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ECONOMICS OF SOIL AND WATER CONSERVATION: THE CASE OF SMALLHOLDER FARMERS IN NORTH EASTERN HIGHLANDS OF ETHIOPIA

ABSTRACT

It is generally believed and supported by empirical evidence that both technology adoption and improving production efficiency increase production. The objective of the study was to examine the determinant of adoption of improved Soil and Water Conservation (SWC) technologies mainly stone bund and soil bund in two districts of North east highlands of Ethiopia. Multinomial Logit model was employed to study farmers' decision to adopt improved SWC technologies. The results of the study provided empirical evidence of the positive impact of education, extension service, severity of soil erosion and economic efficiency in enhancing the adoption of improved SWC technologies to increase production. The result showed that adopters of improved SWC practice had better efficiency as compared to non-adopters. Physical characteristics like distance from farmers' home to markets, roads, and plot played a critical role in the adoption of improved SWC technologies as proximity to information, sources of input supply and markets save time and reduce transportation costs. Given the critical role of proximity to such centers and better roads for promoting adoption and productivity gains, the effort of investment in improved roads infrastructure should be improved to achieve increased production. Production decision of farm household either to be more efficient or less efficient was also significant for likelihood of adoption of improved SWC technologies. Results of the analyses suggest that there is more research focus on improved SWC technology adoption decision and production decision of the farm household.

Key words economic efficiency, Multinomial Logit model, soil bund, south Wollo, stone bund

1. INTRODUCTION

The economic development of Ethiopia is highly dependent on the performance of its agricultural sector. Agriculture contributes 53% of the country's Gross Domestic Product (GDP), 85% of all exports (coffee, livestock and livestock product and oil seeds) and provides employment for 85% of the population (FAO, 2007). Agriculture provides raw material for 70% of industries in the country (MOFED, 2006). In spite of its remarkable potential, the performance of Ethiopian agriculture has been sluggish in the last decades. However the population grows at an average rate of 2.52% per annum (World Bank, 2004; FAO 2007). That means, food production lagged far behind population growth leading to food shortage and thereby resulted in national poverty of 44.2% of the population (FAO, 2007). The dominant economic activity is undertaken by smallholder farm household which are subsistent oriented. Low agricultural productivity due to land degradation mainly accelerated soil erosion is a critical problem throughout Africa (FAO, 2002).

Degradation of arable lands due to soil erosion is a widespread phenomena in the highlands of Ethiopia, which share about 45 percent of Ethiopia's total land area and about 66 percent of Amhara region. On steep slopes soil erosion exceeding 200 tons /ha/year recorded (Kappal, 1996 and SCRP, 1996). Productivity in the agricultural sector has been hindered, among other things, by land resource degradation, particularly soil erosion by water, unfavorable climatic conditions and structural bottlenecks. Human activities such as deforestation, overgrazing, and over cultivation of sloppy and marginal lands could be consistently identified as the major causes for vicious circle of land degradation, drought, famine and chronic poverty in Ethiopia. Rapid population pressure on the limited resource base exerts complex problem on the agro ecosystem, making life sustenance hard for the desperate poor (Ayalneh, 2002). In the same manner, soil degradation contributes to the increment of rural poverty and food insecurity, because productivity is decreased, as a consequence, subsistence farmers are less and less able to accumulate reserves of grain (UNEP, 2002).

There have been few empirical multiple response studies conducted to identify determinants of adoption of physical soil and water

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conservation practices beyond studying the conventional binary response to identify whether the farmers adopt or not the conservation technologies in Ethiopia, except (Bekele and Holden, 1998; Tesfaye, 2003; Woldeamlak, 2003; Berhanu and Swinton, 2003; Senait, 2005; Aklilu, 2006; Chilot, 2007; and Kidane, 2008) but nothing has been done in the study area. Therefore, this study would assess the conditions and identify the determinants of the use of physical soil and water conservation practices by smallholder farmers at farm plot level in the study area in order to fill the information gap. The purpose of this study was to identify determinants of physical soil and water conservation practices at farm plot level that was to study the multiple choice decision of farmers beyond the known conventional binary choice decision among soil and water conservation technologies.

2. MATERIAL AND METHODS

2.1. Description of the study area

This study was carried out in South Wollo. South Wollo is located in the North East part of Ethiopia. South Wollo is one of the eleven administrative zones of the Amhara National Regional State. It is situated between the Eastern highland plateaus of the region and the North Eastern highland plateaus of Ethiopia. It is divided into 20 administrative districts (weredas) and has two major towns (Kombolcha and Dessie) and 18 rural districts. Among the eighteen rural districts, Dessie Zuria and Kutaber are selected for this study. South Wollo is located between latitudes 10^{0}10'N and 11^{0}41'N and longitudes 38^{0}28' and 40^{0}5'E. According to the Central Statistical Agency's population census data, in 2007 the total population of South Wollo was 2,519,450 of which 50.5% were females and 88% were rural residents (CSA, 2008). The total land area in South Wollo, Dessie Zuria and Kutaber is 1,773,681 hectares, 180,100 hectares and 72,344 hectares, respectively. The cultivated land area accounts for 39%, 20% and 35.3% of the total area of Dessie Zuria, Kutaber and South Wollo, respectively.

