AGREKON

Vol 40 Number/Nommer 3
September 2001

Published by the
Agricultural Economics
Association of South Africa

Gepubliseer deur die
Landbou-ekonomievereniging
van Suid-Afrika

ISSN 0303-1853

DETERMINANTS OF ADOPTION OF PHYSICAL SOIL CONSERVATION MEASURES IN CENTRAL HIGHLANDS OF ETHIOPIA: THE CASE OF THREE DISTRICTS OF NORTH SHEWA

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This paper examines factors influencing farmers' adoption decision of physical soil conservation practices in the Central Highlands of Ethiopia. Data were collected from 116 randomly selected farmers through a structured questionnaire. Results from a logistic regression analysis show that security of land ownership, size of cultivated land, technology-specific characteristics, level of schooling, wealth status of the household head, availability of off-farm income and assistance from different sources were important determinants of adoption of physical soil conservation practices. About 97 percent of the sample cases were correctly predicted using the model.

1. INTRODUCTION

In Ethiopia, as in most developing countries, land degradation has manifested itself in rapid rates of natural capital depletion exemplified by deforestation and soil erosion[1]. According to the Soil Conservation Research Project (SCRP, 1996), land degradation from soil erosion and depletion of organic matter and nutrients is taking place at a much faster pace than they can be replaced. This fact can be substantiated by the rate of soil erosion from the highland areas of the nation, which constitute about 45 percent of the total area of the country. The rate of soil erosion from the highland areas is estimated to be 35 tons per hectare per year (EHRS, 1986). According to the same source, it is also estimated that 80 percent of the gross soil loss is from cropped lands, which brings the estimated soil loss in this area to about 100 tons per hectare per year. This happens because of the inherent erodible nature of the soils and the likely expansion of cultivation to these areas to feed the steadily growing population of the country.

With increasing intensity of cropping on slopping lands and with intensive cultivation of smaller farmlands without amendments to replace lost

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nutrients, land degradation becomes a crucial environmental problem to the rural poor and to the economy at large. In response to the extensive degradation of its resource base, Ethiopia has taken some measures to mitigate the problem of soil erosion and enhance the production potential of its agricultural land. Towards this end, since the early 1980s soil conservation measures have been introduced in some degraded and food-deficit areas of the highlands, mainly through the food-for-work (FFW) programmes supported by the World Food Programme. Measures taken so far could only cover one percent of the highlands and at this rate it would take up to 70 years to cover all the highlands (FAO, 1986). The problem of soil erosion is compounded by the fact that some farmers dismantled the conservation structures built in the past through FFW incentives (Shiferaw & Holden, 1998). In fact, until the early 1990s farmers were not allowed to remove the conservation structures once built on their land. However, the introduction of the economic reform programme in 1990 and subsequent liberalisation of the economy also brought more freedom and hence conservation structures could be removed if the land user so wishes.

The joint effect of widespread poverty, land degradation, population pressure, institutional failures, political instability, etc, in Ethiopia, has in recent times begun to manifest itself in deteriorating food security even in years of good weather for agriculture. In this respect, Hurni (1988) reported that, in Ethiopia, areas that suffer from frequent famines are also those exhibiting highest annual rates of soil erosion. Therefore, in many parts of the country appropriate soil conservation measures, which take in to account the various socio-economic, agro-climatic, institutional and cultural environments, are urgently needed in order to promote sustainable land use and attain food self-sufficiency at a national level.

In fact, the efficiency and efficacy of dissemination of soil conservation practices depend on factors that dictate their adoption by the target beneficiaries - the farmers. In this regard, it is imperative that governmental and non-governmental organisations involved in agricultural development understand factors affecting the adoption of conservation measures in order to target and deliver effective programmes. Even though a number of empirical studies have been undertaken on technological adoption under the Ethiopian context, nearly all of these studies have discussed issues of adoption in relation to improved production technologies which have commercial nature. However, farmers' response to improved soil conservation practices have not yet been well investigated. Therefore, the focus of this study was on determining the potential factors which affect the adoption of physical soil conservation practices in three districts in North

Shewa Zone of the Oromia National Regional State[2]. The study employed a binomial logit model in order to identify social, economic, institutional and technical factors that dictate farmers' soil conservation decision, and to quantify the relative importance of these factors.

The rest of this paper is divided into three sections. Section II lays out the research design and methods of data collection and analysis. Section III discusses the analytical findings of the study. The final section summarises the findings and discusses their policy implications.

2. RESEARCH DESIGN AND ANALYTICAL METHOD

2.1 Description of the study area

The study was undertaken in the central highlands of the country, namely in Hidebu Abote, Degem and Kuyu districts of North Shewa Zone, Oromia National Regional State. The study districts cover a total area of 2096 km^2 with an average of 127 inhabitants per km^2. The study areas share a common ecological zone (highland) characterised by upland farming with severe problems of soil erosion. The catchments selected for this study are homogeneous in the sense that they are similar in farming systems, in terms of extension service coverage, rainfall distribution, cropping pattern, etc. Farmers in the study areas practice mixed farming where both livestock and crop production is undertaken side by side. Due to the severe nature of soil erosion in the study areas, three types of physical soil conservation practices, namely check dams, cut-off drains and stone bunds have been popularised since the late 1980s mainly through the FFW programme.

