Ethiop. J. Agric. Sci. 33(2) 9-29 (2023)

Determinants of Farmers' Perception on the Role of Sustainable Land Management Practices: Empirical Evidence from Southern Ethiopia

Genene Tsegaye Mekonnen[1*], Mengistu Ketema[2], Endrias Geta[3] and Moti Jaleta[4]
[1] *Haramaya University, P.O. Box 138, Dire Dawa, Ethiopia.*
[2]*Ethiopian Economics Association, P.O. Box 34282, Ethiopia,* [3]*Ministry of Irrigation and Lowland, Addis Ababa, Ethiopia;* [4]*International Maize and Wheat Improvement Center (CIMMYT), P.O. Box, 5689, Addis Ababa, Ethiopia; Corresponding author e-mail: genenetseg@gmail.com*

Abstract

The heavy dependence of farming communities on agriculture has exposed land resources to continuous depletion and ruin. In the face of land degradation, identifying the perception level and its driving forces are important for development interventions. With this context, this study examined the socioeconomic, institutional, biophysical, and policy factors that influenced farmers' perceptions of sustainable land management practices. Data were collected from 475 households drawn randomly from 6 districts from Sidama, Wolaita, and Siltie zones using a household survey. Qualitative data were also collected using focus group discussions and key informant interviews. Descriptive statistics and ordered probit model were used for data analysis. Results revealed that education, cultivated land, institutional factors (training and land market), and biophysical attributes (plot distance, topsoil erosion, erosion severity, slope status, and soil quality) strongly influenced farmers' perception of sustainable land management practices. The policy attributes, i.e., land certificate, community bylaws, incentives; and agroecological location also influenced farmers' perceptions. The study implies that development programs and policy initiatives should not only depend on implementing physical structures; but also, should equally consider farmers' perceptions within the context of their endowed socioeconomic, institutional, biophysical, and policy factors.

Keywords: Perception; determinant, land management; ordered probit model; southern Ethiopia

Introduction

The livelihood of most people in Ethiopia exclusively depends on agriculture. Ethiopia's agriculture is characterized as rain-fed, underdeveloped, fragmented, and subsistence resulting in low agricultural productivity (Kassie *et al*. 2010; Paul and wa Gĩthĩnji, 2018). Despite its socio-economic importance, the agricultural sector's share of overall economic development is decreasing (Degu, 2019). Declined land productivity, undeveloped market, low access to irrigation, farmland degradation, and climate change are prime challenges and serious threats facing agriculture (Assefa and Hans-Rudolf, 2016; Deressa and Hassan, 2009; Schmidt and Tadesse, 2019; Wendimu, 2021; Yalew *et al*. 2018).

Introducing exotic land management practices in Ethiopia's mid and highland areas since the late 1970s and early 1980s was a significant step towards mitigating land degradation and conserving land resources. In southern Ethiopia, apart from the introduced land management practices, different indigenous practices have been implemented by farmers (Ali and Surur, 2012). Furthermore, since 2008, the Ethiopian government in collaboration with global partners has implemented sustainable land management (SLM) practices. The SLM program was designed and implemented to decrease erosion and increase agricultural yields (Schwilch *et al*. 2011). Nationally, from 2008 to 2012, SLM Project I was implemented in 45 districts, while since 2013, SLMP-II was implemented in 135 districts and 937 rural *kebels*[1] aimed to achieve developmental and environmental objectives (MoA, 2014).

Despite these efforts, SWC measures have not been sustainable in halting land degradation. Land degradation, particularly soil erosion persists and becomes a major threat to the ecosystem and a cause of low productivity and food insecurity (Abera *et al*. 2020; Hörner and Wollni, 2021; Nigussie *et al*. 2017; Teklewold *et al*. 2013). In Ethiopia, over 85% of the land is degraded and a satellite imagery estimate of land degradation hotspots over the last three decades covered more than 23% terrestrial areas (Kirui and Mirzabaev, 2015; Samuel *et al*. 2016). Dagnew *et al*. (2015) reported that soil erosion affects half of the agricultural land and results in an annual soil loss of 1.5-2.0 billion tons which is equivalent to 35-42 tons ha^{-1} $year^{-1}$ and a monetary value of 1-2 billion USD. Over the period 2001-2009, Ethiopia incurred 23% cost (equivalent to US$ 35 billion) of its annual GDP due to land degradation which was a higher loss in the Eastern Africa region (Kirui and Mirzabaev, 2015). The losses caused by land degradation and soil erosion underline to pay proper attention to SLM practices from all perspectives including behavioural attitudes and perceptions of farmers.

.

Understanding the various socioeconomic, institutional, and biophysical factors influencing farmers' perception of soil erosion and their response to invest in SLM practices is crucial for effective land conservation efforts (Adimassu *et al*. 2012; Bekele and Schneider, 2016). Moreover, SLM practice has a dual benefit of maintaining the productivity of land resources to the current population (direct use value) and preserving it for future generations (bequest value). From sociocultural and socio-economic perspectives, farmers have different perception levels, attitudes, and beliefs in using and adopting SLM practices.

[1] *Kebele is the local name for the lowest administration level in Ethiopia.*

Farmers' perception and attitudinal differences arise from ignoring socioeconomic, institutional and biophysical situations in planning and implementation and less willingness in the SLM interventions. Theoretically, perceptions stem from different sources of knowledge, learning, experience and thoughts. It is a basic psychological process by which individuals receive and process information (Gifford, 2014). Perceptions vary and influenced by a personal interest, locations, cultural values, socioeconomic conditions, and institutional and biophysical situations of people (Bennett, 2016; Rodríguez-Rodríguez *et al.* 2021), hence the same applies to farmers' attitudes and perceptions toward SLM practices'.

With these contexts, there are insufficient reports on farmers' perceptions of SLM practices in southern Ethiopia. For example, Assefa and Hans-Rudolf (2016) focused on the causes of soil erosion, fertility decline, and their adaptation behavior. Most of empirical research conducted in northern Ethiopia focused on farmers' perception of land degradation, soil erosion, and severity (Adimassu *et al*. 2013; Nigussie *et al*. 2017) and determinants of farmers' perception of land degradation (Tesfahunegn, 2019), but none of them consider factors that influence farmers' perception on SLM practices as a remedy to land degradation. Therefore, this research was initiated to fill the research gaps by answering the pertinent research questions, i.e., what the perception situation of farmers looks like and the deterministic factors influencing the perception level of SLM. Owing to this, the objective of this study was to quantify the perception level and identify the underlying factors that affect farmers' perceptions of the role of SLM practices in combating land degradation and reducing soil erosion at a household level.

Material and Methods

The study areas

This research was conducted in selected zones of the then-Southern Nations, Nationalities and Peoples' Region (SNNPR). Including Sidama region, it covers a total area of 110931.9 km^2 which share ten percent of the country's total area. The central zones include Sidama region, Wolaita, Hadiya, Kembata-Tembaro, Halaba, Gedio, Siltie, and Gurage zones. They are characterized by high population pressure, 196 persons per square kilometer; low per capita landholding (i.e.,, 0.294 ha in Sidama and 0.51 ha in SNNP regions) (ESS, 2022).