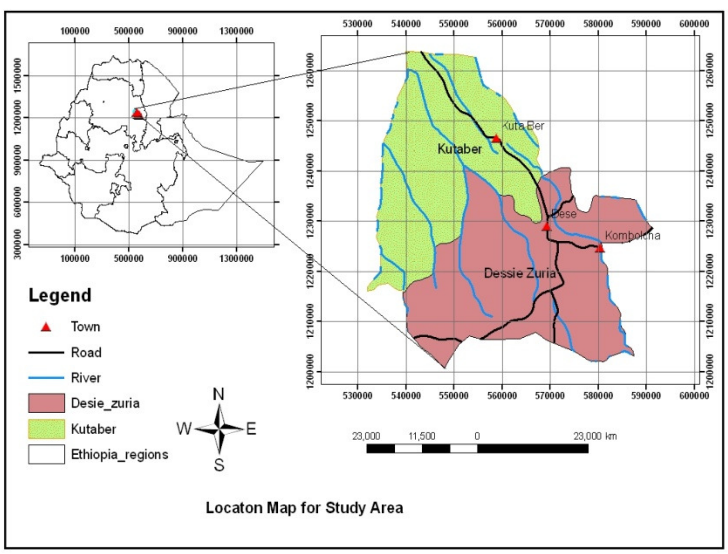

Figure 1. Map showing administrative regions of Ethiopia and the study districts

2.2. Sample size and sampling procedure

Dessie Zuria and Kutaber districts were selected purposively based on their accessibility and relevance of the study. A multistage random sampling method was used for the selection of the sample respondents. In the first stage of sampling, 6 Farmers' Associations (FAs) were selected randomly from a total of 54 FAs (3 from Dessie Zuria and 3 from Kutaber). In other words, as the number of Farmers' Association in Dessie Zuria (28) was equal to that of Kutaber (26), three Farmers' Associations were selected from each district using simple random sampling procedure. In the second stage, a total of 252 farmers were selected using probability proportional to sample size sampling technique (Table 1). These sample household had a total of 803 plots which is the unit of analysis for the study.

Name of District	Name of FA	Total household* head		Sample farm household heads		
				Female	Male	Total
		Male	Female	Number	Number	Number
Dessie Zuria	Tita	686	182	7	27	34
	Bilen	1,179	161	8	45	53
	Endod Ber	688	102	4	27	31
Kutaber	Boru	490	123	5	20	25
	Beshlo	797	201	8	32	40
	Alasha	1,297	458	18	51	69
	Total	5,137	1,227	50	202	252

Source: *Kebele Administration Office (Personal Communication),

Table 1. Distribution of sample farm household heads by farmers' association and district

2.3. Data collection and sources

A structured questionnaire was designed, pre-tested and refined to collect primary data. Experienced numerators were recruited and trained to facilitate the task of data collection. Farm visit, direct observation and informal interview were undertaken both by the researcher and the enumerators. The secondary data were extracted from studies conducted and information documented at various levels of Central Statistical Agency, Ministry of Agriculture and Rural Development and Finance and Economic Development Offices in the study area.

2.4. Analytical Models
2.4.1. Econometric specification of agricultural technology adoption model

Generally, various authors have attempted to use sociological and economic theories of innovation adoption to explain the behavior of farm households towards adoption of agricultural technologies. Innovation diffusion theory has applied to adoption of environmental practices including soil and water conservation. Under this theory, three explanations of adoptive behavior are proposed. These are psychological innovativeness, profitability orientation, or orientation to farming as a way of life (Ervin and Ervin, 1982). Therefore, according to this source, if interest is centered on understanding adoption, which does not necessarily correspond to effectiveness or extensiveness of the use of the technologies, then number of practices implemented would suffice. However, if the ultimate goal of conservation study is erosion reduction, then the variable should reflect the degree of erosion control by each practice and the extent to which it is applied on the farm. The adoption decision depends on the characteristics of the plot and the farm household. For many decades, it was believed that technical innovations combined with scientific method were the answer to soil erosion problem. However, regardless of advance in promotion of development technologies, the soil erosion problems persisted, forcing to change in attitude on the way to tackle the problems. This led to the realization that soil and water conservation is not only a technical issue but also a socioeconomic issue that redirect the attention to socioeconomic and behavioral factors influencing soil and water conservation decision-making. Most of the empirical studies on land degradation analyze and explain physical factors like topography, climate, soil, farming practice and from social aspect population pressure on soil erosion (Bekele and Holden, 1998).

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Factors such as technological characteristics, tenure arrangement, land fragmentation, age and education level affect adoption of soil and water conservation practices (Yohannes, 1992). Bekele and Holden (1999) also indicated one of the multiple challenges that the poor countries with rapid population growth are facing is the deterioration of food production potential of agricultural lands. Smallholder farmers' production and land conservation decision are likely to be influenced by factors related to their dual natures as units of consumption and production. Filho et al. (1998) found that both economic and noneconomic determinants are vital in affecting SWC adoption decision.

