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ANALYSIS

Determinants of adoption and continued use of stone terraces for soil and water conservation in an Ethiopian highland watershed

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A B S T R A C T

In the Ethiopian highlands, land degradation resulting from soil erosion and nutrient depletion is a serious environmental and socio-economic problem. Although soil and water conservation techniques have extensively been introduced over the past decades, sustained use of the measures was not as expected. Based on data obtained from 147 farming households, this paper examines the determinants of farmers' adoption and continued use of introduced stone terraces in an Ethiopian highland watershed. A sequential decision-making model using the bivariate probit approach was employed to analyze the data. The results show that the factors influencing adoption and continued use of the stone terraces are different. Adoption is influenced by farmers' age, farm size, perceptions on technology profitability, slope, livestock size and soil fertility, while the decision to continue using the practice is influenced by actual technology profitability, slope, soil fertility, family size, farm size and participation in off-farm work. Perceptions of erosion problem, land tenure security and extension contacts show no significant influence. Further, the results indicate the importance of household/farm and plot level factors in farmers' conservation decision. It is therefore concluded that 1) analysis of the determinants of adoption per se may not provide a full understanding of the range of factors influencing farmers' decision of sustained investments and 2) conservation interventions should focus not only on the biophysical performance of the measures but also on economic benefits that can be obtained at reasonable discount rates to the farmers in order to enhance sustained use of the measures.

1. Introduction

The reason for the poor performance of agriculture in many low-income countries is believed to be partly the deterioration of the natural resource base (Grepperud, 1995). Land degradation due to soil erosion and nutrient depletion is considered as the main problem constraining the development of the agricultural sector. The problem is very serious particularly in the tropical steep lands where rainfed agriculture constitutes the main livelihood of the people (Hurni, 1988; El-Swaify, 1997; Rymshaw et al., 1997; Shiferaw and Holden, 2001). In many of these countries, however,

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various soil and water conservation (SWC) programs have been unsuccessfully tried to mitigate the land degradation problem (Shiferaw and Holden, 1998). Among others, poor adoption and transitory use of conservation techniques are often mentioned as the major factors limiting efforts aimed at restoration of ecology.

In Ethiopia, agriculture constitutes the largest share of the national economy contributing for 42% of the GDP (2003/04) and 80% of the total employment (MoFED, 2004). Nevertheless, diminishing productivity due to soil erosion induced degradation of agricultural land has been a great concern (e.g. Hurni, 1988; EFAP, 1994). The problem is serious particularly in the highlands (>1500 m a.s.l.) that comprise nearly 44% of the country's total area, 95% of the cultivated area, about 88% of the human population, and two-thirds of the country's livestock (Kruger et al., 1996). Although estimates of the extent and rate of soil erosion lack consistency, the results of various studies highlight the severity of the problem. Estimates show that 3.7% of the highlands (2 million ha) had been so seriously eroded that they could not support cultivation, while a further 52% had suffered various levels of degradation (Kruger et al., 1996; Wood, 1990).

Despite the severity of the problem, it is only very recently, in the past three decades, that land conservation has received policy attention in the country. Conservation projects have been extensively carried out under the auspices of the World Food Program's food-for-work scheme. Focus of the projects has been on the formulation of technological prescriptions for resource-poor farmers. A range of conservation practices, which include stone terraces, soil bunds and area closures, have been introduced into individual and communal lands at massive scales. However, the trend hitherto shows that the projects have had a limited success in addressing the problem. Among others, the approach pursued in the development and transfer of the conservation practices has been considered as contributing to the ineffectiveness of the projects (e.g. Shiferaw and Holden, 1998; Admassie, 2000), leading to problems of adoption and continued use of the technologies already adopted.

This research is aimed at examining the determinants of farmers' adoption and continued use of introduced conservation technologies in a case study watershed in the Ethiopian central highlands. The specific technique under study is a stone terrace that has been widely promoted over the past decades in the area. The paper is organized as follows. In Section 2, we provide a theoretical context to conservation investments. We specify the model in Section 3. The research site and data and the variables are described in Sections 4 and 5, respectively. Results and discussions are given in Section 6. Finally, Section 7 concludes the paper.

2. Theoretical context

The problem of technology adoption in environmental management is increasingly becoming a key issue for researchers and users of natural resources (Guerin, 1999). Hence, research on constraints to the adoption of SWC practices is gaining increasing recognition as the availability of effective technologies is of little value to the individual or society unless it is applied (Smit and Smithers, 1992; McDonald and Brown, 2000).