Agro ecologically, the central zones are categorized in to high and mid land. The study zones are making intensive efforts to implement SLM practices. Such proactive initiatives are crucial for addressing land degradation, promoting environmental sustainability and enhancing agricultural productivity. The farming system of the areas is characterized by mixed farming, mainly dominated by crop productions including cereals, root, fruit and pulse crops, vegetables and spices (ginger only grown in Boloso Bombe).

.

Sampling procedure

The study employed non-randomized purposive sampling to identify zones, each having two or more districts implementing SLM practices on at least one-quarter of owned farmland for five consecutive years (2013-2018). The SLM intervention and non-intervention districts are found in the same highly populated zone; both characterized by land degradation and severe soil erosion. The difference between the two groups is that the SLM districts are supported by the government in implementing SWC and accessing resources (inputs), and training while the non-intervened ones accessed this opportunity through the usual extension services.

Study zones were framed based on population density, number of SLM implementing districts, and intensity of interventions. Thus, three highly densely populated zones with the lowest land holding ratio ESS (2022) having two or more districts included in the SLM project, and those with high effort of land management practices were selected purposively. Based on the criteria, Sidama region, Wolaita, and Siltie zones (Figure 1) were identified purposively. Once zones were identified, stratified random sampling was employed to identify sample units.

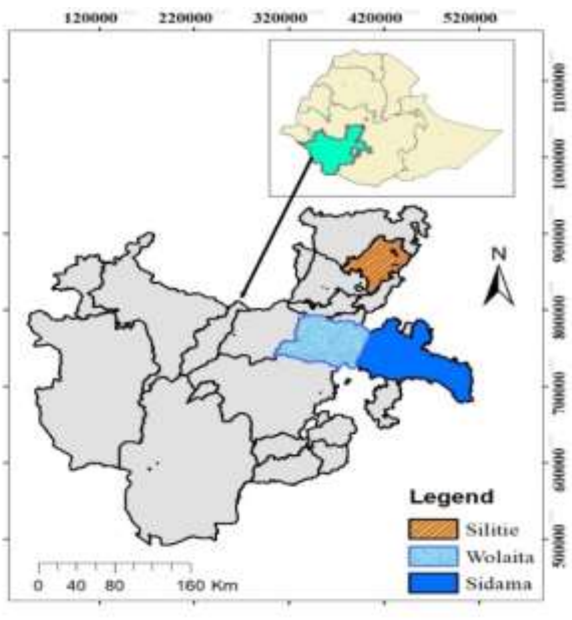

Figure 1. Geographical map of the study areas

The stratification was based on land management intervention, mainly on-farm SWC measures implemented for continuous five years (2013 to 2018). After the stratification of districts, a two-stage sampling technique was employed to select the sample units. In the first stage, one district was included under the SLM project and one from non-SLM, and a total of 6 districts were drawn randomly. During the survey, Sidama had 30 districts (3 SLM and 27 Non-SLM), Wolaita had 16 (3 SLM and 13 non-SLM) and Siltie zone had 10 (2 SLM and 8 non-SLM) districts. The six districts selected were Arbegona and Malega (Sidama region), Boloso Bombe and Boloso Sore (Wolaita zone), and Hulebareg and Dalocha (Siltie zone).

In the second stage, two *kebles* from each district and a total of 12 *kebeles* were selected randomly. A total of 165,343 (i.e., 86,120 from SLM and 79,223 non-SLM districts) population size was considered to decide the sample size using Kothari's (2004) sample size determination formula. As a result, a sample size of 432 was taken based on probability proportional to size (PPS) using a simple random sampling technique. Additionally, 10% of the total sample households (i.e., 43 households) were included in the survey. Finally, a total of 475 households (365 users and 110 non-users) were considered for the survey.

Data type and collection procedure

Cross-sectional data from sample households and plots were collected using a household survey from October to December 2020. The data comprised a mix of socioeconomic, institutional, and biophysical characteristics hypothesized to affect farmers' perception of SLM practices. To substantiate and complement the information collected, qualitative data was also collected using focus group discussions (FGDs) and key informant interviews (KIIs). Moreover, secondary data from published and unpublished sources were collected.

Data analysis strategies

Descriptive statistics

In using descriptive statistics, qualitative and quantitative data are organized, summarized, and presented in a tabular form. Frequency distribution, graphic representation, a measure of central tendency, and dispersion were employed to summarize and present the data.

Ordered probit model

Based on the economics literature, and the research question of the study, an ordered probit model was specified, tested and used for the data analysis. When farmers' perception of SLM role is independent, the multinomial probit or logit model fails to account for the analysis, rather the ordered choice models are applied to estimate the ordinal outcomes jointly on an individual specific basis (Wooldridge, 2010; Greene, 2012). The main assumptions drawn in such cases are (1) the dependent variable is measured on an ordinal scale (2) one or more of the independent variables are continuous, categorical or ordinal (3) no multi-collinearity (4) proportional odds, and (5) the βs are the same for each choice.

The ordered probit and logit models are utilized for the analysis of ordered multi-response outcome variables (Greene, 2012). Both approaches are equivalent, except the ordered probit follows the standard normal cumulative density function (CDF) while the ordered logit follows the logistic CDF. The error term in ordered probit and logit is distributed normally and logistically across observations, respectively. Moreover, the errors ε_i are independently distributed in the ordered probit model. Therefore, we used ordered probit model to analyze farmers' perception of SLM practices.

Following Greene (2012), the ordered probit model built around a latent regression is given as:

$$y_i^* = x_i\beta + \varepsilon_i, \quad \varepsilon_i|xi \sim N(0,1), \; i= 1, 2, 3,\ldots,n \quad (1)$$

where, y* is the unobserved latent variable ranging from -∞ to ∞, x represents the set of explanatory variables and does not contain a constant, β is the parameter estimates, ε is a random error term follows a CDF and i is the observations.

Let μ_1, μ_2 and μ_3 be unknown parameters (cut points) estimated jointly with β, when y_i taking the values 1, 2 and 3 with three categories, the link between the observed ordinal outcome y_i and the unobserved y_i* is related with equation as:

$$y_i = \begin{cases} 1 \text{ if} -\infty \leq y^* \leq \mu_1 \\ 2 \text{ if } \mu_1 \leq y^* \leq \mu_2 \\ 3 \text{ if } \mu_2 \leq y^* \leq \mu_3 \end{cases} \quad (2)$$

Given the standard normal assumption that the error term, ε is normally distributed across the observations, and with the means and variance equal to zero and one, and following Wooldridge (2010) and Greene (2018), the conditional distribution of y_i given x_i, and the probability of each response for farmers' perception of SLM is given as:

$$Pr\,(y = 0|x) = Pr(y^* \leq \mu_1|x) = Pr(x\beta + \varepsilon \leq \mu_1) = \Phi(\mu_1 - x\beta) = 1 - \Phi(x\beta) \quad (3)$$

$$Pr(y = 1|x) = Pr(\mu_1 < y^* \leq \mu_2) = P(\mu_1 < x\beta + \varepsilon \leq \mu_2) = \Phi(\mu_2 - x\beta) - \Phi(\mu_1 - x\beta)$$
$$= \Phi(\mu - x\beta) - \Phi(-x\beta)$$

$$Pr\,(y = 2|x) = Pr(\mu_2 < y^* \leq \mu_3) = P(\mu_2 < x\beta + \varepsilon \leq \mu_3) = \Phi(\mu_3 - x\beta) - \Phi(\mu_2 - x\beta)$$
$$= 1 - \Phi(\mu - x\beta)$$

where, Φ (.) denotes the ordered normal cumulative distribution function.