According to MOA (1986), these physical soil conservation structures have their own features and are defined as follows:

Check-dam refers to an obstruction wall across the bottom of a gully or small river, which reduces the velocity of the runoff and prevents the deepening or widening of the gully. This structure can be made of any material available locally, such as stones, live or dead branches, iron bars wooden poles, etc. Its size depends upon the material available to use and the structure is applicable to any agro-climatic zone. It is mainly used to reduce the velocity of runoff in the gullies.

Cut-off drain is a channel used to collect runoff from the land above and to divert it safely to a waterway or river, thus protecting the land below from excessive erosion. Cut-off drains protect down slope land from upper slope runoff and erosion. Cut-off drains are used in combination with other structures such as waterway, which is a natural or artificial drainage channel along the steepest slope to accommodate runoff.

Stone bund is an embankment along the contour, made of stones with a basin at its upper side. The bund reduces or stops the velocity of overland flow and consequently soil erosion.

2.2 Sampling design

In designing this research, following the proposition made by Storck *et al* (1991), emphasis was given to increasing the number of sample peasants per village than village samples. This is based on the assumption that the variation that exists among the farming households is greater than the variation between villages (in the study "catchments"). In this study, the farming household head was the basic sample unit. Catchments where conservation practices have been introduced were used as sampling frame to select sample respondents. While doing so, homogeneity of these catchments in terms of agro-ecology, topography and physical observation of the degree of erosion problem was considered.

A two-stage sampling procedure was used to select sample farmers. In the first stage, nine catchments where soil conservation practices have been introduced were identified and listed. Among the nine catchments identified in the three districts, five were sampled using a simple random sampling technique.

In the second stage, farmers owning land in the five sampled catchments were listed. Finally, of the 345 farmers owning farmland in the five catchments, 116 household heads were selected using probability proportional to sample size sampling technique (See Table 1). The sample respondents included both users and non-users of physical soil conservation measures. The survey was carried out between September 1998 and January 1999.

2.3 Method of data collection

Relevant data were collected from both primary and secondary sources. The secondary sources included published and unpublished documents about the study areas. The primary information on which the study was largely based was collected from sample farmers in the study areas. A formal survey method, using a structured questionnaire and trained enumerators, was employed. The questionnaire was pre-tested and on the basis of the results

obtained, necessary modifications were made on the contents of the questionnaire.

Table 1: Sampled catchments with their respective household size

No	Cachment	District	Total household size	Sample size
1.	Bada Goro	Kuyu	103	35
2.	Warabi	Degem	54	18
3.	Sulula Dhose	Degem	53	18
4.	Boneya	Degem	75	25
5.	Kore	Hidabu Abote	60	20
Total			**345**	**116**

2.4 Analytical approach

Farmers' adoption behaviour, especially in low-income countries, is influenced by a complex set of socio-economic, demographic, technical, institutional, and biophysical factors (Feder *et al*, 1985). Modelling farmers' response to agricultural innovations has, therefore, become important both theoretically and empirically. A relevant model offers better explanations on underlying relationships between adoption decision and factors influencing it.

Earlier studies used correlation analysis to examine factors affecting technology adoption decisions of farmers. Since these studies had not provided reliable information on the quantitative importance of the explanatory variables, policy-makers could not single out the relative importance of these factors (Sureshwaran *et al*, 1996).

Conceptually, the model used to examine the relationship between adoption and determinants of adoption involves a mixed set of qualitative and quantitative data. The response (dependent) variable is dichotomous taking on two values, 1 if the event occurs and 0 if it does not. Estimation of this type of relationship entails the use of Qualitative Response Models. In this regard, the linear probability, logit and probit models are possible alternatives. However, several estimation problems arise particularly when ordinary least squares (OLS) regression and linear probability models are employed (Aldrich & Nelson, 1990; Feder *et al*, 1985 and Maddala, 1992). The OLS regression technique, when the dependent variable is binary, produces parameter estimates that are inefficient and a hetroscedastic error structure. Consequently, hypothesis testing and construction of confidence interval become inaccurate and misleading. Likewise, a linear probability model may generate predicted values outside the admissible 0-1 bound, which violate the basic tenets of probability. To alleviate these problems and produce relevant empirical outcomes, the most widely used qualitative response models are the logit and probit models (Amemiya, 1981).

Both the probit and logit models yield similar parameter estimates and it is difficult to distinguish them statistically (Aldrich & Nelson, 1990). However, because of the fact that the binomial logit model is easier to estimate and simpler to interpret, it is used in the present study.

