the explanatory variables $X_1, X_2, \ldots, X_k$.

Taking the natural log of the odds ratio of Equation (3), we obtain the following:

$$L_i = \ln\left(\frac{P_i}{1 - P_i}\right) = Z_i = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \cdots + \beta_k X_{ki} \quad (4)$$

In the estimation of the factors affecting the adoption of soil conservation measures, the dependent variable is coded as 1 = adoption and 0 = non-adoption. Definition of all the independent variables and their expected relationship with the dependent variable is given in Table II.

RESULTS

Results of Descriptive Statistical Analysis

In the descriptive analysis, comparison was made between farmers with and without soil conservation measures (adopters and non-adopters) in relation with some important variables hypothesized to influence decision of implementation of soil conservation measures. Chi-square and Mann–Whitney *U*-tests were used for the comparison (Tables III and IV).

About 94 per cent of the sample respondents were male-headed households. The average age of an adopter household head was 46, whereas the average age for the non-adopter was 42. The mean comparison between the two groups showed a statistically significant difference in household head age indicating that adopters are older than non-adopters although this result is contrary to prior expectation that younger people are more willing to accept new technologies than older people.[2] Both adopters and non-adopters have the same average family size of five with a maximum of 11 family members. More farmers (57 per cent) were literate in the adopters group than the non-adopters group (49 per cent); however, the Chi square test did not show a significant relationship between education level and adoption of soil conservation measures. Non-adopters kept more livestock [4·6 tropical livestock unit (TLU)] when compared with adopters (4·3 TLU), although the average difference between the groups was not statistically significant. Similarly, non-adopters earn more income both from crop production and off-farm activities than adopters; however, the mean difference between the groups was not statistically significant.

Farmers who adopt soil conservation measures on their cropland were also found to be those with a larger cropland size. The average landholding of adopters and non-adopters was 0·94 and 0·84 ha, respectively. The Mann–Whitney *U*-test indicated that the difference in land holding between the groups was significant. The other statistically significant relationship noted was between access to credit facility and adoption of soil conservation measures. More adopters had access to credit facility (14 per cent) than non-adopters (7 per cent). About 94 per cent adopters and 91 per cent non-adopters obtain support from extension agents appointed by government regarding the implementation of soil conservation measures, agronomic practices and pest and weed control. No significant relationship was observed between access to extension services and adoption. Similarly, 94 per cent adopters and 93 per cent non-adopters were each given a land use certificate.[3] The statistical test showed no significant relationship between land use certificate and adoption. From the result, it was also examined that there is a statistically significant relationship between fertility condition of the land and adoption. More than 60 per cent household heads who perceive to have infertile land were involved in the implementation of soil conservation measures, whereas the corresponding figure for non-adopters was only 17 per cent. Almost all adopters were already practicing land management activities such as crop rotation, mixed cropping and mulching, whereas only 37 per cent non-adopters were involved in such land management practices. Moreover, farmers' perception about the negative impact of soil erosion on their cropland has a significant relationship with adoption decision of soil conservation measures. About 40 per cent adopters and 17 per cent non-adopters reported that erosion has negative impact on their cropland.

Similarly, farmers' evaluation of the importance of soil conservation measures in preventing soil erosion was significantly related with adoption. More than 90 per cent farmers who considered soil conservation measures important have already implemented one of the soil conservation measures to prevent

[2]In rural Ethiopia, sometimes farmers' self-reported age deviates from actual age because of lack of proper documentation; hence, the results presented here have to be interpreted with care.

[3]Land use certificates allow farmers to use their crop land as long as they are alive and pass it on to their children although they are not allowed to sell or mortgage it.

Table II. Definition of model variables

Variable name	Definition	Hypothesized direction of influence
AGE	Age of the household head in years	–
SEX	Sex of the household head (dummy; 1 = male)	–
LITERACY	Literacy of household head (dummy; 1 = literate)	+
FAMILYSIZE	Total number of family members in the household	+
ACCESSCREDIT	Access to credit facility (dummy; 1 = access to credit)	+
ACCESSEXTENSION	Access to extension service (dummy; 1 = access to extension)	+
LABOUR	Labour availability (dummy; 1 = labour is available for soil conservation activity)	+
LUC	Land use certificate (dummy; 1 = has a certificate)	+
TLU	Total number of tropical livestock unit(1 TLU = 250 kg life weight)	+
INCOMECROP	Total annual income from crop production in **birr**	+
INCOMEOFFFARM	Total annual income from off-farm activity in **birr**	±
LAND	Total cropland in hectare	+
EROSIONIMPACT	Farmers perception about the impact of erosion on their crop land (dummy; 1 = if there is erosion impact)	+
FERTILITYCOND	Perception of farmers about the fertility condition of their land (dummy; 1 = fertile)	–
EVALUATION	Farmers evaluation (perception) of the importance of soil conservation measure (dummy; 1 = important)	+
LOCATION[a] / ELEVATION/	Location of the study area (categorical; Machakel = 1, Gozamn = 2, Senan = 3)	+
LANDMANAGEMENT	Land management practice refers to crop rotation, mixed cropping and mulching (dummy; 1 = if farmers undertake one of the land management practices on their land)	+