An adoption decision by farmers is inherently multivariate. Using bivariate models might exclude useful information contained in the independent variables and simultaneous adoption decisions (Wagayehu, 2003). Since farmers' decisions on the use of soil and water conservation practices involve polychotomous response in which the dependent variables are discrete, it is more appropriate to treat factors which are supposed to determine farmers' decision on the use of soil and water conservation practices as a multiple-choice decision. Thus, multinomial Logit model was used in this study for estimating the determinants of physical soil and water conservation practices based on farm households' plot specific multiple responses. In the multinomial Logit analysis, plots were classified according to their status at the time of the survey and the distribution of plots among groups was explained in terms of the characteristics of the plots and farm households. The unit of observation and analysis of the study were smallholder farmers at their farm plots. Following Greene (2003), the multinomial Logit model for a multiple choice problem is specified as follows:

$$P_{ij} = \frac{\exp(X_i^{'}\beta_j)}{\sum_{j=1}^{J}\exp(X_i^{'}\beta_j)} \qquad (1)$$

Where P_{ij} is the probability of farm household i's choice of a SWC alternative j, and β_j are the parameters to be estimated by maximum likelihood estimator. The estimated equations provide a set of probabilities for the $j+1$ choice for a decision maker with x_i characteristics. For identification of the model, we need to conveniently normalize by assuming $\beta_o = 0$ (Greene, 2003). Therefore, the probabilities are given by:

$$\Pr(y_i = j / X_i) = P_{ij} = \frac{\exp(X_i\beta_j)}{1+\sum_{j=2}^{J}\exp(X_i^{'}\beta_j)}, \quad \text{for } j > 1 \qquad (2)$$

and

$$\Pr(y_i = 1 / X_i) = P_{i1} = \frac{1}{1+\sum_{j=2}^{J}\exp(X_i^{'}\beta_j)} \qquad (3)$$

2.4.2. Definition of Variables and Hypotheses for multinomial Logit

The study aimed to identify major determinants of physical soil and water conservation practices on smallholder farmers' plots to combat accelerated soil erosion by water and reduce its negative consequence on land resources and agricultural production in the study districts. The different SWC practices included in the study were plots with traditional soil and water conservation practices such as earth bunds and stone barriers, including plots with no practices and plots that have improved physical soil and water conservation technologies such as stone check dams, soil bunds, or stone bunds. Therefore, the use of physical soil and water conservation practices in this study defined as the presence of improved physical SWC practices on the farm households' farm plots. Due to small number of plots covered with stone check dam, stone check dam is merged into stone bund due to their similar physical characteristics.

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Dependent Variable

The dependent variable (y_i) in this study was the choice or use of the physical soil and water conservation practices farmers had adopted on their plots. The dependent variable for multinomial Logit model was hypothesized to have the following values:

$y_i = 0$ if a farm household adopted no improved SWC and/or if she/he has adopted traditional SWC practices (j =0);

$y_i = 1$ if a farm household adopted an improved stone bunds (j=1);

$y_i = 2$ if a farm household adopted improved soil bunds (j = 2); and

Independent variables

Based on review of related literature, a number of independent variables influence the adoption decisions of improved soil and water conservation practices by an individual farmer. The independent variables that were assumed to influence the decisions of farmers in the study area to use improved soil and water conservation technologies on their farm plots were described and hypothesized as follows in table 2.

Variable Label	Definitions and measurement of variables	Expected sign
	Dependent variable	
SWCADOP	Use of SWC practices on farm plots, 0=traditional and no use; 1= stone bunds and 2 =soil bunds	
	Explanatory variables	
AGEHHH	Age of farm household head (in years)	+/-
SEXHHH	Sex of farm household head =1 if male; = 0 if female	+
SEVERTPL	Perception of severity of soil erosion by farm household 1=low; 2=medium; 3=high	+
PRIMEDUC	Education is one if completed primary (1-4) education, illiterates as a bench mark	+
ELEMEDUC	Education is one if completed elementary(5-8) education illiterates as a bench mark	+
SECONEDU	Education is one if completed secondary(9-12) education, illiterates as a bench mark	+
TLU	Total livestock holding (in tropical livestock unit)	+/-
AREAPLOT	Area of plot (hectare)	+
NOFAMEMB	Number of family members	-
MENUMB	Number of economically active workforce in the household	+
OFFARMIN	Off farm income gained per household per year (in birr)	+/-
THHASSET	Estimated total household assets in birr	+
SWCEXT	Extension contact in SWC 1=Yes; No =0	+
OWNERSHI	Ownership type of the plot,1=owned; 0 =share cropped	+
CREDITF	Amount of credit obtained from semi formal sources by farm household in birr	+
DISTPLOT	Distance of plots in walking minutes	_
SLOPLOT	Slope of plot as perceived by HH 1=flat; 2=gentle; 3=moderate; 4=steep slopes	+
SOLFERT	Fertility of plots as perceived by HH: 1=low;2=medium; 3=high	?
TCULTLAN	Total cultivated area in hectare	+

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NPLOT	Number of plots	_
DURATPL	Duration of plot use (in years)	+
DISTHOMT	Distance from home to nearest market (walking minutes)	-
DISHOROA	Distance from home to nearest all weather road (walking minutes)	-
CULT5YEA	Owner feels certain to cultivate the same fields after 5 years1=Yes; No =0	+
CULTCHIL	Owner feels certain to leave plots to children1=Yes; No =0	+
COMUNPR	Household head feels pressure from community to conserve soil1=Yes; No =0	+
FFWAVAIL	Food-for-work was available in village1=Yes; No =0	+/-
PUBCAMP	Household had conservation work done on its plot by public campaigns1=Yes; No =0	+
TE	Technical efficiency of the farm household	+
AE	Allocative efficiency of the farm household	+
EE	Economic efficiency of the farm household	+

Table 2. Summary of definitions and measurements of multinomial model variables

3. RESULTS AND DISCUSSION

3.1. Description of the Farm Household

3.1.1. Gender, age and education of the farm household

Age of a farm household head plays an important role on decision to use different types of soil and water conservation technologies. The average age of the total farm households was about 53 years. The age of household heads showed significant mean difference among the users of traditional and improved physical SWC practices. The age of household members may influence the availability of labor that is one of the most important factors of production to farmers in rural areas, which, in turn, determines the decision of farm households to select which conservation practices to use on their farm plots. The survey indicated that there was slightly high proportion of productive workforce for SWC technology users as compared to non-users. The Influence of continuous explanatory variables on use of SWC practices is presented in table 3.