2.4.1 *Binomial logit model*

Following Gujarati (1988) and Hosmer & Lemeshew (1989), the binomial logistic distribution function for the adoption of soil conservation practices can be specified as:

$$P_{(i)} = \frac{1}{1+e^{-Z(i)}} \quad (1)$$

where $P_{(i)}$ is a probability of adopting soil conservation practices by the i^{th} farmer and $Z_{(i)}$ is a function of *m* explanatory variables (X_i), and is expressed as:

$$Z_{(i)} = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_m X_m \quad (2)$$

where β_o is the intercept and β_i are the slope parameters in the model. The slope tells how the log-odds in favour of adopting soil conservation practices change as independent variables change.

Since the conditional distribution of the outcome variable follows a binomial distribution with a probability given by the conditional mean $P_{(i)}$, interpretation of the coefficient will be understandable if the logistic model can be rewritten in terms of the odds and log of the odds (Hosmer & Lemeshew, 1989). The odds to be used can be defined as the ratio of the probability that a farmer uses or adopts the practice ($P_{(i)}$) to the probability that he/she will not ($1-P_{(i)}$).

$$Ln\left(\frac{P_i}{1-P_i}\right) = Ln\left(e^{\beta 0}\sum_{i=1}^{m}\beta_i X_i\right) = Z_i. \quad (3)$$

If the disturbance term U_i is taken into account, the binomial logit model becomes

$$Z_{(i)} = \beta_0 + \sum_{i=1}^{m}\beta_i X_i + U_i. \quad (4)$$

Hence, the above econometric model was used in this study and was treated against potential variables assumed to affect the adoption of soil conservation practices. The parameters of the model were estimated using the iterative maximum likelihood estimation procedure. The latter yields unbiased and asymptotically efficient and consistent parameter estimates.

In reality, the significant explanatory variables do not all have the same level of impact on the adoption decision of the farmers. The relative importance of quantitative explanatory variables in adoption decision can be measured by examining adoption elasticities, defined as the percentage change in probabilities that would result from a percentage change in the value of these variables. To compute the elasticity, one needs to select a variable of interest, compute the associated P_i, vary the X_p of interest by some small amount and re-compute the P_i, and then measure the rate of change as

$$dP_i / dX_{pi},$$

where

dX_p and dP_i stand for percentage changes in the explanatory variable(X_{pi}) and in the associated probability levels (P_i), respectively. When dX_p is very small, this rate of change is simply the derivative of P_i with respect to X_p and it is expressed as follows (Aldrich & Nelson, 1990):

$$\frac{dP_i}{dX_i} = \frac{\exp(Z_i)}{1+\exp(Z_i)} \cdot \frac{1}{1+\exp(Z_i)}\hat{\beta} \quad (5)$$

$$= (P_i)(1-P_i).\hat{\beta}_m \quad (6)$$

The impact of each significant explanatory variable on the probability of adoption is calculated by keeping the continuous variables at their mean values and the dummy variables at their most frequent values (zero or one).

2.4.2 *Working hypotheses and variable specification*

A host of factors including technical, socio-economic and institutional settings affect the adoption of innovations by small farmers. In this study, a dichotomous dependent variable for the adoption decision (CNSRV) was defined as 1, indicating adoption of physical soil conservation practices and 0 otherwise. More specifically, those sample respondents who retained the soil conservation structures built on their land through FFW incentives and/or had introduced the conservation measures on their own at the time of the survey were considered as adopters. Whereas those respondents who removed the original structures and/or did not have conservation structures at the time of the survey were considered as non-adopters.

The independent variables of the study are those which are hypothesised to have association with the dissemination and adoption of soil conservation practices. More specifically, the findings of various empirical studies on the adoption of soil conservation practices, the existing theoretical explanations, and the authors' knowledge of the farming systems of the study areas were used to select 15 explanatory variables and structure the working hypotheses. The potential explanatory variables which are hypothesised to influence the adoption of physical soil conservation measures in the study areas are presented below.

Age (AGE): this variable measures age of the household head in years. Younger farmers are often expected to invest in soil conservation practices because they are often more educated, and, as a result, are more aware of soil erosion problems and solutions. On the contrary, older farmers exert less effort to maintain soil productivity because they do not anticipate the full benefits of conservation within their short planning horizons. Therefore, it is hypothesised that age of the household head and the adoption of physical conservation structures are inversely correlated. This hypothesis is supported by the findings of studies on the adoption of soil conservation practices (see, for example, Gould *et al*, 1989; Sureshwaran *et al*, 1996; Yohannes, 1992 and Shiferaw & Holden, 1998).

Education level (FEDC): this represents the level of formal schooling completed by the household head. Formal schooling enhances farmers' entrepreneurial ability, which is the ability to perceive, interpret and respond to new events under the context of risk. It is expected that those farmers with increased formal education are disposed to use physical soil conservation practices because of increased information on erosion control techniques as well as the associated benefits and costs. Thus, it is hypothesised that the adoption of physical soil

conservation practices is positively correlated with the level of formal schooling. In several studies, the level of education has been found to positively affect adoption of soil conservation practices (Ervin & Ervin, 1982; Yohannes, 1992; Pender & Kerr, 1996 and Sureshwaran *et al*, 1996).