Experience has shown that appropriate technologies are not always adopted, even where the need is obvious (Guerin, 1999). Farmers may reject or abandon many technologies that have been useful, and adopt others in their place since they consider a variety of factors in deciding whether or not to adopt particular conservation practices (McDonald and Brown, 2000; Soule et al., 2000). This highlights the need to develop a better understanding of the conditions that encourage sustained adoption of conservation practices (Lapar and Pandey, 1999).

McDonald and Brown (2000) indicated that farmers rarely sustain the technical solutions offered by external interventions in the long term unless consideration is given to the various socio-economic, cultural and institutional, as well as biophysical and technical factors. According to Lapar and Pandey (1999), such factors could be farmer-specific, farm-specific, and technology-specific. In addition, Guerin (1999) noted problems in the transfer and adoption process, particularly the lack of testing and the limited role of extension agents, as important reasons for non-adoption of recommended technologies. Smit and Smithers (1992) give emphasis to the nature and characteristics of the innovation being relevant to improving the rates of adoption.

One reason for the lack of agreement on relevant factors and barriers is the high degree of locational and technological specificity of environmental practices (Wandel and Smithers, 2000). For instance, empirical research in the Philippines (Lapar and Pandey, 1999) revealed that adoption of conservation practices depends on several plot and farmer characteristics and the relative importance of these factors differs across sites. Nevertheless, empirical information on the factors that determine farmers' investment decision in SWC in developing countries is limited (Pender and Kerr, 1998; Baidu-Forson, 1999). There are relatively many reports on the constraints of farmers' adoption of conservation measures. The conditions that influence sustained use of the measures after adoption remain, however, scarcely investigated.

3. Model specification

The analytical model presented in this paper is based on the literature on conservation investments. Logit and probit models have extensively been used in the study of farmers' adoption decision of conservation technologies (e.g. Baidu-Forson, 1999; Burton et al., 1999; Lapar and Pandey, 1999; Soule et al., 2000; Franzel et al., 2001). Both of these models provide the possibility of analyzing the probability of adoption or non-adoption of introduced conservation technologies.

However, decision-making on adoption and continued use of introduced conservation measures is generally a multistage process undertaken most often sequentially (see e.g. Paudel and Thapa, 2004). De Graaff et al. (2005) divided the process of technology adoption into three phases: acceptance, actual adoption, and continued use. According to Jabbar et al. (1998), the adoption process involves a sequence of learning, adoption and continued or discontinued use of introduced conservation technologies. On the other hand, Feather and Amacher (1994) used a two-stage process model to specify varying intensity levels of use once the initial decision to adopt has been made. Similarly, Shiferaw and Holden (1998) employed a two-stage conservation decision model: a model of perception of erosion problem in the first stage and a model of adoption and level of use of conservation practices in the second stage of their analysis.

We developed a sequential model using the bivariate probit estimation (biprobit) with sample selection procedure to investigate the determinants of farmers' adoption and sustained use of stone terraces. As all the farmers included in the study had prior knowledge about the stone terraces, we specified a two-stage model for adoption and continued use. The model is applied sequentially in two stages to regress the variables that explain the likelihood of adoption and further investigate the variables that explain the probability of continued use of the technology. Hence, the farmers are grouped as 'adopters' and 'non-adopters' in the first stage of the analysis, and as 'continued using' and 'not continued using' in the second stage for adopters of the practice.

Therefore, we assume unobserved or latent variables Y_{1i}^* and Y_{2i}^* that generate observed variables Y_{1i} and Y_{2i}, which represent farmers' adoption decision and continued use of conservation practices, respectively. Following Greene (2000), the two equations are specified as follows:

$$Y_{1i}^* = \beta_1 X_{1i} + \varepsilon_{1i}$$

$$Y_{2i}^* = \beta_2 X_{2i} + \varepsilon_{2i},$$

where β_1 and β_2 are parameters to be estimated; X_{1i} and X_{2i} are vectors of explanatory variables; and ε_{1i} and ε_{2i} are normally distributed random errors. We observed data for the second stage of the analysis (continuity of use) only for adopters of the conservation practice. The bivariate probit model with sample selection is therefore specified as follows:

$$Y_{1i} = 1 \quad \text{if} \quad Y_{1i}^* > 0; \quad 0 \quad \text{otherwise},$$

$$Y_{2i} = 1 \quad \text{if} \quad Y_{2i}^* > 0 \quad \text{and} \quad Y_{1i}^* > 1; \quad 0 \quad \text{otherwise}.$$