The marginal effect is computed to report the partial effects of a small change in explanatory variables, on the predicted probabilities of the ordered response variables (Greene, 2012) .

Proceeding equation 3, the marginal effects of the regressors are derived as:

$$\frac{\partial\, Prob\,(y=0|x)}{\partial x} = -\Phi(x\beta)\beta$$
$$\frac{\partial\, Prob\,(y=1|x)}{\partial x} = [\Phi(-x\beta) - \Phi(\mu - x\beta)]\beta \qquad (4)$$
$$\frac{\partial\, Prob\,(y=2|x)}{\partial x} = \Phi(\mu - x\beta)\beta$$

The βs is jointly estimated with cut points, μ1, μ2 . . . μm-1, m is possible outcomes estimated by ordered probit model using the maximum log-likelihood procedure using Stata[2].
Following Wooldridge (2010), the log-likelihood function was specified as:

$$L_i(\mu,\beta) = 1(y_i = 0)Log[\Phi(\mu_1 - x_i\beta)] + 1(y_i = 1)Log[\Phi(\mu_2 - x_i\beta) - \Phi(\mu_1 - x_i\beta)] + 1(y_i = 2)Log[\Phi(\mu_3 - x_i\beta) - \Phi(\mu_2 - x_i\beta)] \qquad (5)$$

Description of variables and working hypothesis

The dependent variable is a trivalent response of farmers' perception of SLM role (l= low, 2 = medium, and 3 = high perception) computed as index in a three Likert scale as an ordinal variable. Likert-type data falls into an ordinal measurement scale of which frequency distribution show variability and the chi-square ($\chi 2$) measure the association (Boone and Boone, 2012). Level soil bunds, bench terrace, fanyajju, and integrated SWCs are the commonly applied on-farm SWC measures in the study areas. How farmers perceive the role of SLM practices to combat land degradation and reduce soil erosion was asked during the survey. Even though the survey result indicated level soil bunds, fanyajju, bench terraces and integrated SWCs are commonly applied SLM practices, initially farmers were asked to respond their perception about the role of SLM, specifically, SWC measures as one general statement. The choices were not considered as different independent responses to categorize farmers' perception levels during the survey.

The explanatory variables hypothesized are household socioeconomic, institutional, biophysical and policy attributes. The socioeconomic characteristics include farming experience, gender, active labor force, education, livestock holdings, farm revenue, off-farm income, and cultivated land size. The institutional variables include training, extension service, and land rental market.

[2] *Stata 17.0 basic edition (BE) statistical package with license serial number: 301709001668 was utilized for data analysis*

The biophysical plot attributes are topsoil erosion occurrence, perceived slope, soil fertility status, soil erosion severity (minor, moderate, and severe) and land quality (minor, moderate and high) and location of the parcel (lower and upper stream). The policy variables include land certificate, community bylaws, access to incentives, and tenure arrangement. Moreover, the study locations, that is, Sidama, Wolaita and Siltie were considered as dummy variables (Table 1).

Table 1. Explanatory variable description and predicted hypothesis

Variable name	Measurement	Description	Ho sign
Dependent			
Perception level	Ordinal categorical	Farmers' perception level (1= low, 2 = moderate and 3 = high)	
Independent			
Farming experience	Number of years	Farming experience of household heads	+
Gender	1= male, 0 = female	Sex of household head	±
Active labor force	Count	No. of active family members (15-64 years) living with household	+
Education level	Years of formal education	Attained formal education level by household heads (continuous)	+
Livestock holding	Tropical livestock units (TLUs)	Total livestock holding of the household in TLU	+
Farm revenue	Ethiopian Birr (ETB)	Value of crop at harvest and income from livestock sale	+
Non-farm income	Ethiopian Birr (ETB	Income obtained from non-farm and off-farm activities	-
Cultivated land size	Hectare (ha)	Cultivated land size in ha	±
Training	Dummy (1 = yes, 0 = no)	Training on land management taken by household heads	+
Extension service	1= yes, 0 = otherwise	Extension service accessibility by households	+
Land rental market	Dummy (1=yes, 0 = no)	Farmers' involvement in land renal market (rent/share)	-
Plot distance	Kilometers (km)	Average plot distance from households resident	-
Slope status of plot	Gentle, moderate, steep (yes/no)	Perceived slope gradient status of plots (dummy)	±
Soil fertility status	Poor, moderate, fertile (yes/no)	Perceived soil fertility status	±
Soil erosion	Dummy (1 = yes, 0 = no)	Perceived topsoil erosion presence	+
Soil erosion severity	Minor, moderate, severe (yes/no)	Perceived soil erosion severity status	±
Soil quality status	Poor, moderate, good (yes/no)	Perceived soil quality status	±
Farm plot location	1 = upper, 0 = lower stream	Location of the farmland in the study areas/watershed	±
Land certificate	Dummy (1 yes, 0 = no)	Whether farmers received land certificate or not	+
Community bylaws	Dummy (1= yes, 0= no)	The presence of enforced community bylaws	+
Incentive	Dummy (1=yes, 0= no)	The availability of incentive to implement SLM practices	+
Tenure arrangement	1=owned, 0=family	Landownership status of household heads	+
Sidama	Dummy (1=yes, 0 = no)	Location of the specified study zone	+
Wolaita	Dummy (1= yes, 0 = no)	Location of the specified study zone	+
Siltie	Dummy (1= yes, 0 = no)	Location of the specified study zone	+

Note: Hypothesis is made for discrete change from 0 to 1 for dummy variables

Results and Discussion

Descriptive results

Descriptive statistics is done to quantify the perception level and summarize the variables. The descriptive result indicates that approximately 61% of farm households perceived the role of SLM as high, 23.6% perceive it as medium and 15.4% as low (Table 2).

Table 2. Perception level of households on the role of SLM

Location	Farmers perception level to SLM role			Total	χ^2-value
	Low	Medium	High		
Sidama	27 (5.68)	43 (9.05)	116 (24.42)	186 (39.16)	0.258
Wolaita	29 (6.11)	43 (9.05)	86 (18.11)	158 (33.26)	4.402 *
Siltie	17 (3.58)	26 (5.48)	88 (18.52)	131 (27.58)	2.852
Total	73 (15.37)	112 (23.58)	290 (61.05)	475 (100)	

* $p < 0.1$

The descriptive result indicates that the mean farm revenue from crop produced and livestock sale was ETB 35210 per annum. The mean livestock holding was found to be 4.4 TLU ranged from 0.32 to 23.8. The average cultivated land holding was found to be 1.1 ha ranging from 0.31 to 5.0 ha. It is expected that farmers with higher capital assets could easily afford to implement land management practices on their farm plots.