[a]Senan district, which is at higher altitude and has steep slope gradient, is assumed to suffer from serious soil erosion followed by Gozamn and Machakel districts that are at a relatively lower altitude and have less severe slopes. Hence, it is assumed that farmers in Senan district will be more willing to adopt soil conservation measures than farmers in Gozamn and Machakel district.

Table III. Descriptive statistical result for continuous variable

With and without soil conservation measures		AGE	FAMILYSIZE	TLU	INCOMECROP	INCOMEOFFFARM	LAND
Without soil conservation	Mean	42	5	4·63	10 522·07	403·63	0·84
	Minimum	18	1	0·10	1625·00	0·00	0·13
	Maximum	87	11	17·84	80 400·00	2880·00	3·00
$N = 248$	Standard deviation	14·17	1·84	3·11	11 861·42	757·57	0·49
With soil conservation	Mean	46	5	4·32	9785·47	289·12	0·94
	Minimum	20	1	0·00	2400·00	0·00	0·19
	Maximum	95	11	17·88	66 760·00	2760·00	3·00
$N = 250$	Standard deviation	13·78	1·86	2·99	9048·29	619·63	0·51
Total	Mean	44	5	4·47	10 152·29	346·15	0·89
	Minimum	18	1	0·00	1625·00	0·00	0·13
	Maximum	95	11	17·88	80 400·00	2880·00	3·00
$N = 498$	Standard deviation	14·09	1·85	3·05	10 539·27	693·44	0·50
	Mann–Whitney U	26 015·00	28 328·50	29 350·00	29 517·50	29 274·50	26 956·00
	Wilcoxon W	56 891·00	59 204·50	60 725·00	60 393·50	60 649·50	57 832·00
	Z	−3·10	−1·68	−1·02	−0·92	−1·48	−2·54
	Asymptotic significance (two-tailed)	0·00***	0·09	0·30	0·35	0·13	0·01***

TLU, tropical livestock unit.
***Significant at 1 per cent probability level.

Table IV. Descriptive statistical result for discrete variables

Variables	Without soil conservation N = 248	Per cent	With soil conservation N = 250	Per cent	Total N = 498	Per cent	X^2
SEX							
Female	15	6	16	6	31	6	0·87
Male	233	94	234	94	467	94	
Total	248	100	250	100	498	100	
LITERACY							
Illiterate	126	51	107	43	233	47	0·07
Literate	122	49	143	57	265	53	
Total	248	100	250	100	498	100	
ACCESSCREDIT							
No access to credit	231	93	215	86	446	90	0·00***
Have access to credit	17	7	35	14	52	10	
Total	248	100	250	100	498	100	
ACCESSEXTENSION							
No access to extension service	21	9	12	5	33	7	0·10
Have access to extension service	227	91	238	95	465	93	
Total	248	100	250	100	498	100	
LABOUR							
Labour not available	159	64	140	56	299	60	0·06
Labour available	89	36	110	44	199	40	
Total	248	100	250	100	498	100	
LUC							
No certificate	17	7	14	6	31	6	0·56
Have certificate	231	93	236	94	467	94	
Total	248	100	250	100	498	100	
LANDMANAGEMENT							
No land management	155	63	8	3	163	33	0·00***
Have land management practice	93	37	242	97	335	67	
Total	248	100	250	100	498	100	
EROSIONIMPACT							
No impact	205	83	151	60	356	72	0·00***
Has impact	43	17	99	40	142	28	
Total	248	100	250	100	498	100	
FERTILITYCOND							
Infertile	43	17	153	61	196	39	0·00***
Fertile	205	83	97	39	302	61	
Total	248	100	250	100	498	100	
EVALUATION							
Not important	164	66	21	8	185	37	0·00***
Important	84	34	229	92	313	63	
Total	248	100	250	100	498	100	
LOCATION							
Gozamn	78	31	92	37	170	34	0·39
Machakel	77	31	67	27	144	29	
Senan	93	38	91	36	184	37	
Total	248	100	250	100	498	100	

***Significant at 1 per cent probability level.

soil erosion, whereas 34 per cent non-adopters acknowledged the importance of soil conservation measures in preventing soil erosion. More than 40 per cent of adopters and 30 per cent of non-adopters responded that they have sufficient labour for the implementation of soil conservation measures. However, the statistical test did not indicate relationship between labour availability and adoption. Finally, location was found to have no association with adoption. Out of the 250 adopters, 37 per cent live in Gozamn, 27 per cent in Machakel and 36 per cent in Senan. From the 248 non-adopters, 31 per cent live in Gozamn, 31 per cent in Machakel and 38 per cent in Senan.