Sex of the farm household heads might affect access to soil and water conservation technology information provided by extension agents and soil and water conservation projects operating in the study area. Due to cultural barriers which might lead to gender discrimination, male extension agents tend to work with male-headed households. This situation discriminate female headed households from access to information and this probably hindered their perception of the soil erosion problem and reduces their interest and willingness to use improved soil and water conservation measures on their farm plots. Moreover, the study revealed that most physical SWC activities were more labor intensive which are difficult to be performed by female, except material transportation that used for construction of soil and water conservation structures. The Influence of discrete explanatory variables on use of SWC practices is presented in table 4. To measure whether there was a difference in sex between traditional SWC practice and soil buds and stone bunds physical SWC practices or not, the chi-square test has been conducted. The result indicates that there was statistically significant difference among the groups of physical SWC practices by sex.

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Variables	traditional and no use (272)	stone bund (426)	soil bund (105)	Full sample (803)	F
Total area in hectare for the plot	0.15	0.20	0.13	0.18	11.28***
Distance of the plot from home	30.18	18.35	17.93	22.30	19.77***
Duration of plot operated	26.93	29.25	28.09	28.31	2.17
Distance from to nearest market	76.62	80.91	76.06	78.82	0.78
Distance from home to road	35.07	37.58	32.11	36.02	1.11
Respondent's age	53.61	53.54	49.39	53.02	4.24***
Number of family members	5.82	6.21	6.30	6.09	3.04**
Number of man equivalent	3.86	4.09	4.25	4.04	2.43*
Total cultivated area in hectare	0.73	0.80	0.69	0.76	2.73*
Number of plots	4.96	5.01	5.09	5.00	0.10
Total Tropical Livestock Unit	3.81	3.86	3.88	3.85	0.05
Total off-farm income in one year	2,110.31	2,324.67	2,170.08	2,231.85	0.32
Estimated total household assets	50,435.08	62,147.88	52,015.73	56,855.53	3.81**
Amount of credit obtained	691.88	911.13	716.67	811.43	2.27***
Technical Efficiency	0.4943	0.4969	0.5160	0.4985	0.494
Allocative Efficiency	0.6645	0.6593	0.6257	0.6567	4.687***
Economic Efficiency	0.3257	0.3255	0.3259	0.3256	0.001

Significant *at 10%, ** at 5% and *** at 1% probability level

Table 3 Descriptive statistics for continuous variables for SWC practices (Means)

Education is an important instrument to enhance agricultural technology adoption decision in general and physical soil and water conservation technologies in particular via acquired knowledge and information which are considered to be the essences of education. Awareness of farmers about the compatibility, complexity, trialability and comparative advantage of soil and water conservation practices, observation of the negative consequence of accelerated soil erosion in long-term and short-term perspectives might influence farmers to adopt soil and water conservation practices. Regardless of the government efforts to promote education, illiteracy is persistent in Ethiopia. The survey indicated that the levels of education of the sample farm household heads were heterogeneous. Those who completed primary education (grade 1-4) comprise about 31 percent, elementary education (grade 5-8) were about 24 percent and secondary education were 7 percent and illiterates were 69 percent. The majority of the sample farm households (about 69%) had never got formal schooling.

3.1.2. Land holding, number of plots, duration plot used and plot distance

Land is the leading resource to achieve the objectives of food security and economic development of the region in general, the study districts in particular. However, the land shortage which partly aggravated the land degradation problem, because of population pressures on the natural resources base might lead to further land fragmentation, over-grazing, deforestations, steep slope cultivation and absence of fallowing, which in turn increase the accelerated soil erosion which is inherently severe in the study area. The average total land holding of sample households found to be 0.69 hectare for the full sample. In addition the physical soil and water conservation structures occupy much land surfaces in fragmented and small plots which cause reduction of production and productivity of the cultivable land that could not be compensated by the benefits of conservation (Wagayehu and Drake, 2003; Chilot, 2007). The survey result indicated that

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area of cultivated land had significant influence on the use of improved physical SWC practices.

The number of plots managed by the farmers might affect their decision to use physical soil and water conservation technologies on their farm plots. The farm households whose farm plots were scattered in different places, given the low road infrastructure coverage in the rural peasant associations of the study area and the rugged topography, which takes long time and high labor to reach and construct conservation structure, might be difficult. The survey indicated that the sample farm households were managing 803 farm plots. The average number of plots of all farm households was 5. The average number of plots managed by the farm households as traditional, stone bunds and soil bunds found to be 4.96, 5.01, and 5.09, respectively. The result of statistical analysis revealed that there was no statistically significant difference between traditional and improved physical soil and water conservation practices users groups in relation to the number of plots hold by the farm households. The time (in walking minutes) and labor required to travel to farm plots would probably influence farm households' decision to use soil and water conservation technologies. It was presumed plots that are far away from home known to hinder farm household's decision to adopt improved soil and water conservation technologies. The survey showed that the average time required to reach their plots per household was 22.3 minutes for the full sample. The average distance of plots per households for traditional structure, improved soil bund and stone bund structures users groups were 30, 17, and 18 minutes, respectively. The result indicated that, there were statistically significant mean differences between the groups across the structures. In this regard, farm households might be reluctant to use conservation measures on farm plots far from residence. This finding is consistent to Wagayehu (2003) and Chilot (2007). The average duration (in years) that a farm household operated its farm plots was about 28 for the full sample. The results indicated that there was no significant difference in the duration of farm household’s plot among the users of physical SWC practices.