In this case, three categories of observations with their respective unconditional probabilities can be identified.

$$Y_{1i} = 1, \quad Y_{2i} = 1: \quad \text{Prob}(Y_{1i} = 1, Y_{2i} = 1) = \Phi_2(\beta_1 X_{1i}, \beta_2 X_{2i}, \rho)$$

$$Y_{1i} = 1, \quad Y_{2i} = 0: \quad \text{Prob}(Y_{1i} = 1, Y_{2i} = 0) = \Phi_2(\beta_1 X_{1i}, -\beta_2 X_{2i}, -\rho)$$

$$Y_{1i} = 0: \quad \text{Prob}(Y_{1i} = 0) = \Phi(-\beta_1 X_{1i})$$

where Φ_2 is a bivariate normal cumulative distribution function, Φ is a univariate normal distribution function, $n_{1,1}$ is the set of observations i for which $Y_{1i}=Y_{2i}=1$ (those who are adopters and continue using the practice), $n_{1,0}$ is that for which $Y_{1i}=1$ and $Y_{2i}=0$ (those who are adopters but did not continue using it), and n_0 is those observations for which $Y_{1i}=0$ (respondents who are not adopters and, therefore, did not continue using it). The corresponding log-likelihood function is then:

$$L_i = \sum \ln_{1,1} \Phi_2(\beta_1 X_{1i}, \beta_2 X_{2i}, \rho) + \sum \ln_{1,0} \Phi_2(\beta_1 X_{1i}, -\beta_2 X_{2i}, -\rho) + \sum \ln_0 \Phi(-\beta_1 X_{1i})$$

The estimation was done employing Stata/SE 8.2 software. After running the model, the results were taken to the field and discussed with the farmers.

4. The research site and data

This research is undertaken in the Beressa watershed located in the central highlands of Ethiopia. The area lies approximately 140 km to the northeast of Addis Ababa, the capital city, on the way to Dessie. The area is known for higher levels of land degradation in the country (FAO, 1986). The average annual rainfall is 887 mm (1984–2002), with over 80% of the total rainfall between May and September. Elevation ranges between 2740 and 3600 m a.s.l. The Beressa watershed is an agricultural watershed that is settled by rainfed agriculturalists for several thousands of years. Agriculture is dominated by mixed crop and livestock farming. Yet, the area exhibits a subsistence economy where most of the agricultural production is for own consumption. The main crops grown include barley, wheat, beans, field peas, and lentils. Cattle, sheep, donkeys, horses, mules and poultry are among the common livestock types raised in the area. It is rare to find a farming household not raising livestock of any kind.

Given a population growth rate of 3% per annum (the national estimate), the pressure on land resources has led to agricultural intensification but with limited use of conservation measures and fertility amendments. As a result, soil erosion and nutrient mining becomes a serious problem in the area. On the other hand, the area is perhaps one of the most intervened areas through various conservation and rehabilitation works by governmental and donor organizations for several decades. Among others, stone terrace construction on cultivated areas was the main activity that has been undertaken through campaign works by mobilizing farmers' labour. The construction involved collecting of stones and lay them down according to prescribed dimensions and positions by the coordinating organ, which is the Ministry of Agriculture.

Data for this research were mainly obtained through a household survey that was conducted during the 2002/2003 cropping season using a structured survey questionnaire. A random sample of 147 farm households managing 713 farm plots was included in the survey. Of the total, 95 farmers were adopters of the stone terraces out of which 52 farmers

Table 1 – Characteristics of adopters, non-adopters and continued users of introduced stone terraces in the Beressa watershed, highlands of Ethiopia

	Adopters	Non-adopters	Continued users
Number of sample households	95	52	52
Average age of the farmer	47	39	48
Average household size	5.6	4.8	5.4
Average farm size (ha)	1.70	1.55	1.80
Total number of plots	483 (5.3) [a]	230 (4.7)	304 (5.4)
Total number of plots with stone terraces	163 (1.9) [a]	–	99 (1.7)

[a] Mean values in parentheses.

continued using the practice after adoption. Farmers were interviewed using the survey questionnaire. The instrument included questions pertaining to farmers' personal attributes, farm characteristics, the technology, socio-economic and institutional factors. Further, interviews and discussions were held with key informants and groups of farmers, and with government officials and workers of non-governmental organizations concerned in the conservation of soil and water. Table 1 depicts the characteristics of adopters, non-adopters and continued users of the stone terraces in the watershed area.