Binary Logistic Regression Model Result

A forward and backward stepwise logistic regression analysis was estimated using SPSS® to predict factors that influence smallholders' adoption decision of soil conservation measures.

Both the forward and backward methods chose the same variables indicating how well the model is performing. A test of the full model against a constant only model was also found to be statistically significant proving that the predictors do have a significant effect and create essentially a different model (Chi square = 465·42, $p < 0{\cdot}000$ with $df = 8$). Nagelkerke's R^2 of 0·8 showed a moderately strong relationship between the explanatory variables and the outcome variable. The Hosmer and Lemeshow (H-L) goodness of fit test statistics, which is an alternative measure of goodness of fit, has also resulted in a *p*-value greater than 0·05, suggesting that the model prediction does not significantly differ from the observed. The overall prediction success of 91·6 per cent (89·5 per cent for non-adopters and 93·6 per cent for adopters) showed that the model predicted both the adopters and the non-adopters fairly accurately. Out of the 17 variables that were hypothesized o influence the adoption of soil conservation measures, six were found to be significant at 1 per cent probability level (TLU, EROSIONIMPACT, FERTILITYCOND, EVALUATION, LAND and LANDMANAGEMENT), and two variables (ACCESSCREDIT and LABOUR) were significant at 5 per cent probability level. The maximum likelihood estimates for the binary logit model are set out in Table V.

The model output discloses that the likelihood of adoption increases with access to credit facility. Farmers with access to credit facility are 3·5-times more likely to adopt soil conservation measures than farmers who have no access to credit facility, *ceteris paribus*. This indicates that credit is an important incentive for farmers to implement soil conservation measures. Given the money shortage subsistence smallholders' have, credit could be an additional source of cash to hire labour or buy materials for the implementation and maintenance of soil conservation measures. Shiferaw and Holden (1999) and Tiwari *et al*. (2008) also reported that the use of credit encouraged farmers to adopt improved soil conservation technology. As anticipated, farmers' perception of the negative impact of soil erosion on their cropland influences adoption decision positively and significantly. The adoption of soil conservation measures is 3·4-times higher among farmers who perceive the negative impact of soil erosion compared with those who do not perceive the same way, if the influence of other independent variables is held constant. Our result is consistent with similar studies conducted by Shiferaw and Holden (1998) and Asrat *et al*. (2004) who indicated strong positive association between farmers' perception of soil erosion problems and their willingness to invest in soil conservation practices. Similarly, recognizing the importance of soil conservation measures in preventing soil erosion plays a significant role in adoption decision. The result shows that the chances of adoption are more than 50-times higher for farmers who acknowledge the importance of soil conservation measures than the corresponding farmers who do not acknowledge the importance, keeping all other factors constant. Perception of the fertility condition of cropland has a significant inverse relationship with adoption. The odds ratio indicates that the likelihood of adoption decreases from 1 to 0·1 for famers who perceive to have fertile cropland than those farmers who do not perceive their cropland condition the same way, when other variables are controlled. That is, when farmers notice that they have fertile cropland, they become less interested to conserve their land from possible future degradation; instead, they discount the future heavily without considering that the livelihood of the future generation is also based on the land.

Table V. Maximum likelihood estimates of the binary logistic model

Variable	Coefficient	Standard error	Wald statistics	Significance level	Odds ratio
CONSTANT	−5·22	0·88	35·21	0·00***	0·00
ACCESSCREDIT	1·27	0·61	4·35	0·03**	3·58
TLU	−2·36	0·78	9·00	0·00***	0·09
EROSIONIMPACT	1·23	0·43	7·86	0·00***	3·42
FERTILITYCOND	−2·49	0·42	34·72	0·00***	0·08
EVALUATION	4·01	0·45	78·41	0·00***	55·14
LABOUR	0·86	0·40	4·54	0·03**	2·36
LANDMANAGEMENT	4·61	0·55	69·57	0·00***	101·32
LAND	5·64	1·75	10·35	0·00***	282·85
HOSMER & LEMESHOW χ^2	9·59				
−2 LOG LIKELIHOOD	224·94				
MODEL χ SQUARE	465·42				
COX & SNELL R^2	0·60				
NAGELKERKE R^2	0·81				
PERCENTAGE CORRECT	91·60				
NUMBER OF OBSERVATION	498.00				

TLU, tropical livestock unit.
**Significant at 5 per cent probability level.
***Significant at 1 per cent probability level.