Total cultivated land (TCULTLND): this variable stands for the total cultivated land owned by the sample respondents at the time of the survey. The results of past studies indicate that the effect of farm size on the adoption of physical soil conservation practices has been variable. For instance, it is often assumed that farmers with large farm size have more cash to hire labour required to undertake soil conservation investment. Several studies confirmed the positive role of this variable on conservation decision (Ervin & Ervin, 1982; Norris & Batie, 1987; Gould *et al*, 1996; Sureshwaran *et al*, 1996 and Shiferaw & Holden, 1998). On the other hand, given that farmers are aware of the benefits of soil conservation and its management practice, as farms become smaller and intensification occurs, there is more incentive to carefully manage the declining land resource base by adopting more of the recommended practices (Boserup, 1965).

Extension contact (DAVIST): agricultural extension is an important source of information, knowledge and advice to smallholder farmers in Ethiopia. The agricultural extension service measured by the average frequency of monthly contact with the extension agents is an indicator of reception of the service. Farmers who have closer contact with extension agents are expected to be aware of the severity and impacts of the natural resource degradation. Therefore, extension contact is expected to have a positive effect on conservation. Previous research found a positive role of this variable on conservation decisions (Graff, 1996 and Shiferaw & Holden, 1998).

Land security (SECURITY): refers to the security of land ownership right. Insecurity in land rights is generally regarded as one important deterrent to conservation investment. When a system of property rights fails to provide sufficient security to enable individual users to reap future benefits from their investment, they fail to undertake otherwise profitable and environmentally sound investments. Therefore, in this study it is hypothesised that security of tenure has a positive effect on conservation decisions. In several empirical studies, this variable has been found to positively affect conservation decisions (Ervin & Ervin, 1982; Norris & Batie, 1987; Yohannes, 1992; Desalegn, 1994 and Graff, 1996).

Perception of erosion (ERSNPRB): refers to the farmers' perception of the threats of soil erosion. Perception of soil degradation problems is hypothesised to have a positive influence on the adoption of soil conservation practices. More specifically, farmers who have perceived the problem of soil erosion are more likely to adopt soil conservation practices and apply them adequately than those who are not aware of the problem. Previous research found a positive role of this variable on conservation decisions (Ervin & Ervin, 1982 and Shiferaw & Holden, 1998).

Assistance (ASSIST): this refers to any form of support (material, technical, financial and other types of incentives) provided to farmers in view of encouraging them to use soil conservation measures. As noted earlier, physical soil conservation measures are labour intensive and require financial and material inputs which farmers may not afford. As a result, assistance from any source encourages farmers to adopt physical conservation measures. Therefore, it is expected that in areas where governmental and non-governmental organisations are involved in agricultural development activities, the propensity to invest in land conservation measures increases. Empirical studies have shown that this variable has been positively correlated with adoption and soil conservation effort (Ervin & Ervin, 1982; Norris & Batie, 1987; Graff, 1996 and Sureshwaran *et al*, 1996).

Labour shortage (LBSHRT): refers to the household head's opinion about the shortage of labour to construct conservation structures. It is hypothesised that farmers experiencing labour shortages will be resistant to invest in conservation measures. Consequently, labour shortage is expected to affect adoption decisions negatively. Empirical studies indicate that labour shortage has a negative effect on conservation decisions (Graff, 1996; Pender & Kerr, 1996 and Sureshwaran *et al*, 1996)

Type of house (CRHOUSE): in the study areas, the type of house is an important indicator of the wealth status of farmers. Therefore, it can be used as a proxy for wealth in that those farmers who own corrugated iron-roofed houses are relatively rich as compared to those who own grass-thatched houses. It is hypothesised that farmers with corrugated iron-roofed houses are more likely to invest in soil conservation practices. Therefore, this variable is expected to affect the adoption of soil conservation measures positively.

Characteristics of the technology (RDNTSRS): refers to the attributes of soil conservation measures as perceived by the sample respondents. The technology or the practice that farmers decide to adopt has to be compatible with their environment. Some of the physical conservation measures are known to be sources of rodents, which cause tremendous damage to crops. This variable shows whether or not the soil conservation structures are

considered as sources and breeding-grounds for rodents. Therefore, the farmers' perception of the conservation structures as conducive environment for rodents will influence the adoption of soil conservation practices negatively. Previous research indicates the significant role of the perception of technology attributes in shaping adoption (Yohannes, 1992 and Shiferaw & Holden, 1998).

Tenure arrangements (SZRNTLND): in the context of this study, this variable refers to the size of the land rented-in by the household. Those farmers who are renting-in land are expected to have a relatively better chance of extending their cropland especially in areas where cropland is characterised by poor, infertile and degraded soils. This enables the farmers to harvest more crops, relative to others who are not renting-in land, thereby increasing their cash income which enables them to conserve their cropland. Thus, a positive relationship is expected between this variable and the decision to adopt physical soil conservation measures.