5. Empirical analysis and variables

In this research, adoption is defined by considering the implementation of introduced stone terraces on farmers' plots. A farmer is considered adopter (ADOPT) of the stone terraces if s/he implemented the measure at least in one of her/his plots. Hence, non-adopters include those farmers who never used the stone terraces introduced in any of their plots. Based on this information, the farmers were classified into two categories: adopters and non-adopters of the technology. Once the response on adoption/non-adoption is obtained, further investigation was made on continued use of the practice, given a positive response on adoption. In this case, the current state of the farmers regarding continuity of use of the stone terraces is considered. Adopters were considered to be continued users (CONTUSE) if they kept the stone terraces in any of their plots and continued investing in it. In case of inconsistencies in farmers' responses, field visits were carried out for verification. The term non-adoption in this study does not take any negative connotation on the farmers for not employing introduced conservation structures.

A range of explanatory variables was considered, although the use of these variables often lacks consistency in the conservation literature. Previous studies have related farmers' conservation decisions to a range of variables that are often classified as personal, physical, socio-economic and institutional factors (Baidu-Forson, 1999; Lapar and Pandey, 1999; Mbaga-Semgalawe and Folmer, 2000; Bekele and Drake, 2003). In this research, the variables considered relate to personal attributes, plot and cropping characteristics, the technology, socio-economic and institutional factors. Taking into account the level of their effect, we classified the variables into two categories: household and/or farm level attributes and plot level attributes. Collinearity diagnostics using multivariate analysis indicated weak correlation ($r<0.3$) among the independent variables included in the analysis. Table 2 presents description and summary statistics of the variables used.

Table 2 – Description and summary statistics of the variables used in the biprobit estimation of farmers' adoption and continued use of stone terraces in the Beressa watershed, highlands of Ethiopia ($n=147$)

Variables	Description	Mean	S.D.
Household/farm level attributes			
AGE	Farmer's age (in years)	44.0	12.35
SEX	Sex of the farmer (1=male, 0=female)	0.78	–
FAMSIZ	Household members (N)	5.3	2.35
FARMSIZE	Size of the farm (in ha)	1.7	0.91
PERCEROS	Perception on erosion problem (1 if erosion is perceived, 0 otherwise)	0.71	0.45
PERPROF	Perceived profitability of the technology (1 if perceived profitable, 0 otherwise)	0.7	0.46
OFFFARM	Off-farm work (1 if participate in off-farm work, 0 otherwise)	0.34	0.47
LIVESTOC	Livestock holding (in TLU)	2.7	1.69
PERCTENU	Perceptions on land tenure security (1 if feel secure, 0 otherwise)	0.25	0.44
EXTEN	Contacts with extension agents (1 if there is contact, 0 otherwise)	0.59	0.49
Plot level attributes			
Slope			
GENSLOP	Gentle slope (1 if slope is gentle, 0 otherwise)	0.37	0.34
MODSLOP	Moderately steep slope (1 if slope is moderately steep, 0 otherwise)	0.45	0.48
STPSLOP	Very steep slope (1 if slope is very steep, 0 otherwise)	0.18	0.20
Soil fertility condition			
LOWFERT	Low fertility (1 if soil fertility is low, 0 otherwise)	0.32	0.36
MODFERT	Moderate fertility (1 if soil fertility is moderate, 0 otherwise)	0.54	0.48
HIGHFERT	High fertility (1 if soil fertility is high, 0 otherwise)	0.15	0.19
DISTANCE	Mean distance to farm plot from home (in walking minutes)	12.3	12.9
ACTPROF	Actual profitability of the technology adopted (1 if found profitable, 0 otherwise)	0.72	0.31
Dependent variables			
ADOPT	Adoption of stone terraces (1 adoption, 0 non-adoption)		
CONTUSE	Continued use of stone terraces (1 continued use, 0 non-continued use)		

5.1. *Household/farm level attributes*

The most important household/farm level attributes considered in the analysis include farmers' age (AGE), sex (SEX), family size (FAMSIZ), farm size (FARMSIZE), perceptions on erosion problem (PERCEROS), perceived profitability of the technology (PERPROF), off-farm work (OFFFARM), livestock holding (LIVESTOC), perceptions on land tenure security (PERCTENU) and contacts with extension agents (EXTEN).