3.1.3. Land tenure security

Three different measures were used to capture the degree of land tenure security, an institutional factor in investment risk. In the immediate period, risk was measured in terms of whether or not the land was owned or leased. For the medium-term, tenure security was measured by whether farmers believed that they would cultivate the same plots 5 years from the time of the survey. Long-term tenure security was gauged by whether farmers believed they would bequeath the plot to their children. At the village level, time elapsed since the last land distribution was used as measure of the stability of land tenure.

		Type of SWC practice used for the plot			Full sample (803)	Pearson Chi-Square
		traditional and no use (272)	stone bund (426)	soil bund (105)		Value
Owner feels certain to cultivate the same fields after 5 years	no	5	14	4	23	1.639
	yes	267	412	101	780	
Owner feels certain to leave plots to children	no	13	22	11	46	5.087*
	yes	259	404	94	757	
Household head feels pressure from community to conserve soil	no	28	10	3	41	22.897***
	yes	244	416	102	762	
Food-for-work was available in village	no	44	50	24	118	9.030**
	yes	228	376	81	685	

Household had contact with extension SWC service	no	151	8	9	168	299.803***
	yes	121	418	96	635	
Household had conservation work done on its plot by public campaigns	no	190	156	48	394	73.906***
	yes	82	270	57	409	
Respondent's sex	female	48	67	26	141	4.752*
	male	224	359	79	662	
Primary education of the HH	no	184	294	70	548	0.282
	yes	88	132	35	255	
Elementary education of the HH	no	209	323	78	610	0.281
	yes	63	103	27	193	
Secondary education of the HH	no	245	399	102	746	6.537**
	yes	27	27	3	57	
Ownership dummy	no	15	29	9	53	1.211
	yes	257	397	96	750	

Significant *at 10%, ** at 5% and *** at 1% probability level

Table 4 Discrete variable chi-square statistics for SWC practices

3.1.4. Slope, soil fertility, and perception of severity of soil erosion

Slope is one of the farm characteristics that aggravate land degradation in general and soil erosion in particular. Among others, severity of soil erosion is determined by the variation of slope gradient of farm plots and other factors, such as, soil type and land use practices. Farmers, who have farm plots in areas which are more prone to soil erosion such as gentle, moderate and steep slopes and land between narrow valleys, their plots are expected to be exposed to more accelerated soil erosion and therefore assumed to recognize the impact of top soil loss due to erosion more easily than farmers having farm plots located on flat areas. Therefore, it was assumed that vulnerability of farm plots to erosion is likely to motivate farmers to decide on use of improved soil and water conservation practices. The slopes of each farm plot operated by farm households were classified by own perception, as flat, gentle, moderate and steep slopes. According to their' perception, out of total 803 plots, 25, 47, 24 and 4 percent were located on flat, gentle, moderate and steep slopes, respectively. The Influence of ordered explanatory variables on use of SWC practices is presented in table 5. Consequently based on farmers' perception, plots were classified based on soil fertility into low, medium and high fertile. According to their' perception, out of total 803 plots, 15, 67 and 18 percent were located on low, medium and high fertile, respectively. Moreover, based on farmers' perception, plots were classified based on soil erosion severity into low, medium and high severe. According to their' perception, out of total 803 plots, 26, 52 and 22 percent were located on low, medium and high severe areas, respectively. Plots were also classified into owned (93%) and shared (7%).

3.1.5. The market access factors

The market access factors affect the relative profitability of investment in conservation practices. Ideally such factors would include crop prices, cost of labour and materials used for conservation and the yield effect of conservation practices (Berhanu and Swinton, 2003). However, information on the effect of conservation on yield was not available. Moreover, the large number of infra-subsistence farmers meant that crop sale prices were unavailable. Instead, relative prices were proxied by distance from marketplace. Labour input is a major cost component in conservation investment in the study area. Distance from an all-weather road was used to proxy for differences in the opportunity cost of labour. The expected effects of these on conservation investment were ambiguous, as distance reduces both crop

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income and off-farm work opportunities during the dry season.

Variable name	Plot characteristics	Type of SWC practice				Chi-Square
		Traditional and no use (272)	Stone bund (426)	Soil bund (105)	Total (803)	Value
Fertility of the plot	Low	43	66	13	122	12.72***
	Medium	153	309	76	538	
	High	76	51	16	143	
Slope of the plot	Low	140	44	20	204	135.7***
	Gentle	100	225	55	380	
	Moderate	25	135	28	188	
	Steep	7	22	2	31	
Severity of the plot	Low	148	35	22	205	207.5***
	Medium	112	242	67	421	
	High	12	149	16	177	
Type of ownership	Owned	257	397	96	750	1.266
	Shared in	9	16	4	29	
	Shared out	6	13	5	24	
Type of soil	Loam	128	165	51	344	5.193*
	Sandy	127	239	50	416	
	Sandy-Loam	17	22	4	43	

Significant *at 10%, ** at 5% and *** at 1% probability level

Table 5. Ordered data Kruskal Wallis Test Statistics for SWC practices

Procedure and results of efficiency measurement

The input and output variables that were used in the DEA model were defined as follows.