Well-established and functional institutions matter the efficiency and degree of implementing development initiatives. Institution influences individual thoughts, learning and behavior that allow or do not allow to think and to do so (Dequech, 2009). Delivery of training and extension advice affects the perception level by building up the awareness of what, how, where, and when to implement land management practices. On the other hand, farmers participating in the land rental market are expected to have low perception level to implement SLM practices.

The bio-physical attributes include distance of farm plots, location, slope gradient, soil fertility status, land quality, and topsoil erosion and its severity. Households owning moderate to steep slope farmland are expected to have a higher perception level because they are aware of how hilly and mountainous land is susceptible to soil erosion. A household that owns infertile farmland, low quality, and highly eroded farm plots located in the lower stream of watershed was expected to have a high perception.

Farmers' behavior in perceiving and adopting land management practices is affected by policy issues. In Ethiopia, land certification is a policy reform that minimizes the fear of tenure insecurity and improves land-use practices (Mengesha *et al*. 2019). About 92% of the households received land certification books that contributed positively to perceive the role of SLM practice. Furthermore, a well-functioned community bylaw influences the perception level of farm households. Incentive and tenure arrangements are also expected to influence perception level differently. Moreover, the perception level across the study zones was found to be different that implies scope of land management practices are location specific.

Table 3. Summary of descriptive statistics of variables

Variable	Mean	Std. Dev	Min	Max
Farming experience	24.37	9.52	6	50
Gender	0.95	0.22	0	1
Active labour force	3.73	1.90	1	12
Education level	4.20	3.78	0	15
Livestock holding	4.37	2.81	0.32	23.86
Farm revenue (in 1000 ETB)	35.21	26.34	3.27	370.83
Non-farm income (in 1000 ETB)	8.10	5.75	1.00	33.50
Cultivated land size	1.10	0.59	0.31	5.0
Training	0.77	0.42	0	1
Extension service	0.94	0.24	0	1
Land rental market	0.53	0.50	0	1
Plot distance	0.49	0.45	0.02	3.05
Gentle slope status	0.38	0.49	0	1
Moderate slope status	0.50	0.50	0	1
Steeply slope status	0.12	0.33	0	1
Low soil fertility	0.13	0.34	0	1
Moderate soil fertility	0.74	0.44	0	1
High soil fertility	0.13	0.34	0	1
Soil erosion	0.78	0.41	0	1
Minor soil erosion severity	0.45	0.50	0	1
Moderate soil erosion severity	0.46	0.50	0	1
Severe soil erosion severity	0.09	0.29	0	1
Poor soil quality	0.09	0.28	0	1
Moderate soil quality	0.71	0.45	0	1
Good soil quality	0.20	0.40	0	1
Farm plot location	0.64	0.48	0	1
Land certificate	0.92	0.27	0	1
Community bylaws	0.47	0.50	0	1
Incentive	0.81	0.40	0	1
Tenure arrangement	0.86	0.35	0	1
Sidama	0.39	0.49	0	1
Wolaita	0.33	0.47	0	1
Siltie	0.28	0.45	0	1

Source: Authors' computation, 2022.

The likelihood of framers to perceive the role of land management practices as lowest, medium, and highest perception levels was 15.2%, 23.6%, and 61.1%, respectively (Table 4). The mean predicted probability of majority of farmers to perceive land management practice role is the highest (i.e., 61.1%) implying that farmers in the study areas are willing to participate and implement SLM practices to combat land degradation in the long run and soil erosion in the short run expecting use and non-use value of the land resources.

Table 4. Predicted probability of perception level of SLM (N=475)

Predicted probability level	Mean	Std.dev	Min.	Max.
Lowest perception	0.152	0.166	0.001	0.799
Moderate perception	0.236	0.103	0.008	0.367
Highest perception	0.611	0.243	0.036	0.991

Ordered probit model results

Before rushing into the estimation of the econometric model, different tests were performed. First, the exact perfect linear correlations between the independent variables were tested using the variance inflator factors and found that there is no linear relationship. Second, the Kernel density estimation for the discrete variable was assessed and show normality and moderately smooth as the density approaches the normal curve (Figure 2).

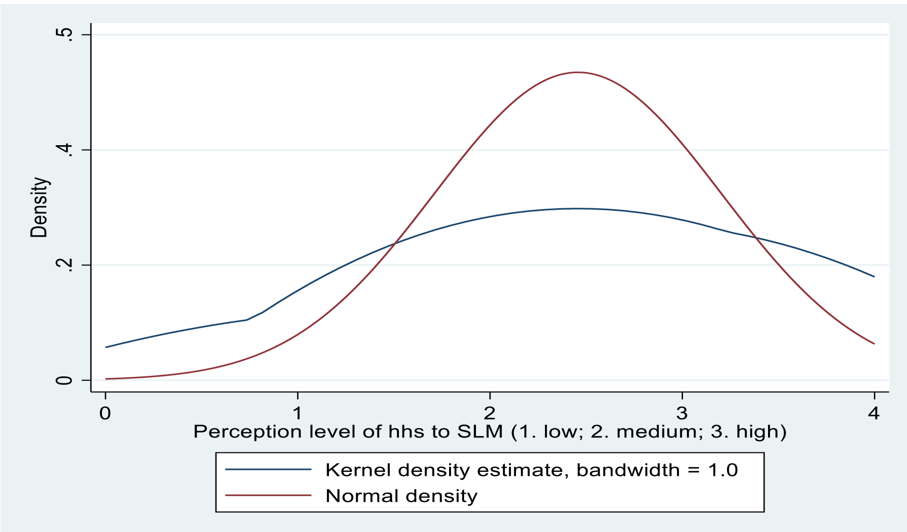

Figure 2. Kernel density estimate of perception level of SLM

Third, Hausman specification test was carried out to detect an endogeneity problem of regressors and the error term. The test showed that the asymptotic distribution under the null hypothesis is accepted or the estimator is efficient and consistent. Fourth, the model fitness was also tested with the Likelihood-ratio (LR- $\chi 2$) and Wald test. The LR test statistic (i.e., LR chi2 (12) = 13.19; Prob > chi2 = 0.355) is found to be insignificant (Table 5). Moreover, the LR test, Akaike and Bayesian information criterion (AIC and BIC) are used for the comparison of restricted and unrestricted ordered probit models (Greene and Hensher, 2010). The observed insignificant LR test, and smaller AIC and BIC revealed that the inclusion of all hypothesized independent variables in the ordered probit model resulted in a better goodness of fit (Table 6) than the constrained model (Table 5 and 1A). Therefore, the post-estimation test concluded that the ordered probit model is a consistent and efficient to estimate the parameters with no heteroscedasticity.