The effect of age of the farmer on conservation decision may be either negative or positive (Baidu-Forson, 1999; Lapar and Pandey, 1999; Bekele and Drake, 2003). Older age often associated with long years of farming experience could positively influence conservation decisions. In contrast, younger farmers with longer planning horizons are likely to invest more in conservation. The difference in the level of conservation investments between male-headed and female-headed households is also examined.

Family size might have dual effects on land users' conservation decisions. Large family size may relax labour constraints needed for the construction and maintenance of conservation measures. Further, it may encourage investment in conservation practices due to the higher demand for more produce. The effect is therefore expected to be positive.

The influence of farmers' perception of erosion problems on their conservation decision is well documented in the literature (Shiferaw and Holden, 1998; Mbaga-Semgalawe and Folmer, 2000). Farmers who perceived the problem better are expected to invest more in conservation, suggesting a positive hypothesized effect.

The effect of farm size on conservation decision is not clear. Large farms could reflect greater capacity that encourages conservation (Cramb et al., 1999). On the other hand, more land may reduce the need to conserve land (Gebremedhin and Swinton, 2003), while the potential loss of land for conservation may discourage investments on small farms.

Inclusion of the perceived technology profitability variable is based on the assumption of the technology characteristics – user's context model in which the characteristics of the technology underlying land users' agro-ecological, socio-economic and institutional contexts play a central role in the adoption decision process (Scoones and Thomson, 1994). Hence, the effect on conservation decision is expected to be positive.

Participation in off-farm work could keep the labor force needed for conservation away from the farm. Further, income obtained from off-farm work may obscure the benefits accruing from investments in conservation. By contrast, income from off-farm work may be used to hire labour for stone terraces. Therefore, the effect of off-farm work on conservation is difficult to determine a priori.

As indicated in the sections above, livestock ownership is an important component of the farming system in the area since farming is integrated with crop and livestock production. Therefore, the fact that livestock is considered as an asset that could be used in the production process or exchanged for cash or other productive assets suggests a positive influence on conservation decision (Bekele and Drake, 2003). Conversely, more specialization into livestock away from cropping may reduce the economic impact of soil erosion, and/or increase the availability of manure needed to counter nutrient depletion (Shiferaw and Holden, 1998). The effect on farmers' conservation decision is then difficult to determine beforehand.

The effect of land tenure security on conservation investments has been conceptualized in many ways (Soule et al., 2000; Gebremedhin and Swinton, 2003). In Ethiopia, land is under public ownership and farmers have only usufruct rights. Research in various parts of the country report differing results regarding the effect of land tenure security on farmers' conservation decisions (e.g. Shiferaw and Holden, 1998; Bekele and Drake, 2003; Slegers et al., submitted for publication). It is therefore difficult to determine its effect a priori.

Contact with extension agents, a proxy for access to information, is likely to contribute to farmers' conservation decisions. As indicated in innovation diffusion theory, a positive effect is expected of this variable.

5.2. *Plot level attributes*

Plot level attributes included in the estimation were slope (categorized into three classes), soil fertility (categorized into three levels), distance of the farm plot from homestead (DISTANCE), and actual profitability of the technology as perceived by the farmers (PERPROF).

In our analysis, slope is used to proxy erosion potential. The three slope classes used in the empirical model include gentle slope (GENSLOP), moderately steep slope (MODSLOP), and very steep slope (STPSLOP). Since erosion severity is likely to increase with steepness in slope, the effect of steep slope is hypothesized to be positive on adoption decision of conservation measures (Ervin and Ervin, 1982; Pender and Kerr, 1998).

The soil fertility variable is also categorized into three levels: low fertility (LOWFERT), moderate fertility (MODFERT), and high fertility (HIGHFERT). Because marginal productivity loss due to erosion will be higher from plots with fertile soils that are expected to give high return in the short-term, soil fertility is expected to influence conservation decision positively (Bekele and Drake, 2003). Hence, the effect of high soil fertility on conservation investments is hypothesized to be positive.

Distance of the farm plot from homestead is expected to detract from investments in conservation due to increased transaction costs (Gebremedhin and Swinton, 2003). Thus, the closer the farm plot is to the farm dwelling area the closer supervision and attention it would get from the family (Bekele and Drake, 2003).

Conservation technologies that proved effective often encourage investments in soil and water conservation technologies. Hence, the effect of actual technology profitability on farmers' conservation investment is hypothesized to be positive.