i. **Outputs** physical yield of crops and livestock and their respective prices were used to compute the value of output of the farm. The value of crop and livestock output was derived from output of improved and local wheat, barley, *teff*, local and improved horse bean, field pea, maize, local and improved potato, oat, fenugreek, garlic, lentil, chickpea, grass pea, sorghum, haricot bean, linseed, milk of improved and local dairy cow milk, improved and local poultry, local and improved beehives, number of sheep and goat products. These outputs were multiplied by their respective market price to obtain the value of crop and livestock output. The respective monthly market prices were collected from South Wollo department of agriculture and rural development office. The averages of these prices were used for computational analysis.

ii. **Inputs** these were defined as the major inputs used in the production of crop and livestock. They were:

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Land This represented the physical unit of cultivated land and grazing land in hectares;
Human labour This was man days worked by family, exchange and hired labour for land preparation, planting, weeding, or cultivation, irrigation, harvesting and rearing livestock;
Oxen labour This was oxen days worked by the household using oxen labour for land preparation, planting and threshing;
Material inputs This included the cost of veterinary, feed, organic and chemical fertilizers, improved and local seeds and pesticides used by the farm household.

Cost function variables

iii. Input prices the input prices of land, human labour and oxen labour needed for deriving the dual cost frontier in the parametric and nonparametric method were collected. Moreover, the value of the output of crop and livestock was used as computed above and adjusted for statistical noise.

The frequency distribution and summary statistics of technical (TE), allocative (AE) and economic (EE) efficiency scores from non-parametric methods are presented in Table 6. The average TE, AE and EE score for non-parametric approach using the Data Envelopment Analysis Constant Returns to Scale (DEACRS) were 50%, 64% and 31%, respectively. These imply that there were substantial inefficiencies in production and hence rooms for production gain through efficiency improvement. This suggests that the farm households could reduce their production costs by 50%, 36% and 69% if they could operate at full technical, allocative and economic efficiency levels, respectively. The frequency distribution given in Table 6 showed that there was significant number of farmers whose efficiency scores were less than 50%. The number of farmers whose technical, allocative and economic efficiency scores were greater than 90% in DEACRS was 19, 4 and 3, respectively.

The standard deviation (SD) of the efficiency scores from non-parametric methods showed that there was variability of efficiency scores across the farmers. For instance, the SD of TE, AE and EE in DEACRS were 21, 14 and 15, respectively. The minimum and maximum TE in DEACRS was 12.3% and 100%, respectively. However, the minimum and maximum EE in DEACRS was 4.65% and 100%, respectively.

	DEACRS (N)		
	TE	AE	EE
<10	0	0	11
10_20	8	4	42
20_30	24	5	83
30_40	59	6	57
40_50	55	14	37
50_60	40	36	14
60_70	19	107	4
70_80	12	54	0
80_90	16	22	1
>90	19	4	3
Mean	50.15	64.26	31.84
S D	21.25	13.51	14.84
Minimum	12.30	15.30	4.65
Maximum	100	100	100

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Table 4.18. Frequency distribution of technical (TE), allocative (AE) and economic (EE) efficiency from non-parametric methods DEACRS

N=number of farmers

These efficiencies indices were used as explanatory variable in Multinomial Logit model.

3.2. Econometric estimation procedure and results of empirical adoption models

3.2.1. Estimation procedure of empirical adoption models

There are farmers who have adopted and non-adopted improved SWC technologies. These farmers can use the new technology in a different level. Therefore, the probability of adoption of SWC practices was estimated using multinomial Logit model. Accordingly explanatory variables were checked for problems of multicollinearity, endogeneity and heteroscedasticity. Following Gujarati (1995), the problem of multicollinearity for continuous explanatory variables was investigated using a technique of variance inflation factor (VIF) and tolerance level (TOL), where each continuous explanatory variable is regressed on all the other continuous explanatory variables. The larger is the value of VIF, the more worrying is the multicollinearity or collinear is the variable (X_j). As a rule of thumb, if the VIF of a variable exceeds 10 and R^2 exceeds 0.90 the variable is said to be highly collinear. The values of VIF were less than five and hence no signals of multicollinearity problems.

To observe the degree of association between dummy explanatory variables contingency coefficients were computed. Contingency coefficient is a chi-square based measure of association where a value 0.75 or above indicates a stronger relationship between explanatory variables (Healy, 1984). This was also checked and less than 0.7. For endogeneity an attempt was made to exclude dependent variable as explanatory variable. To avoid heteroscedasticity problem, robust standard error was estimated.

3.2.2. Determinants of Improved physical SWC Practices using Multinomial Logit

Farmers were classified into adopters and non-adopters. Adopters are farmers who use one of the improved agricultural technologies; soil bund and stone bund. Non-adopters are farmers who use none of these technologies during the survey year (2008/2009 production year). The maximum likelihood parameter estimate of the multinomial Logit model employed to identify factors affecting farmers' decision on adoption of improved SWC practices is presented in Table 7. In all analyses the likelihood ratio test statistics suggest the statistical significance of the fitted regression.