From the model results, it is also noted that land management practices contribute positively and significantly to adoption. Farmers who are involved in land management practices are 100-times more likely to adopt soil conservation measures than farmers who are not involved in such practices, *ceteris paribus*. This may be because households who are already undertaking some kind of land management practices such as crop rotation, mixed cropping and mulching could be aware of the benefit of conserving their land and, thus, may not hesitate to adopt conservation measures. As expected, larger cropland has a significant positive impact on the adoption of soil conservation measure. This strong relationship is revealed through the large odds ratio value, which indicates that a 1 ha increase in cropland size increases the odds of adoption about 300-times, *cetaris paribus*. This is linked with the fact that soil conservation measures take some part of the cropland that could otherwise be used for crop production. It could also be related to reluctance of vulnerable smallholders to take the risk to engage in alternative land use practices; hence, the probability of adoption will be higher for farmers with larger farm size. This result implies that smallholding does not encourage adoption of soil conservation measures. Our result corresponds with the findings of Enki *et al*. (2001), Tadesse and Belay (2004) and Amsalu and de Graaff (2007) who identified significant positive influence of land size on farmers' decision to adopt soil conservation measures.

Contrary to the expectation, TLU is found to have an inverse relationship with adoption. The odds ratio shows that the likelihood of adoption decreases from 1 to 0·1 for famers who have more TLU, keeping other things constant. The possible explanation could be that farmers who keep bigger TLU need more feed for their cattle. To provide sufficient fodder for livestock, farmers use all possible means including letting their cattle graze on their cropland especially after harvesting. However, this practice would destroy soil conservation structures put on the cropland. Therefore, farmers with bigger TLU size could be less interested to have conservation structures on their cropland. This result is in line with the finding of Amsalu and de Graaff (2007) where big livestock size discouraged conservation investment in one of the Ethiopian highlands watershed. The relationship examined between labour availability and adoption of soil conservation measures was also significant. Households with sufficient family labour for the implementation of soil conservation measures are more willing to be involved in the implementation of the measures. The odds of adoption is 2·4 times more likely for households with sufficient family labour than otherwise, *ceteris paribus*. This indicates that labour is one of the crucial inputs for the implementation of soil conservation measures.

The impact of location of the study area on the adoption of soil conservation measures was tested by adding interaction terms such as land size, farm and off-farm income and perception of erosion impact on cropland. However, no significant relationship could be detected between study location and adoption of soil conservation measures. Although similar studies indicated that slope of cropland is an important factor in determining adoption of soil conservation measure, this study could not analyse its impact on adoption decision because of lack of data. Variables such as age, sex, family size, literacy, extension service, land use certificate and income from farm and off-farm activities were found to have no significant relationship with adoption of soil conservation measures.

CONCLUSION

The aim of this study was to investigate the main factors that influence smallholders' adoption decision of soil conservation measures in the three districts (Gozamn, Machakel and Senan) of the Gedeb watershed where soil erosion is causing both on-site productivity decline and off-site damage to reservoirs and irrigation schemes across political borders. Data from 498 household heads that live in the three districts were analysed using the binary logistic regression model. We find that farmers need adequate cash to invest in soil conservation measures. Moreover, farmers would be more encouraged to implement soil conservation measures when they have larger cropland. Despite the various benefits livestock provide, farmers who keep more TLU were not willing to adopt soil conservation measures. This indicates the importance of multiple feed sources to keep away animals from grazing cropland residues and farm borders. Availability of sufficient labour in a family also plays a significant role in the adoption decision of soil conservation measures. We examine that when farmers believe that they have fertile land, they exploit more from the land. This may hint the need for advice about the benefit of sustainable use of farmers' cropland so that they could be able to maintain their land and pass on to the future generation. Farmers' awareness about the benefit of land management practices and recognition of the problem erosion is causing on their crop land are central to their decision to adopt soil conservation measures. Furthermore, to adopt these measures, farmers have to be convinced about the effectiveness of these measures. Thus, awareness creation and demonstration of the effectiveness of these measures is essential.

A policy that encourage soil conservation measures as a means to prevent soil erosion may need to emphasize incentives such as credit facility and raising awareness of smallholders about the negative impacts of soil erosion and the advantage of soil conservation measures. To compensate the area loss due to the implementation of soil conservation measures, smallholders could be advised to grow grass, fodder and trees on the bunds as a source of income. The transboundary nature of the problem implies the need for mutual agreement between policy makers of upstream (Ethiopia) and downstream (e.g. Sudan) countries on ways of joint conservation efforts and benefit sharing.

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