6. Results and discussion

Table 3 presents the results of the biprobit estimation of the determinants of farmers' adoption and continued use of introduced stone terraces. Overall, significant relationships are observed between the probabilities of the dependent variables and the set of explanatory variables included in the model.

A range of variables is found to have influence on farmers' conservation decision. Unexpectedly, however, the factors influencing adoption and continued use of the stone terraces are not the same. For most of the variables the estimated coefficients differ in terms of sign and significance for adoption and continued use. Fig. 1 illustrates the direction of effect of the variables included in the estimation. Variables with estimated coefficients below 0.10 and insignificant effects are not shown in the figure.

6.1. *Determinants of adoption*

Results of the biprobit analysis reveal that adoption of stone terraces is influenced by several variables. The variables found to have a positive and significant influence include age, farm size, perceptions on technology profitability and steep slope,

Table 3 – Biprobit estimates for adoption and continued use of stone terraces, with sample selection, in the Beressa watershed, highlands of Ethiopia

Explanatory variables	Adoption		Continued use	
	Coefficient	S.E.	Coefficient	S.E.
AGE	0.020*	0.011	0.008	0.006
SEX	−0.285	0.342	−0.043	0.139
FAMSIZ	0.070	0.059	−0.023*	0.031
FARMSIZE	0.382**	0.178	−0.035*	0.106
PERCEROS	0.421	0.310	0.168	0.184
PERPROF	1.391***	0.320	–	–
OFFFARM	−0.212	0.283	−0.386**	0.126
LIVESTOC	−0.285***	0.100	−0.026	0.077
PERCTENU	0.275	0.342	0.081	0.156
EXTEN	−0.261	0.281	−0.101	0.118
GENSLOP	−0.049	0.330	−0.456	0.516
STPSLOP	1.424***	0.319	0.448**	0.579
LOWFERT	−0.181	0.237	0.461**	0.539
MODFERT	−0.397	0.104	−0.706	0.553
HIGHFERT	−1.016**	0.777	−0.632	0.528
ACTPROF	–	–	0.434**	0.442
DISTANCE	0.014	0.012	0.002	0.005
CONSTANT	−1.505***	0.569	1.288**	1.156
Log likelihood function = −117.404				
Number of observations = 147				
Censored observations = 52				

MODSLOP is dropped from the estimation due to collinearity.
* P<0.10.
** P<0.05.
*** P<0.01.

while livestock size and high soil fertility are the variables with significant negative influences (Fig. 1).

Although there is inconsistency of evidence about the relationship between age and innovativeness (Baidu-Forson, 1999), the effect of age of the farmer (AGE) on adoption is found to be positive in the Beressa watershed. This indicates that the likelihood of adoption of conservation practices is more among older farmers than the younger ones, perhaps due to the experiences of older farmers to perceive erosion problems and their limited participation in off-farm activities. Low level of adoption among young farmers could be due to their small farm size and also to their involvement in off-farm activities (Tenge et al., 2004). Thus, the argument that older farmers happen to be resistant to innovations might not hold true everywhere and at all times.

The effect of farm size (FARMSIZE) is also found to be positive and significant, suggesting that farmers who hold large farms are more likely to invest in conservation. This agrees with the argument that larger farms offer operators more flexibility in their decision-making, greater access to discretionary resources, more opportunity to use new practices on a trial basis and more ability to deal with risk (Nowak, 1987). Further, the farmers noted that the loss of land to terracing and temporal yield declines discouraged adoption of stone terraces on smaller farms. This result is in line with the findings of Tenge et al. (2004) in Tanzania where adoption is low among farmers with small farm size. Further, ploughing would become more difficult with a pair of oxen on smaller farms and thus limit the potentials of stone terrace adoption.

Farmers' perceived profitability of stone terraces (PERPROF) positively and significantly influenced their adoption decision. Since there has been a wider introduction of stone terraces in the highlands of the country, it appears that the farmers had prior information that somehow influenced their attitudes towards the measures promoted. In the discussions, the farmers noted that although they were well aware of the use and construction of stone terraces traditionally, they were much engrossed with the campaign works that could relieve them from labor constraints. Hence, farmers would likely adopt conservation practices if they perceived the technology profitable, suggesting the importance of demonstrating profitability of the measures. This indicates that conservation function per se may not induce adoption unless the conservation practice also increased productivity and profitability.