	Stone bund			Soil bund		
Variable	Coefficient	Standard Error	Marginal Effect	Coefficien t	Standard Error	Marginal Effect
AREAPLOT	2.673	1.185**	0.3284	0.764	1.472	-0.1224
SOLFERT	-0.557	0.226**	-0.0485	-0.4284	0.266	-0.0013
SLOPLOT	0.30	1.9	0.0181	0.326	0.227	0.0107
SEVERTPL	2.014	0.258***	0.1960	1.269	0.293***	-0.0231
DISTPLOT	-0.012	0.006*	-0.0007	-0.0132	0.0076*	-0.0004
DURATPL	0.012	0.011	0.0016	-0.00016	0.0145	-0.0008
CULT5YEA	0.446	1.278	-0.0852	2.012	1.397	0.1676
CULTCHIL	0.92	0.736	-0.0852	-0.28	0.754	0.1676
COMUNPR	1.57	0.69**	0.0180	2.799	0.904***	0.1627
FFWAVAIL	2.307	0.505***	0.1186	2.877	0.541***	0.1157

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SWCEXT	4.34	0.477***	0.3809	3.285	0.528	0.0055
PUBCAMP	0.986	0.276***	0.0785	0.855	0.341	0.0121
DISTHOMT	-.001	.0029	-0.0001	-0.00024	0.0036	0.0001
DISHOROA	-0.0038	0.0038	0.0002	-0.0099	0.0050*	-0.0007
SEXHHH	0.249	0.375	0.0126	0.653	0.446	0.0466
AGEHHH	-0.013	0.013	0.0005	-0.032	0.016**	-0.0022
MENUMB	-0.005	0.083	-0.0116	0.1462	0.101	0.0150
TCULTLAN	0.506	0.360	0.0657	0.096	0.432	-0.0280
NPLOT	-0.083	0.059	-0.0124	0.0065	0.078	0.0068
TLU	-0.0869	0.084	-0.0124	-0.058	0.099	0.0068
OFFARMIN	0.0000579	0.0000497	0.0000065	0.000081	0.000056	0.0000054
THHASSET	0.0000037	0.0000041	0.00000067	0.0000024	0.0000047	-0.000000017
CREDITF	0.00013	0.0000979	0.000032	-0.000027	0.00012	-0.0000151
PRIMEDUC	0.748	0.539	0.0517	0.754	0.611	0.0197
ELEMEDUC	0.367	0.659	0.0033	0.666	0.725	0.0392
SECONEDU	1.372	0.621**	0.0009	2.673	0.827***	0.1648
OWNERSHI	-2.294	0.826***	-0.1811	-2.014	0.907**	-0.0304
TE	5.254	2.70*	0.4933	3.55	2.99	0.0361
AE	7.719	2.159***	0.5994	6.90	2.52***	0.1152
EE	8.608	4.259**	0.7212	6.989	4.748	0.0577
Log likelihood function= -476.2 Chi squared = 603.8*** Degrees of freedom = 58 Percent Correctly Predicted= 76.34				Number of observations=803 Restricted log likelihood =-778		

Significant *at 10%, ** at 5% and *** at 1% probability level

Table 7. Maximum Likelihood estimate of Multinomial Logit for physical SWC adoption

The age of the household head in years was negatively significantly affecting SWC adoption. This is consistent with Bekele and Holden (1998) but in contrast with Yohannes (1992) and Aklilu (2006). Younger farmers might have longer planning horizon and, hence, might be more likely to invest in conservation. Household head Education represented the level of formal schooling attended by the household headed. Educated farmers are more likely and significantly affecting to use physical SWC than non-educated farmers which is consistent with (Bekele and Holden, 1998; Chilot, 2007). Secondary education was significant in affecting the farmers' ability to get and use of information. Therefore, secondary education should have to be expanded to increase the adoption of improved physical SWC practices.

Farm size is often correlated with farm income and wealth, which probably ease the liquidity constraint to invest to increase land quality. In addition, conservation structures compete for area of cultivation on small plots and the benefit from conservation on such plots would not be enough to compensate for the decline in production due to the loss of farm land devoted to conservation structures. Therefore, those farmers with larger farm size have more cash to hire labor to undertake conservation investment for stone bund which is consistent with (Bekele and Holden, 1998; Mulugeta, 1999; Tesfaye, 2003; Wagayehu, 2003; Million and Belay, 2004; Paulos *et al.,* 2004; Aklilu, 2006 and Chilot, 2007). The slope of plot was correlated positively for soil and stone bund which is consistent with other empirical studies in different parts of Ethiopia on the farmers' decision on conservation strategies of land management (Bekele and Holden, 1998; Tesfaye, 2003; Wagayehu and Drake, 2003; Paulos *et al*., 2004; Senait, 2005; Aklilu, 2006 and Chilot, 2007). Distance of plots from farmers' home was measured in walking minutes required to reach to the plot on foot. Distance had negative and significant relationship with the use of physical SWC which is consistent with (Bekele and Holden 1998; Senait, 2005 and Chilot, 2007). Farmers whose plots were near to their home use soil and water conservation measures because time and energy required was relatively lesser than remote plots. Fertility condition of cultivated plots is an important determinant of farmers' investment in conservation practices. The study depicted a negative effect of high fertility on stone bund adoption decision (Aklilu, 2006) but in contrast with Wagayehu and Drake (2003). Farmers who already have perceived the severity of soil erosion hazards were more likely to use SWC activities on their farm plots than those who have not perceived the problem. Farmer's awareness on erosion hazard and perception of the severity of soil degradation problem had positive influence on the adoption of soil and water conservation practices (Bekele and Holden, 1998; Tesfaye, 2003; Million and Belay, 2004; Paulos *et al*., 2004; Tenge *et al.,* 2004 and Chilot, 2007).