Table 5. Likelihood ratio test

Model	N	ll (null)	ll (model)	Df	AIC	BIC
OprobitRst	475	-441.63	-370.97	18	777.895	852.89
oprobitUnrst	475	-441.63	-364.38	30	788.76	913.66

Assumption: The restricted model is nested within unrestricted ordered probit model
LR Chi (12) = 13.19; Prob > chi2 = 0.355 (35.5%)

Determinants of farmers' perception

The maximum likelihood estimation output of the ordered probit model revealed that education level, cultivated land size, training, plot distance, slope (moderate and steep), moderate soil fertility, topsoil erosion, moderate soil erosion severity, land certificate, community bylaws, and incentive found to influence household perception of SLM role positively and significantly. In contrast, land market, soil quality (low and moderate) and the dummy Wolaita affect farmers' perception statistically negatively (Table 6).

Education plays a crucial role in shaping individuals' perception levels. Individuals who have received a higher level of education are more likely to have a positive perception of SLM. Marginal effect analysis confirms this association, indicating that a one-year increase in formal education level raises the probability of having a high perception level by 1.3% but reduces the probability of having low and medium perception by 0.6% and 0.7%, respectively (Table 6). This finding agrees with Ewunetu *et al*. (2021) who reported that education has a positive effect on farmers' decisions and perception to implement SLM technologies in upper Blue Nile of Ethiopia. By contrast, where the formal education curriculum is not well suited to deliver programs in mitigating land degradation, it will have a negative association that educated farmers are less likely to perceive SLM (Nigussie *et al*. 2017). In conclusion, this study underlines that proper attention should be given to raise educational status of farmers that ultimately raise their perception how, why, and where to implement land management practices.

Cultivated land size is found to affect the perception level positively and significantly. The result revealed that an increase in cultivated land size by one hectare raises the probability of having a high perception level by 10.8% and the likely probability of farmers having low and moderate perception levels decreases by 4.9% and 5.9%, respectively. A plausible justification, as cultivated farmland increases, farmers are interested in allocating part of it to implement on-farm SWC measures to maximize the use value of SLM interventions. At the same time, it minimizes the adverse effects of soil erosion on farmlands. A similar study testified that farmers with large farm holdings perceive more benefits from land management practices (Gamo *et al*. 2021).

Training is an institutional factor that enables farmers to perceive and acquire knowledge and skills to apply SLM practices. The marginal effect analysis verified that farmers who have training opportunities are likely to have a 10.7% higher perception level of SLM. This finding is consistent with Miheretu and Yimer (2017) and Ewunetu *et al*. (2021) who reported that training increases farmers' awareness in implementing SLM practices. Thus, this study verified that training targeting smallholder farmers to increase their awareness and perception of SLM practices is a key institutional factor that should be considered during interventions.

Plot distance affects the perception of farm households differently. As the farm plot distance gets close to farmers’ residents, the perception tends to be low and medium by 5.1% and 6.1%, respectively, while as it gets farther it becomes the highest (i.e., 11.2%). The argument for this association is that farm plots located at the nearest distance are usually utilized for homestead garden activities that demand less land management practices, however, as it gets far labor-intensive work is required to maintain and sustain the productivity. The nobility of this finding is that plot distance vs. perception types varies among land management practices that guide development practitioners to identify land use types before designing and implementing.

Land market is the selling, mortgaging, renting, and transferring of land rights on a cash, lease, or contractual basis. However, in Ethiopia, except for the usufruct rights of access, control, and some alienation rights of rent out/in and bequeath, the other tenure systems are constitutionally prohibited. Land market imposed a negative effect that farmers who engaged in land market reduced the probability of having a high perception level by 8.5% ($p < 0.1$). The justification could be: those who have engaged in land rent in/out are less willing to implement on-farm SWC measures, rather, they prefer to switch to non-farm activities that can generate short-term benefits. This is supported by Worku and Mekonnen (2012) who reported that plots that are either mortgaged or rented receive lower intensity of land conservation than farmland cultivated by the land owner. This implies a need to refine the existing policy related to the land rental market and how to engage landholders in land-related management practices investment to maintain and conserve its potential for sustainable use.

Slope affects the perception level of farm households either positively or negatively. Farmers who owned moderate and steep slope farmland found to have a probability of having high perception level of SLM than those with flat or gentle slope (i.e., 12.2% and 19.1%, respectively). The possible explanation is that farmland located in steep or moderately slope areas is exposed to severe soil erosion, fertility depletion, and high runoff caused by heavy rainfall. This result is in line with Abera *et al*. (2020), Bekele and Schneider (2016) and Nigussie *et al*. (2017) who found that farmers who own steep slope farmland are more likely to perceive SLM as a remedy to soil erosion. The implication is that unless responsive strategy and agricultural policy are designed and implemented to increase farmers' perception to invest in land management practices on steep and moderately slope farmland, it is hardly possible to maintain and restore land productivity.

Soil erosion and its severity are a biophysical attribute that influenced farmers' perception of SLM role. The marginal analysis verified that farmers whose farmland is susceptible to topsoil erosion and with moderate severity are likely to have a higher perception of SLM role by 28.5% at $p < 0.01$ and 13.1% ($p < 0.01$), respectively than farmers with less environmental threat. The possible reasons are: farmers whose farmland is exposed to moderate to severe erosion are aware of the negative effects imposed on land productivity, and vice versa. Similar findings were reported that farmers who noticed and perceived the existence of severe soil erosion on their farmlands are cautious in investing in SLM practices (Adimassu *et al*. 2013;Assefa and Hans-Rudolf, 2016; Miheretu and Yimer, 2017). The implication is that farmers should be alarmed and well aware of soil erosion problems and its severity to raise their perception.

Farmers' perceptions of land quality and fertility level influence SLM investments (Teshome *et al*. 2016). The result verified that farmers who owned farmland with low and moderate soil quality, decreased the probability of having high perception by 33.1% ($p < 0.01$) and 23.6% ($p < 0.01$), respectively, as compared to farmers with high quality farmland. Moreover, farmers who owned farmland with moderate soil fertility was found to have high perception level (i.e., 13.2%) as compare to farmers with infertile land. The possible justification is farmers who own farmland with high soil quality and fertility levels are highly aware of maintaining its attribute. In line with this, Assefa and Hans-Rudolf (2016) reported that long experiences of farmers about farmland quality raise their perception of land management practices to mitigate land degradation.

Community bylaws were found to increase probability of having high perception by 12.2% ($p < 0.01$) and in its absence, it reduced to low and moderate by 5.6%

and 6.7% ($P < 0.05$), respectively. Community bylaws enable households to be aware and internalize the benefit of land management practices in conserving farmland. It governs and facilitates communities by developing a sense of ownership in conserving land resources to offer economic benefits to the current and future generations (Cardenas *et al*. 2011). Limited involvement of local communities in formulating and weak responsibility of organizations to enforce bylaws (East Africa); ignoring indigenous laws and customs in collective management of natural resources (Ethiopia), and top-down community-based initiative (Tanzania and Uganda) led to low perception of land management practice in curbing natural resource abuse (Mowo *et al*. 2016).