Man-land ratio (MECLT): is the ratio of family size (measured in man equivalent) to cultivated land. Previous studies indicate that the effect of this variable on conservation decisions has not been uniform. For instance, under a land-scarce degraded environment, vulnerability to starvation increases with an increase in man-land ratio. As conservation structures occupy part of the scarce productive land, often without appreciably improving yields, a high man-land ratio discourages adoption of conservation structures (Shiferaw & Holden, 1998). On the other hand, poverty induced intensification of farming, which follows from a decline in the per capita land endowment, may lift up the degree of erosion to the level easily discernible by the land user. Under such circumstances, a higher man-land ratio would increase the propensity to adopt conservation measures so as to combat the hazard of erosion that further shrinks farmers' means of livelihood (Boserup, 1965).

Livestock holding (TLU/ha) (STKRTLU): is the total number of livestock holding measured in Tropical Livestock Unit (TLU) per hectare of grazing land[3]. A higher livestock-grazing land ratio may result in overgrazing which, in turn, results in erosion. This being the case, a higher livestock-grazing land ratio is a signal for the farmers to introduce conservation measures both on their cropland, which is the main source of animal feed, and grazing-land. Therefore, this variable is hypothesised to have a positive effect on conservation.

Off-farm income (OFFINCM): this variable shows whether or not the sample respondents earn additional income from non-farm activities. Diversification out of agriculture (off-farm activities) may serve as an additional source of income thereby easing the liquidity constraint needed for soil conservation investments. Therefore, it is hypothesised that this variable affects the adoption of soil conservation measures positively. Empirical studies have verified the positive relationship between off-farm income and adoption of soil conservation practices (Ervin & Ervin, 1982 and Clay *et al*, 1998).

Parcel of land (SMLPARCL): refers to the farmers' judgement about the sizes of their plots on which conservation structures are to be built. When physical conservation structures are built on farmlands, ploughing between the structures is often very difficult. This is attributed to the very nature of the structures which occupy part of the scarce productive land and engender difficulties to plough with oxen between the structures. Therefore, as farmland gets smaller, farmers refrain from investing in land conservation technologies, thereby affecting their adoption decision negatively. Previous studies indicate that positive effect of plot size on adoption of conservation practices (Yohannes, 1992 and Shiferaw & Holden, 1998).

The definition of the variables and units of measurement used are presented in Table 2. The table shows also that seventy-one farmers (61.2 percent of the sample respondents) reported that they had physical soil conservation structures on their farms at the time of the survey. Whereas the remaining (45 farmers) reported that they had no physical soil conservation structures on their farms.

Table 2: Definition, units of measurement and summary of the variables used in the logistic regression

Variables	Value	% with a Value 1	Mean ± SD
CNSRV	Dummy, 1 if physical soil conservation structures are adopted; 0 if not	61.2	
AGE	Age of the household head		48±7
FEDUC	Schooling years of the household head		4.2±2.7
TCULTLND	Total cultivated land holding (hectare)		2.3±1.3
SZRNTLND	Total land rented-in (hectare)		0.43±0.2
OFFINCM	Dummy, 1 if the farmer earns off farm income; 0, otherwise	9	
MECLT	Man-equivalent to cultivated land ratio		1.69±0.87
STKRTLU	Livestock size in TLU per grazing land in hectare		9.5±11.5
DAVIST	Dummy, 1 if the farmer is being visited more than two times per month by extension agent; 0, if not.	26	
SECURITY	Dummy, 1 if the farmer feels that the land belongs to him at least in his life time; 0, if not	52	
EROSNPRB	Dummy, 1 if erosion problem is perceived as a serious problem; 0, otherwise	92	
ASSIST	Dummy, 1 if the farmer gets assistance from governmental and non-governmental organisations to adopt soil conservation practices; 0, otherwise	45	
LBSHRT	Dummy, 1 if the farmer has shortage of labour; 0, if not	78	
CRHOUSE	Dummy, 1 if the farmer has corrugated iron roof house; 0, if not	16	
RDNTSRS	Dummy, 1 if the farmer fears that the physical soil conservation measures are breeding ground (source) for rodent; 0, otherwise	62	
SMLARCL	Dummy, 1 if the parcel of land is assumed to be too small to establish conservation measure; 0, otherwise	34	

Note: Sample Size, N = 116; SD = Standard Deviation

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3. ANALYTICAL FINDINGS AND DISCUSSION

3.1 Socio-economic and institutional characteristics

The average family size of the sample farmers was 6.4, a figure which was above the national average of 5 persons (Befekadu & Berhanu, 2000). About 93.1 percent of the sample households were male-headed and the remaining (6.9 percent) were female-headed. The survey shows that the average dependency ratio was about 0.96, i.e., each economically active person in a family supported almost one economically inactive person. With regard to labour availability, 77.6 percent of the respondents reported that they had labour shortage. The average age of the sample household head was about 48 years. However, this average does not clearly indicate differences in age among sample household heads, which ranged from 18 years to 80 years. In this study, 61.2 percent of the respondents were illiterate while about 13.8

percent could only read and write and the rest (25 percent of the sampled farmers) had formal schooling of different levels.