As expected, a significant positive relationship was found between steep slope (STPSLOP) and adoption of stone terraces. This is consistent with the finding of earlier studies in different parts of Ethiopia that report a positive and significant effect of the slope variable on the decision to adopt soil conservation structures (e.g. Shiferaw and Holden, 1998;

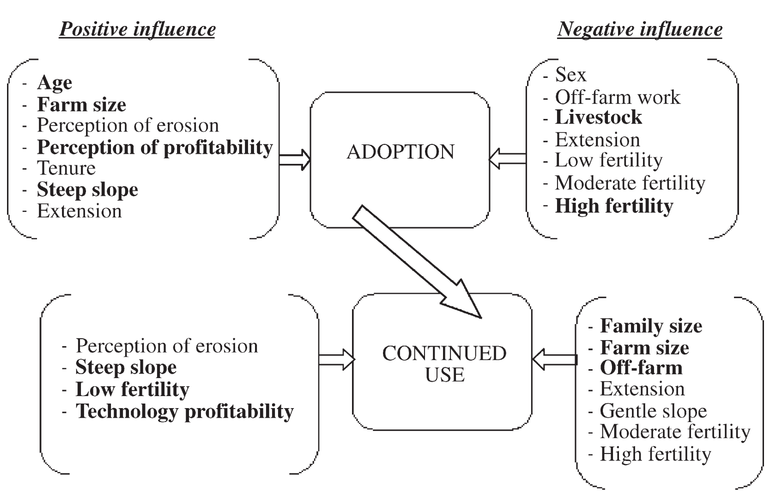

Fig. 1 – Positive and negative influences of the variables on adoption and continued use of stone terraces in the Beressa watershed, highlands of Ethiopia (bold in case of significant influences, $p<0.10$).

Bekele and Drake, 2003; Gebremedhin and Swinton, 2003). The results indicate that farmers invest on plots where they expect more benefits from conservation. This suggests that conservation efforts should target areas where expected benefits are higher, like on the steep slopes, in order to encourage adoption.

Livestock constitutes an important component of the farming system in the area. However, the biprobit results show that the effect of livestock size (LIVESTOC) on adoption decision was significantly negative. This indicates that large livestock size discourages conservation investments, perhaps due to the tendency of households to focus more on livestock than on crop production. In addition, temporal yield gains through manure application might reduce potential productivity losses due to erosion, and thus reduce conservation efforts.

Contrary to our expectations, the effect of high soil fertility (HIGHFERT) on adoption decision was found to be negative and significant. Plots with fertile soils negatively influenced farmers' adoption of stone terraces. Perhaps the farmers did not see the negative effects of erosion on their plots, at least in the short run, and the need for conservation.

6.2. *Continued use of conservation practices*

Adoption of conservation practices alone may not lead to sustained land rehabilitation unless the technologies are utilized continuously. Thus, the determinants of farmers' continued use of stone terraces among adopters of the technology are identified in the second stage of the sequential model. The biprobit estimation shows that actual technology profitability, steep slope and low soil fertility are with significant positive influence on continued use of the stone terraces while family size, farm size and participation in off-farm work are with significant negative influences (Fig. 1).

As expected, the influence of actual profitability (ACTPROF) of the technology on farmers' decision of continued use is significantly positive. This indicates that farmers who found the technology profitable retained it. Therefore, as Sain and Barreto (1996) noted, to ensure continued adoption, the conservation component must be profitable to the farmer in the medium and the long run. Particularly, farmers are very curious about the yield effect of the technology since the structures take up productive land, and maintenance is often labor intensive and costly (Shiferaw and Holden, 1998). Farmers who did not retain adopted stone terraces indicated that the benefits from adopting the technology were not as expected; perhaps they did not stay with it long enough to see accumulated benefits. Further, they complain about yield losses due to pest infestation associated with the stone terraces rather than effectiveness of the measure in erosion control. This is also found to be the case among the farmers in Wolaita and Wello (Beshah, 2003). As a result, most of the farmers switched to their 'traditional' practices instead of continuously using introduced stone terraces.

Like its effect on adoption, the effect of steep slope (STPSLOP) on continued use of the stone terraces is found to be significantly positive. Apparently, the farmers were encouraged to continue to use the stone terraces perhaps due to effectiveness of the measure in erosion control on steep slopes. This suggests that targeting the stone terraces on steep plots might induce sustained use of the measure.