Incentives and land certificate are policy tools that stimulate developmental works. Farmers who access incentives were found to have a high perception level (i.e., 16.8%, $p < 0.05$), while with its absence; it reduced to low and moderate by 8.8% and 8%, respectively. This observation is supported by Hartman and Cleveland (2018) that reported incentive stimulates long-term investment in SLM practices in the Bolivian Andes. Furthermore, Getnet *et al*. (2014) reported that natural resource management with long payback periods need economic incentives to be perceived by farmers. Likewise, land certificate was found to increase farmers' perception to a higher level by 19.7% ($p < 0.05$) and conversely, farmers with no land certificate found to have low and moderate perception, i.e., 11.1% and 8.6%, respectively. The implication of this finding should be seen with caution that dependency syndrome attributes of incentives and land certificate role should be considered from its long-term contribution and tenure security.

With regard to the study location, the marginal effect revealed that farmers at Wolaita found to decrease their perception as it converges to a higher level by 15.9%. Conversely, it shows positive associations as the probability switches to low and medium levels. The possible justification could be the landholding ratio of Woliata found to be relatively small (i.e., 0.28 ha) as compared to Sidama region (0.29 ha), SNNPR (0.51 ha), and Ethiopia (0.92 ha) (ESS, 2022) that farmers seem pessimistic to apply exotic land management practices. Furthermore, the FGDs verified that in Wolaita (Boloso Bombe and Boloso Sore) farmers prefer indigenous land management practices, expecting short-term benefits rather than exotic SWC measures with long payback periods.

Table 6. Parameters estimation and marginal effects of the ordered probit (unrestricted model)

Variables	Coefficients (Robust SE)	Marginal effect for different perception levels		
		Low =1	Medium =2	High =3
Farming experience	-0.0003(0.007)	0.0001 (0.001)	0.0001 (0.001)	-0.0001 (0.003)
Gender	0.140 (0.252)	-0.026 (0.050)	-0.028 (0.048)	0.054 (0.098)
Active labour force	0.034 (0.039)	-0.006 (0.007)	-0.007 (0.008)	0.013 (0.015)
Education level	0.034 (0.019)*	-0.006(0.003)*	-0.007 (0.004)*	0.013 (0.007)*
Livestock holding	0.0001 (0.034)	-0.0001 (0.006)	-0.0001(0.007)	0.0001 (0.013)
Farm revenue (ln)	0.090 (0.118)	-0.015 (0.020)	-0.018 (0.024)	0.034 (0.044)
Nonfarm income (ln)	-0.011 (0.015)	0.002 (0.003)	0.002 (0.003)	-0.004 (0.006)
Cultivated land size	0.288 (0.154)*	-0.049 (0.027)*	-0.059 (0.032)*	0.108 (0.058)*
Training	0.278 (0.148)*	-0.052 (0.031)*	-0.054 (0.028)*	0.107 (0.058)*
Extension service	0.018 (0.242)	-0.003 (0.042)	-0.004 (0.049)	0.007 (0.091)
Land market	-0.227 (0.128)*	0.039 (0.022)*	0.046 (0.026)*	-0.085 (0.047)*
Plot distance	0.299 (0.170)*	-0.051 (0.029)*	-0.061 (0.036)*	0.112 (0.064)*
Slope_moderate	0.327 (.136)**	-0.056 (0.024)**	-0.066 (0.028)**	0.122(0.050)**
Slope status_steep	0.565 (0.225)**	-0.073 (.023)***	-0.118 (0.046)**	0.191 (0.066)***
Soil fertility_low	0.336 (0.262)	-0.049 (0.032)	-0.071 (0.056)	0.119 (0.087)
Fertility_moderate	0.345 (0.172)**	-0.066 (.036)*	-0.067 (0.032)**	0.132 (0.067)**
Topsoil erosion	0.737(0.149)***	-0.162 (.041)***	-0.123 (.023)***	0.285(0.056)***
Erosion_moderate	0.352 (0.131)***	-0.059 (0.023)**	-0.072 (.027)***	0.131 (0.048)***
Erosion_high	0.235 (0.228)	-0.035 (0.030)	-0.049 (0.049)	0.085 (0.079)
Soil quality_low	-0.856(0.288)***	0.217 (.097)**	0.114 (0.019)***	-0.331(0.105)***
Soil quality_moderate	-0.679 (0.165)***	0.097 (0.022)***	0.139 (0.035)***	-0.236 (0.052)***
Farm plot location	0.191 (0.126)	-0.031 (0.024)	-0.035 (0.026)	0.066 (0.049)
Land certificate	0.505 (0.249)**	-0.111 (0.067)*	-0.086 (.033)***	0.197 (0.098)**
Community bylaws	0.329(0.126)***	-0.056 (0.022)**	-0.067 (.026)**	0.122(0.046)***
Incentive	0.433 (0.180)**	-0.088 (0.042)**	-0.08 (0.031)***	0.168 (0.070)**
Tenure arrangement	-0.339 (0.226)	0.049 (0.028)*	0.071 (0.048)	-0.121 (0.075)
Sidama	-0.289 (0.214)	0.052 (0.040)	0.058 (0.042)	-0.109 (0.081)
Wolaita	-0.418(0.215)*	0.078 (0.044)*	0.081 (0.040)**	-0.159(0.082)*
Cut 1/μ_1	1.765 (1.065)*			
Cut 2/μ_2	2.718(1.072)***			
Log likelihood	-364.38			
Wald chi2 (28)	137.53***			
No. of observation	475			
Predicted probability		10.01	26.60	63.39

Notes: Standard errors in parentheses; *** p<0.01, ** p<0.05 and * p<0.1

Conclusion

Land degradation has long been a widespread problem affecting Ethiopian farmers' livelihood. Various efforts, notably land management practices, have been implemented to mitigate land degradation and soil erosion. However, the problem persists and becomes a major threat to the environment as well as to the livelihood of people. Key socioeconomic, institutional, biophysical, and policy attributes contribute positively or negatively to farmers' perception of land management practices, specifically on-farm SWC measures. This study was conducted to quantify the perception level and identify the underlying factors influencing farmers' perceptions of the role of SLM practices using household survey data in Southern Ethiopia.

The study revealed that education, cultivated land size, training, plot distance, land market, slope gradient, topsoil erosion and its severity, soil quality and fertility, policy attributes of community bylaws, incentives, land certificate and the agro-ecological specific location are key socioeconomic, institutional, policy, and biophysical driving forces affecting farmers' perception of SLM roles. This paper concluded that the non-monetary physical, social, institutional, and policy attributes of the farming communities and their farmland should be given proper attention and be linked to other developmental initiatives to improve the perception status and understanding of smallholder farmers aimed at maintaining and conserving the land resources for the current and future generations. Moreover, development programs and policy initiatives should not only depend on implementing and rehabilitating physical structures; but should equally consider the perception of farmers on the role of SLM in restoring degraded land and reducing soil erosion. Thus as policy implication, it is essential to consider the socioeconomic and institutional setups farmers operate in as these contexts strongly influence farmers' perception towards considering the implementation of SLM practices on their farms.

Acknowledgement

This paper is part of a PhD study financed by the South Agricultural Research Institute. We acknowledged the institute for financing the research. Moreover, the authors are very grateful to participant farmers and enumerators for their engagement during the interviews. Finally, district level Agriculture staff is acknowledged for providing available documents, facilitating data collection, and engaging in KIIs.