The average land holding of the sample farmers was 3.17 hectares and the human to cultivated land ratio was 2.8, which is relatively higher seen from the fragile, degraded and infertile land of the area[4]. About 73 percent of the average land holding was put under cultivation, regardless of the low productivity of the land caused by soil erosion. However, the real average cultivated area was 1.49 hectares netting out about 0.81 hectares of land, which was put out of production due to soil erosion. About 93.1 percent of the sample respondents reported that they owned livestock and their average livestock holding was 4.08 TLU. However, the grazing-land was small and amounted to 0.70 hectares for a representative farmer, indicating a high stocking rate.

Forty-six respondents (about 39.7 percent of the sample farmers) reported that they rented-in land. The average size of the rented-in land was 0.43 hectares. Of the 46 respondents who reported to have rented-in land, 35 (76.1 percent) and 11 (23.9 percent) were users and non-users of physical soil conservation practices, respectively. Those farmers who rented-in land were found to be wealthy and progressive.

On the other hand, land is rented-out by some farmers who were relatively aged (had no sufficient labour) and by poor farmers who had no oxen and sufficient inputs. Thirteen respondents (about 11.2 percent of the sample farmers) reported that they rented-out an average of 1.2 hectares of their land. In fact, among those who rented-out their land, 46.2 percent and 53.8 percent were users and non-users of physical soil conservation practices, respectively.

Adoption of land conservation technologies seems to require an incentive or support from either the government or non-governmental organisations. This is so because the benefit of the investment can be reaped in the long run while the subsistence farmers' planning horizon is short. In this study, about 44.8 percent of the respondents reported that they received assistance from different sources, which enabled them to construct physical soil conservation structures on their farms. The assistance that farmers received took the form of building structural measures on their croplands, often without their involvement, with food-for-work incentives, maintenance of the structures through food-for-work incentives, taking part in tailor-made training programs on constructing and maintaining conservation structures and receiving financial and material support to construct conservation structures.

Stone bund, check dam and all types (stone bunds, check dams and cut-off drains) were reported to increase the productivity of the land by 88.7, 28.6 and 66.7 percent of the farmers who reported to have used the respective physical soil conservation practices, respectively. As an important attribute, the soil retention capacity of stone bund, check dam, cut-off drain and all types (stone bunds, check dams and cut-off drains) was underscored by 85.9, 14.3, 46.7 and 33 percent of the farmers who used the respective structures, respectively.

Physical soil conservation measures are known to be costly mainly because of their labour requirement. This was evaluated using the man-days that would be required to get 100 metres of the structure constructed (as reported by the farmers themselves). As shown in Table 3, constructing 100 metres of stone bund, check dam and cut-off-drain was reported to require 30.6, 56.3 and 11.4 man-days, respectively, regardless of other necessary engineering components of the structures in question. Compared to the national norm, the farmers underestimated the labour requirement for check-dam and cut-off drain and overestimated that of the stone bund since the figure reported by the farmers for stone bund construction was twice the national norm set by the MOA (1997)[5]. However, the farmers reported also an undesirable attribute of these structures, which is the possibility that they could be used as homes and breeding grounds for rodents.

Table 3: Attributes of physical conservation measures as perceived by the technology users

Technology attributes	Technology type							
	Stone bund		Check dam		Cut-off drain		All types	
	N (71)	%*	N(7)	%*	N (15)	%*	N(6)	%*
Increase productivity	63	88.7	2	28.6	-	-	4	66.7
Minimise soil loss	61	85.9	1	14.3	7	46.7	2	33.3
Labour required (Md./100m)	30.6		56.3		11.4		-	
National norm (Md./100m)	15.0		100		40		-	
Rodent source	69	97.2	-	-	-	-	2	33.3

** Percentage relative to the total number of sample farmers using the physical soil conservation practices in question.*
Figures in parenthesis indicate the number of farmers who used the respective practice
Source: Survey Results and MOA, 1997

In this respect, amongst the structures being popularised to the farmers, stone bund was found to be a good rodent source. In fact, above 97 percent of the users of the physical soil conservation practices reported the structure as a source of rodent despite the fact that it is the most widely used structure in the areas.

3.2 Analytical findings

The maximum likelihood method of estimation was used to elicit the parametric estimates of the binomial logistic regression model and statistically significant variables were identified in order to measure their relative importance on farmers' soil conservation decisions. The binomial logistic model required eight iterations to generate the parameter estimates and the results of the maximum likelihood estimates (see Table 4).