Extension contact refers to whether a farm household has contact with development agents or not during the survey year to get agricultural extension services concerning physical SWC practices. The study showed a positive and significant relationship between extension contact and stone bund adoption The farm households with access to extension services and information might have better understanding of the land degradation problem and soil conservation practices and hence might perceive profitability of SWC practices (Bekele and Holden, 1998; Paulos *et al*, 2004; Senait, 2005; Chilot, 2007 Yitayal *et al*., 2007). Plot ownership type indicated the type of ownership of the farm plots operated by the respondents. It was measured in terms of household ownership type and took the value (1) for owned operated plot, (0) for shared plots. Senait (2005) and Chilot (2007) indicated that physical soil and water conservation practices require investments, but its benefits are gained in long and medium-terms, farmer could construct terrace/stone bunds, and soil bunds on owned fields than on hired or shared-in cropped lands. In this study ownership of the plot had a negative and significant relationship with soil and stone bund adoption decision. This might be related to the limitation of the land ownership in Ethiopia which is state ownership. Farmers could not have felt real ownership of the plot and hence could not construct SWC practices.

Distance from home to nearest all weather roads in walking minutes was also used as a proxy for the market access factors affect the relative profitability of investment in conservation practices. Distance from an all-weather road was used to proxy for differences in the opportunity cost of labour. The variable had a negative relationship but insignificant. Community pressure to invest on SWC practice was expected to encourage farmers toward investing in soil conservation. The variable had expected sign to increase with Improved SWC practices. The variable had positively and significantly influence for Improved SWC practices.

Availability of Food for Work (FFW) projects was expected to encourage farmers toward investing in soil conservation. Adoption had positively and significantly related with food for work availability for soil and stone bund adoption. Soil conservation by public campaign was expected to encourage farmers toward investing in soil conservation. Public soil conservation campaign beneficiaries were expected to invest more in private soil conservation. The variable had positively and significantly influence for improved stone bund. Production efficiency of the farm household is the production decision of the farm household either to be more efficient or less efficient. Technical efficiency (TE) Allocative Efficiency (AE) and Economic Efficiency (EE) of the farm household had the expected positive and significant effect on the adoption of SWC practices. This finding is consistent with the findings of Ghosh *et al.* (1994).

4. SUMMARY AND CONCLUSION

This study examined the farm level efficiency of mixed crop-livestock production and attests the production decision of the household on the adoption of improved soil and water conservation technologies mainly soil bund and stone bund in two districts of North east Ethiopia. There has been a growing concern by researchers, extension personnel and policy makers about the effectiveness of adoption of improved agricultural technologies particularly on the area allocated of these technologies and farmers learning process to alleviate the food shortage problem in the country. Therefore, this study was initiated to identify factors that affect the probability of farmers' decision to use improved SWC technologies by incorporating the farmers production decision as a factor that influence adoption decision. There are several studies on farmers' adoption of improved agricultural technologies using static and dynamic models in developing country including Ethiopia but there are no similar studies made in the study area. This study employed cross-section data to analyse the effect of farmers production decision socioeconomic and institutional setting and physical attributes on the likelihood of improved SWC technologies. Multinomial logit model was employed to study farmers' decision to adopt improved technologies. To better understand farmers' adoption decision, we incorporated the production decision of the household which is the technical, allocative and economic efficiency of the household as a factor that influence SWC adoption decision.

Dessie Zuria and Kutaber districts were selected to represent medium and high agro-ecological environment in south Wollo. Then 252 farmers were selected using simple random sampling technique and distributed proportionately over the six peasant associations. The study was made at 803 farm plot level. Data collection was accomplished in a frequent visit using structured questionnaire to obtain information for the specified period on the farmers' adoption. Comparison of adopters and non-adopters of improved SWC technologies farmers revealed that adopters are slightly young, educated and slightly resource endowed (land and livestock) than non-adopters. The production efficiencies calculated from non-parametric method were used as factors affecting SWC technology adoption decision. The results of the study provided empirical evidence of the positive impact of secondary education in enhancing the adoption of improved SWC technologies to increase production. The result showed that adopters of improved SWC had better production efficiency as compared to non-adopters.

The study found access and availability of extension service to be more powerful than other factors in explaining adoption of improved SWC technologies. The age of the farmer was significant on probability of adoption of SWC technologies. Younger farmers adopted more improved agricultural technologies than older farmers suggesting attention for young farmers to enhance production and productivity. Farm plot slope, severity, fertility and size were critical in the adoption of improved SWC technologies. Farmers with less fertile farm land could increase their production by using improved SWC technologies. Moreover, farmers with more severe farm land areas would like to adopt improved SWC practices. Farmers with large farm plot had a positive and significant influence on the adoption of improved SWC practices mainly stone bund which had long run effect on the sustainable land resource management.

Physical characteristics like distance from farmers' home to markets, roads, and plot played a critical role in the adoption of improved SWC technologies as proximity to information, sources of input supply and credit and markets save time and reduce transportation costs. Given the critical role of proximity to such centers and better roads for promoting adoption and productivity gains, the effort of investment in improved roads infrastructure should be continued to achieve increased production. Production decision of farm household either to be more efficient or less efficient was also significant for likelihood of adoption of improved SWC technologies. The scaling up strategy of best performing farmers in the extension service in particular and government in general should be expanded to alleviate the production and food shortage problem in the country. Results of the analyses suggest that there is more research focus on improved technology adoption decision and production decision of the farm household in Ethiopia.

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