Authors' contribution

GT was involved at the conception of the research, data collection instrument design, data collection, analysis, interpretation, and drafting the manuscript. MK, gave feedback for the analytical tools, and reviewed the manuscript. EG and MJ contributed to the conception of the research, provided advice for analytical tools, and critically reviewed and edited the final version.

References

Abera, W., Assen, M., and J. Budds. 2020. Land Use Policy Determinants of agricultural land management practices among smallholder farmers in the Wanka watershed , northwestern highlands of EthiopiaI. *Land Use Policy*. *99:* 1–9.

Adimassu, Z., Kessler, A., and H. Hengsdijk. 2012. Exploring determinants of farmers' investments in land management in the Central Rift Valley of Ethiopia. *Applied Geography*. *35*(1–2): 191–198. https://doi.org/10.1016/j.apgeog.2012.07.004

Adimassu, Z., Kessler, A., Yirga, C., and L. Stroosnijder . 2013. Farmers' perceptions of land degradation and their investments in land management: A case study in the central rift valley of Ethiopia. *Environmental Management*. *51*(5): 989–998.

Ali, M., and K.Surur. 2012. Soil and Water Conservation Management Through Indigenous and Traditional Practices in Ethiopia: A Case Study. *Ethiopian Journal of Environmental Studies and Management*. *5*(4). https://doi.org/10.4314/ejesm.v5i4.3

Assefa, E., and B. Hans-Rudolf. 2016. Farmers ' Perception of Land degradation and Traditional knowledge in Southern Ethiopia — Resilience and Stability. *Land Degradation and Development*. *27*(6): 1552–1561.

Bekele, W. G., and F.G. Schneider. 2016. Preferences for forms of land conservation investment in the Ethiopian Highlands: A household plot-level analysis of the roles of poverty, tenure security and market incentives. *Environment and Development Economics*. *21*(1):78–108.

Bennett, N. J. 2016. Using perceptions as evidence to improve conservation and environmental management. *Conservation Biology*. *30*(3): 582–592. https://doi.org/10.1111/cobi.12681

Boone, H. N., and D.A. Boone. 2012. Analyzing Likert Data. *Journal of Extension*. *50*(2): 1–5.

Cardenas, J. C., Rodriguez, L. A., and N. Johnson. 2011. Collective action for watershed management: Field experiments in Colombia and Kenya. *Environment and Development Economics*. *16*(3):275–303. https://doi.org/10.1017/S1355770X10000392

Dagnew, D. C., Guzman, C. D., Zegeye, A. D., Tibebu, T. Y., Getaneh, M., Abate, S., Zemale, F. A., Ayana, E. K., Tilahun, S. A., and T.S. Steenhuis. 2015. Impact of conservation practices on runoff and soil loss in the sub-humid Ethiopian Highlands: The Debre Mawi watershed. *Journal of Hydrology and Hydromechanics*. *63*(3): 210–219.

Degu, A. A. 2019. The Causal Linkage Between Agriculture, Industry and Service Sectors in Ethiopian Economy. *American Journal of Theoretical and Applied Business*. *5*(3):59–76. https://doi.org/10.11648/j.ajtab.20190503.13

Dequech, D. 2009. Journal of Economic Behavior & Organization Institutions , social norms , and decision-theoretic norms. *Journal of Economic Behavior & Organization*. *72*: 70–78. https://doi.org/10.1016/j.jebo.2009.05.001

Deressa, T. T., and R.M. Hassan. 2009. Economic Impact of Climate Change on Crop Production in Ethiopia : Evidence from Cross-Section Measures. *Journal of African Economies*. *18*(4):529–554.

Ethiopian Statistics Service [ESS]. 2022. *The Federal Democratic Republic of Ethiopia Ethiopian Statistical Service, Agricultural Sample Survey 2021/22 (2014 E.C.):*

Report on Land Utlization (Private Peasant Holding, Meher Season). Statistical Bulletin, Volume IV. Addis Ababa, Ethiopia.

Ewunetu, A., Simane, B., Teferi, E., and B.F.Zaitchik. 2021. Relationships and the determinants of sustainable land management technologies in north Gojjam sub-basin, upper blue nile, Ethiopia. *Sustainability (Switzerland). 13*(11). https://doi.org/10.3390/su13116365

Gamo, B. R., Mekonnen, G. T., Teshale, W. H., and D. B-Park. 2021. Socio-Economic Analysis of Sub-watershed Development Impacts: A Case Study from Ethiopia. *Journal of Rural and Community Development. 16*(2): 190–207.

Getnet, K., Pfeifer, C., and C. MacAlister. 2014. Economic incentives and natural resource management among small-scale farmers: Addressing the missing link. *Ecological Economics.108*:1–7. https://doi.org/10.1016/j.ecolecon.2014.09.018

Gifford, R. 2014. Environmental psychology matters. *Annual Review of Psychology. 65*: 541–579. https://doi.org/10.1146/annurev-psych-010213-115048

Greene, W. H. 2012. Models for Discrete Choice. In *Econometric analysis* (7th ed.). Pearson Education Limited, Edinburgh Gate, Harlow, England.

Greene, W. H. 2018. *Econometric Analysis* (8th ed.). Pearson Education, Inc., New York,NY.

Greene, W. H., and D. A. Hensher 2010. Modeling Ordered Choices. In *A primer* (1st ed.). Cambridge University Press, New York.

Hartman, B. D., and D.A. Cleveland. 2018. The socioeconomic factors that facilitate or constrain restoration management: Watershed rehabilitation and wet meadow (bofedal) restoration in the Bolivian Andes. *Journal of Environmental Management. 209:*93–104.

Hörner, D., and M. Wollni. 2021. Integrated soil fertility management and household welfare in Ethiopia. *Food Policy.100*:1–14. https://doi.org/10.1016/j.foodpol.2020.102022.

Kassie, M., Zikhali, P., Pender, J., and G. Köhlin. 2010. The Economics of Sustainable Land Management Practices in the Ethiopian Highlands. *Journal of Agricultural Economics. 61*(3): 605–627. https://doi.org/10.1111/j.1477-9552.2010.00263.x

Kirui, O. K., and A. Mirzabaev. 2015. Costs of land degradation in Eastern Africa. *Agriculture in an Interconnected World, Centre for Development Research, University of Bonn, Germany*.

Kothari, C. R. 2004. *Research Methodology, Methods and Techniques* (2nd ed.). New Age International (P) Ltd., Publishers, New Delhi, India.

Mengesha, A. K., Mansberger, R., Damyanovic, D., and G. Stoeglehner. 2019. Impact of land certification on sustainable land use practices: Case of Gozamin District, Ethiopia. *Sustainability.11*(20). https://doi.org/10.3390/su11205551

Miheretu, B. A., and A.A.Yimer. 2017. Determinants of farmers ’ adoption of land management practices in Gelana sub- watershed of northern highlands of Ethiopia. *Ecological Processes. 6*(1): 6–19. https://doi.org/10.1186/s13717-017-0085-5

Ministry of Agriculture [MoA]. 2014. *The Federal Democratic Republic of Ethiopia Ministry of Agriculture, Project Implementation Manual for Land Management Project-2 (2014-2018). Addis Ababa, Ethiopia.*

Mowo, J., Masuki, K., Lyamchai, C., Tanui, J., Adimassu, Z., and R. Kamugisha. 2016.