Table 4: The maximum likelihood estimates of the binomial logit model

CNSRV	Estimated Coefficients	Odds Ratio	Wald Statistic	Significance Level
CONSTANT	-5.6628			
AGE	-0.0320	1.034	0.537	0.464
FEDUC	0.0329	1.034	3.610	0.057*
TCULTLND	1.0901	2.975	4.215	0.040**
ERSNPRB	3.34998	28.502	0.576	0.448
DAVIST	0.1263	1.135	0.007	0.936
SECURITY	8.7085	6054.3	13.749	0.000***
SZRNTLND	0.0177	1.018	1.971	0.160
ASSIST	2.2623	9.605	2.819	0.093*
CRHOUSE	3.4512	31.553	3.527	0.060*
LBSHRT	-1.5697	0.2081	1.141	0.285
RDNTSRS	-4.5993	0.0101	5.774	0.016**
SMLPARCL	-0.1044	0.9001	0.005	0.946
OFFINCM	5.0507	156.139	2.917	0.088*
MECLT	0.7765	2.174	0.419	0.518
STKRTLU	0.0427	1.044	0.196	0.658
Likelihood Ratio Index (LRI)		0.77		
Pearson χ^2		49.46**		
Likelihood Ratio Test		120.46***		
Correctly Predicted		96.55[a]		
Sensitivity		98.59[b]		
Specificity		93.33[c]		

*** *significant at less than 1percent probability level*
** *significant at 5 percent probability level*
* *significant at 10 percent probability level.*
[a] *Based on a 50-50 probability classification scheme*
[b] *Correctly predicted adopters based on a 50-50 probability classification scheme*
[c] *Correctly predicted non-adopters based on a 50-50 probability classification scheme*
Source: *Model Output*

The likelihood ratio index (LRI) indicates that approximately 77 percent of the total variation in the dependent variable is explained by the binomial logistic

model. This is a reasonable result for analysis of this nature. The likelihood ratio test statistics exceeds the chi-square critical value with 15 degrees of freedom at less than 0.01 level of significance, indicating the hypothesis that all the coefficients except the intercept are equal to zero is rejected. The value of Pearson chi-square indicates also the goodness-of-fit test for the fitted model.

Another measure of goodness of fit is based on a scheme that classifies the predicted value of CNSRV as 1 if $P_{(i)} \geq 0.5$ and 0 otherwise. The model correctly predicts 112 of 116, or 96.55 percent of the observations. The sensitivity (correctly predicted adopters) and the specificity (correctly predicted non-adopters) of the binomial logistic model are 98.59 percent and 93.33 percent, respectively. Thus, the model predicts both groups, users and non-users of physical soil conservation practices, fairly accurately.

The maximum likelihood estimates for the binomial logistic model are presented in Table 4. In the empirical findings, the direction of the effects of all the predictor variables turned out to be consistent with *a priori* expectations. Moreover, out of the fifteen variables hypothesised to influence adoption of physical soil conservation practices, seven were found to be statistically significant at less than 10 percent probability level.

Results of the binomial logistic model reveal that literate farmers with formal schooling are more likely to invest in soil conservation practices than those who are illiterate or with limited formal education. This implies that formal schooling enhances the farmers' awareness towards the level and severity of soil erosion problems. The result of the study by Ervin & Ervin (1982) substantiated the link between the level of educational attainment and early adoption of soil conservation practices, which is consistent with the results of this study.

The model output confirms that total cultivated land, which is a proxy for a host of factors including wealth and income, had a significant and positive influence on the decision to adopt soil conservation practices. The possible explanation is that those farmers with larger cultivated land earn more income be it from crop production or livestock rearing. This helps them to hire more labour to undertake physical conservation practices, which are known to be costly for they demand more labour and materials.

As expected, farmers' perception of security of land ownership (SECURITY) had a significant and positive effect on the adoption of soil conservation practices. The strong relationship between security of land ownership and adoption of soil conservation practices can be explained by the fact that benefits from conservation investments are anticipated in the long planning horizon. Thus, frequent land redistribution, which mostly results in depriving user-right security or ownership-right, dissuades farmers from adopting physical soil conservation practices. Similarly, Desalegn (1994) argued that, in the Ethiopian context, insecurity of tenure and absence of land market lower the value of farmland and the incentive to invest in its quality improvement. It is important to note that in Ethiopia all land is under state ownership and farmers have only user-rights where land is not an object of market transactions.

Likewise, the variable ASSIST, which stands for the assistance and support that farmers get to put physical soil conservation structures on their farms, was found to be significant at 10 percent probability level. As already noted, farmers are not likely to invest in soil conservation activities unless encouraged or assisted by governmental and non-governmental organisations. This is mainly because physical soil conservation practices are costly, and benefits are anticipated in the long run.

The type of house (CRHOUSE) which indicates the level of wealth is positively and significantly related to the adoption of soil conservation practices. The implication is that farmers with higher income levels appear to be more likely to adopt conservation practices. In other words, the probability of investing in soil conservation measures, if all other factors are kept constant, increases with wealth level.