The soil fertility condition of cultivated plots is an important determinant of farmers' investment in conservation practices. Our results show that low soil fertility (LOWFERT) has a significant positive effect on continued use of the stone terraces; farmers cultivating less fertile plots continued using the stone terraces. This is contrary to expectations that farmers invest more on fertile plots in order to maximize production. Shrinking farm size might probably account for the conservation efforts put on less fertile plots.

The significant negative effect of family size (FAMSIZ) on farmers' conservation decision implies that households with large family size are not likely to continue using the stone terraces. Bekele and Drake (2003) also found similar results in the eastern highlands of the country. They noted that in a family with a greater number of mouths to feed, competition arises for labor between food generating off-farm activities, like daily labor, and investment in SWC. In the Beressa watershed, households participate in non-farm activities such as dung selling in the urban market, mainly in Debre Birhan town. Thus, households keeping more livestock considerably involve in dung cake making and marketing, in which labour is diverted away from conservation.

Farm size (FARMSIZE) significantly influenced both adoption and continued use of stone terraces among the farmers of the Beressa watershed. While its effect on adoption is positive, the effect on continued use is found to be negative. This implies that continued use of the stone terraces is likely to be lower with increase in farm size, perhaps due to diminishing marginal returns. Otherwise this result does not support the argument that larger land holding, as associated with greater wealth and increased availability of capital, makes investment in conservation more feasible, nor are wealthier people willing to bear more risk than poorer people (Bekele and Drake, 2003). In highland Ethiopia where there is increasing population pressure and limited area for agricultural expansion, declining per capita farm area often results in production intensification.

The negative influence of off-farm income on farmers' conservation investment is in line with the findings of several studies (e.g. Pender and Kerr, 1998; Mbaga-Semgalawe and Folmer, 2000; Gebremedhin and Swinton, 2003; Tenge et al., 2004). Although the labour market outside farming in the area is generally weak, farmers engage themselves in off-farm income earning activities in the nearby urban center, Debre Birhan town. Hence, the effect of OFFFARM on continued use of stone terraces is found to be significantly negative. Short-term benefits from off-farm activities seem to attract farmers' labor more than investments in conservation. Based on the findings in Illela region of Niger, Baidu-Forson (1999) noted that the availability of land-enhancing technologies that provide short-term profit would lead to a greater probability of adoption and intensity of use. This suggests that the lack of time for conservation measures due to involvement in off-farm work may have been more a matter of lack of cash income (Cramb et al., 1999) rather than capital accumulation.

The biprobit estimation also shows that perceptions of erosion problem, land tenure security and extension contacts show no significant influence both on adoption and continued use of stone terraces. The negative effect of extension contacts (EXTEN) implies that farmers having contacts with extension agents tend to reduce investments in conservation, which is counterintuitive. Discussions with extension staff in the area reveal that agricultural extension is more focused on crops and livestock production than on SWC. The results suggest that SWC should be given due attention in the extension system to positively influence farmers' conservation decisions.

7. Conclusions

As can be seen from the results of several studies, there seems to be disparity in the relative importance of the factors determining land users' conservation decisions. This suggests that for various groups of farmers under varying agro-ecological and socio-economic conditions the relative significance of influencing factors may also differ.

In the Beressa watershed, a range of factors influences farmers' conservation decision. However, the factors influencing adoption and continued use of the stone terraces are not the same. Adoption of stone terraces is significantly influenced by age, farm size, perceptions on technology profitability, slope, livestock size and soil fertility, while continued use is influenced by actual technology profitability, slope, soil fertility, family size, farm size and participation in off-farm work. Perception of erosion problem, land tenure and extension contacts show no significant influence on farmers' conservation decision.

The likelihood of adoption is higher with increase in age of the farmer, perception of technology profitability, increase in farm size and increase in livestock number. Continued use of the stone terraces is likely to be lower with increase in farm size, perhaps due to diminishing marginal returns. Participation in off-farm work negatively influenced continued use. Apparently, long-term conservation investments are traded off for short-term gains through off-farm activities. Although farmers' (adopters) have positive perception about the benefits of the stone terraces, sustained adoption could only be realized as long as the technology remains profitable in the short-run.

Therefore, the results of this research highlight that (1) analysis of the determinants of adoption per se may not provide a full understanding of the range of factors influencing farmers' decision of continued investments and (2) 'blanket approach' to conservation intervention could make the measures inappropriate to local conditions and eventually unacceptable by the farmers. Hence, interventions should consider not only the biophysical performance of the measures but also economic returns to investments at reasonable discount rates in order to enhance sustained use of the measures.

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