By-laws formulation and enforcement in natural resource management: Lessons from the highlands of eastern Africa. *Forests Trees and Livelihoods*. *25*(2):120–131. https://doi.org/10.1080/14728028.2016.1159998

Nigussie, Z., Tsunekawa, A., Haregeweyn, N., Adgo, E., Nohmi, M., Tsubo, M., Aklog, D., Meshesha, D. T., and S.Abele. 2017. Farmers' Perception about Soil Erosion in Ethiopia. *Land Degradation and Development*. *28*(2): 401–411. https://doi.org/10.1002/ldr.2647

Paul, M., and M. wa Gĩthĩnji. 2018. Small farms, smaller plots: land size, fragmentation, and productivity in Ethiopia. *Journal of Peasant Studies*. *45*(4):757–775. https://doi.org/10.1080/03066150.2016.1278365

Rodríguez-Rodríguez, G., Ballesteros, H. M., Martínez-Cabrera, H., Vilela, R., Pennino, M. G., and J.M.Bellido. 2021. On the role of perception: Understanding stakeholders' collaboration in natural resources management through the evolutionary theory of innovation. *Sustainability*. *13*(6):1–11. https://doi.org/10.3390/su13063564

Samuel, G., Kirui, O. K., and A. Mirzabaev. 2016. Economics of Land Degradation and Improvement in Ethiopia. In E. Nkonya, A. Mirzabaev, & V. J. Braun (Eds.), *Economics of Land Degradation and Improvment- A global assessment for Sustainable Development* (1st ed., pp. 401–430).

Schmidt, E., and F. Tadesse. 2019. The impact of sustainable land management on household crop production in the Blue Nile Basin, Ethiopia. *Land Degradation and Development*. *30*(7): 777–787. https://doi.org/10.1002/ldr.3266

Schwilch, G., Bestelmeyer, B., Bunning, S., Critchley, W., Herrick, J., Kellner, K., Liniger, H. P., Nachtergaele, F., Ritsema, C. J., Schuster, B., Tabo, R., van Lynden, G., and M. Winslow. 2011. Experiences in monitoring and assessment of sustainable land management. *Land Degradation and Development*. *22*(2): 214–225. https://doi.org/10.1002/ldr.1040

Teklewold, H., Kassie, M., and B. Shiferaw. 2013. Adoption of multiple sustainable agricultural practices in rural Ethiopia. *Journal of Agricultural Economics*. *64*(3): 597–623. https://doi.org/10.1111/1477-9552.12011

Tesfahunegn, G. B. 2019. Farmers' perception on land degradation in northern Ethiopia: Implication for developing sustainable land management. *Social Science Journal*. *56*(2): 268–287. https://doi.org/10.1016/j.soscij.2018.07.004

Teshome, A., Graaff, J. de, Ritsema, C., and M. Kassie. 2016. Farmers' Perceptions about the Influence of Land Quality, Land Fragmentation and Tenure Systems on Sustainable Land Management in the North Western Ethiopian Highlands. *Land Degradation and Development*. *27*(4):884–898. https://doi.org/10.1002/ldr.2298

Wendimu, G. Y. 2021. The challenges and prospects of Ethiopian agriculture. *Cogent Food and Agriculture*.*7*(1): 1–26. https://doi.org/10.1080/23311932.2021.1923619

Wooldridge, J. M. 2010. Econometric Analysis of Cross Section and Panel Data. In *Taiwan Review* (5th ed.). The MIT Press, Cambridge, Massachusetts.

Worku, G. B., and A. Mekonnen. 2012. Investments in Land Conservation in the Ethiopian Highlands: A Household Plot-level Analysis of the Roles of Poverty, Tenure Security, and Market Incentives. *International Journal of Economics and Finance*. *4*(6):32–50. https://doi.org/10.5539/ijef.v4n6p32

Yalew, A. W., Hirte, G., Lotze-Campen, H., and S. Tscharaktschiew. 2018. Climate change, agriculture, and economic development in Ethiopia. *Sustainability (Switzerland)*. *10*(10): 1–23. https://doi.org/10.3390/su10103464

Appendix

Table 1A. Parameter estimation and marginal effects (restricted model)

Variable	Coefficients (Robust SE)	Prob (prcpn =1)	Prob (prcpn =2)	Prob (prcpn =3)
		dy/dx (SE)	dy/dx (SE)	dy/dx (SE)
Education level	0.034 (0.017)**	-0.006(0.003)**	-0.007 (0.004)*	0.013 (0.006)**
Cultivated land size	0.403 (.122)***	-0.071(.022)***	-0.08 (0.026)***	0.151 (0.046)***
Training	0.324 (0.132)**	-0.064(0.029)**	-0.061 (0.024)**	0.125 (0.051)**
Plot distance	0.345(0.168)**	-0.061 (0.029)**	-0.069 (0.035)*	0.130 (0.063)**
Land market	-0.214 (0.124)*	0.038 (0.022)*	0.043 (0.025)*	-0.080 (0.046)*
Slope_moderate	0.271 (0.128)**	-0.048 (0.023)**	-0.054(0.026)**	0.102 (0.048)**
Slope_steep	0.582 (0.207)***	-0.077(.021)***	-0.119(.041)***	0.196 (0.060)***
Fertility_moderate	0.222 (0.137)	-0.042 (0.028)	-0.043 (0.026)*	0.085 (0.053)
Soil erosion	0.787 (0.141)***	-0.18 (0.04)***	-0.124 (.021)***	0.304 (0.053)***
Erosion severity_mod	0.301 (0.122)**	-0.052(0.022)**	-0.060 (0.025)**	0.112 (0.045)**
Soil quality_low	-0.62 (0.233)***	0.147 (0.071)**	0.096 (0.024)***	-0.242 (0.09)***
Soil quality_modertae	-0.556(0.149)***	0.085(0.022)***	0.113 (0.031)***	0.197(0.049)***
Land certificate	0.302 (0.192)	-0.062 (0.045)	-0.055 (0.032)*	0.117 (0.076)
Community bylaw	0.325 (0.122)***	-0.057(.022)***	-0.064 (.025)***	0.121 (0.045)***
Incentive	0.256 (0.154)*	-0.050 (0.032)	-0.049 (0.028)*	0.099 (0.060)*
Wolaita	-0.254 (0.137)*	0.047 (0.027)*	0.049 (0.026)*	-0.096(0.053)*
Cut 1/μ_1	0.831 (0.311)***			
Cut 2/μ_2	1.764 (0.322)***			
Log likelihood	-370.97			
Wald chi2 (16)	122.58***			
LR chi2 (12)	13.19 (p= 0.356)			
Predicted probability		10.1	26.4	63.5

*Notes: *** p<0.01, ** p<0.05 and * p<0.1*