Farmers' perception of the conservation structures as the source of rodent (RDNTSRS) is associated negatively and significantly with the probability of adoption[6]. The implication is that farmers will be reluctant to invest in physical soil conservation practices if they feel that the structures are homes and breeding grounds for rodents.

As anticipated, those farmers who earn off-farm income are likely to invest in soil conservation practices. The model estimate confirms the significant impact of this variable on the adoption of soil conservation practices. The possible explanation for this is that increased off-farm income improves the farmers' financial position, which in turn encourages investment in soil conservation technologies.

3.3 Sensitivity analysis

All qualitative and quantitative explanatory variables do not have the same

level of impact on the farmers' adoption decision. The relative importance of the qualitative explanatory variables can be seen by examining the changes in probabilities that would result from changes in values of these variables. To rank these factors, a " typical farmer" is defined by the most frequent values of the qualitative variables included in the model. Thus, a typical farmer is one who feels secured about his land ownership right (52 percent of the respondents), perceives soil erosion as a serious problem (92 percent of the respondents), has a problem of labour shortage (78 percent of the respondents), and thinks that the physical soil conservation structures are breeding grounds for rodents (62 percent). In this study, the probability of adoption for a typical farmer evaluated at the sample means of significant explanatory variables is 0.748, a value virtually higher than the actual level of adoption indicated by the survey data. Table 5 shows the effect of changing the values of statistically significant qualitative explanatory variables, specified in the model, on the probability of adoption.

Table 5: Changes in probability of adoption resulting from changes in qualitative explanatory variables

Variables	Probability	Change in Probability	Percentage Change (%)
Typical farmer	0.748		
Typical farmer but insecure ownership right	0.005	-0.75	99
Typical farmer but gets off-farm income	0.99	0.25	33
Typical farmer but has no labour shortage	0.93	0.19	25
Typical farmer but gets assistance from different sources	0.97	0.22	29
Typical farmer but has corrugated roofed house	0.98	0.24	32
Typical farmer but does not fear practices as rodent source	0.99	0.25	33

Source: Computed from Model Output

Accordingly, a typical farmer without secured ownership of land has the lowest probability of adoption to the extent that the farmer refuses implementing the practices. Similarly, the probability of adoption among farmers with a typical profile but who don't consider the soil conservation structures as sources of rodents and who don't have labour shortage, increases by 33 percent and 25 percent, respectively. In the same vein, an offer of assistance for a typical farmer, possibility of earning additional off-farm income and improvement in wealth status (CRHOUSE) increase the probability of adoption of physical soil conservation practices by 29 percent, 33 percent and 32 percent, respectively. These results show that the importance of each variable in the adoption of physical soil conservation practices is different.

The relative importance of the quantitative factors in the adoption decision can be seen by examining variable elasticity, defined as the percentage change in the value of these variables. Accordingly, a 10 percent increase in the value of total cultivated land holding (from an average of 2.3 hectare to 2.5 hectares) increases the probability of adoption of a typical farmer by 5.5 percent, which is equivalent to a probability level of 0.79. This implies that total cultivated land has a positive impact on soil conservation investment decision.

4. CONCLUSION

This study attempted to capture important factors which influence adoption of physical soil conservation practices in the Central Highlands of Ethiopia. Results of the econometric estimation show that the adoption of physical soil conservation practices is highly influenced, among others, by security of land ownership, technological traits, farm size, level of formal schooling, wealth status, off- farm income, and assistance provided to the farmer.

In line with the current thinking on soil conservation measures, the findings of this study indicate that any intervention in land conservation should recognise the heterogeneity in household characteristics, land, institutional patterns and technology-specific traits. Above all, this study reveals that policy towards ensuring ownership security will lift up the farmers' land conservation investment decision.

ACKNOWLEDGMENTS

The authors are very grateful to the two anonymous referees for their sharp and perceptive comments and suggestions on an earlier version of this paper. The authors would like also to express their heartfelt thanks to Dr. Kebede Kassa for his invaluable assistance in editing the manuscript.

NOTES

1. *The term land degradation is used here to denote the reduction in the capability of the land to produce benefits from a particular land use under specific form of land management.*

2. *According to the Ethiopian Federal Democratic Republic administrative hierarchy, the country is divided into 11 regional states, which in turn are divided into zones, districts and kebeles (local administration units), in that order.*
3. *One Tropical Livestock Unit (TLU) is equal to 250 Kg which is equivalent to 1 camel; 0.7 cattle; 0.8 horse/mule; 0.5 donkey; 0.1 goat/sheep (ILCA, 1992).*
4. *The average land holding of the sample respondents is divided into 0.17 ha of homestead, 2.3 ha of cultivated land and 0.70 ha of grazing-land.*
5. *The national norm is computed as an average of the data generated from soil conservation sites located in different parts of the country.*
6. *This variable is used as a proxy for the characteristics of the technology in question.*

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