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Determinants of Smallholder Farmers' About Choices of Sustainable Land Management Practices in West Wollega Zone, Oromia Region, Ethiopia

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Abstract

Background: Due attention has recently been given to the choices of sustainable land management practices (SLMPs) to reduce land degradation and improve the livelihood of smallholder farmers in developing countries. A rising number of people believe that Sustainable Land Management is an essential strategy for enhancing food security. For generations, Ethiopia has been regarded as a hotspot of land degradation, posing a severe threat to agricultural productivity leading to widespread rural poverty. Hence, this study aimed at identifying the determinants of smallholder farmers' choice of SLMPs in the West Wollega zone, Oromia region of Ethiopia using the Multivariate Probit (MVP) model.

Results: Results of the MVP model show that the predicted probabilities of adopting organic fertilizer, area closure, soil and water conservation, crop rotation, and compost were 37.2, 35.3, 40.5, 38.3, and 38.5% respectively. The MVP model results also show that the five SLMPs are complementary and the probability that households choose all five SLMPs was 23% which is low. Further, results of the MVP model show that cooperative membership, model farmer contact, farm size, non-farm income, credit, farm experience, perceived soil erosion, social capital, livestock owned, farmland slope, NGO intervention, information access, and training have a significant positive influence while age, family size, and perceived input cost significantly and negatively impacted the choice of SLMPs by households in the study area.

Conclusions: The findings of the study confirm that socioeconomic, household, farm and institutional characteristics of the households have a significant impact on the choices of SLMPs and hence the need to focus on the above-mentioned factors to enhance the choices of SLMPs and reduce land degradation problem in the study area. The results also highlight the significance of environmentally-friendly policies, which include sustainable development, SLMPS plan determination, environmental permits, and incentive programs for managing the sustainability of land management performance in land-use policy within the local context.

Keywords: land degradation, sustainable land management practices, Multivariate Probit model, adoption, and west Wollega zone

1. Background

Land degradation is a global issue affecting rural communities that rely on farmland resources, making them vulnerable to poverty. It lowers agricultural productivity, enhances desertification, biodiversity loss, the cost involved with food and energy security, disturbance of the socioeconomic system, and loss of human livelihoods (Salih et al., 2017). According to Le et al. (2016), over 40% of the world's degraded lands occur in areas with the highest incidence of poverty indicating the linkage between poverty and land degradation. The causes and drivers of land degradation are complex, interactive, and self-reinforcing both across areas and generations (Gebreselassie et al., 2016). As a result, around 1.5 billion people worldwide are affected by land degradation, which covers roughly 23% of the world's land surface and is expanding at a rate of 5 to 10 million hectares per year (Pingali et al., 2014). For instance, due to the adverse effects of land degradation, about a quarter of the world's seven billion people experience food insecurity (FSIN, 2018). From this, soil erosion has been identified as a leading driver of land degradation resulting in desertification in many dryland and non-dryland areas (Haregeweyn et al., 2017; FAO, 2019a; Fenta et al., 2020; Prăvălie et al., 2021).

According to a global meta-analysis synthesis, soil erosion causes a global median loss of 0.3% of annual crop yield, with a total loss of 10% projected for 2050 (FAO, 2019a). This yield loss due to continued soil erosion could be equivalent to removing 4.5 M ha yr-1 of crop production (FAO & ITPS, 2015; FAO, 2019a). Moreover, as per recent projections, the rate of soil erosion will increase by up to 66% globally between 2015 and 2070 (Borrelli et al., 2020).

According to estimates, land degradation affects 46% of Africa's land area, affecting at least 485 million (65%) people and costing USD 9.3 billion per year. This revealed that between 75 and 80% of the continent's farmland appears to be degraded, with annual nutrient losses ranging from 30 to 60 kilograms per hectare (AGNES, 2020). As a result of these hazards, a sizable portion of the $7 billion in agricultural productivity was lost due to land degradation between 2000 and 2012 (David & Michae, 2013).

Similarly, Ethiopia is one of the worst-affected countries with significant land degradation and its negative effects on farm productivity, food security, and the well-being of communities (Berendse et al., 2015; Brevik et al., 2015; Taddese, 2018; Abiye, 2019). The agricultural sector has significant importance in many developing countries' economies and community livelihoods, as it contributes significantly to the country's GDP, creates employment opportunities, and ensures a steady supply of domestic food (Bisht et al., 2020; Dixon et al., 2001). Agriculture is also the primary sector in Ethiopia, where nearly 84% of the population is directly dependent on agriculture, land degradation is a serious issue that must be addressed (Nigussie et al., 2017a). Agriculture, for example, contributes significantly to the country's economic growth (Belachew et al., 2020; Collier & Dercon, 2014). On the other hand, the agricultural sector is still dealing with natural resource depletion, land degradation, soil erosion, climate change, and a lack of modern/productive inputs, to name a few (Belachew et al., 2020; Kagoya et al., 2017). As a result, while this sector faces threats from land degradation, there is no doubt that it is a more pressing issue for Ethiopia's agriculture-based economy and farmers' livelihoods (Nigussie et al., 2017a; Miheretu & Yimer, 2017; Abera et al., 2020).

In this regard, sustainable land management practices (SLMPs) are widely acknowledged as critical to slowing land degradation, preventing desertification, and restoring degraded lands (Eekhout & de Vente, 2022). Researchers, land users, and other stakeholders have been working on issues related to land degradation and the adoption of various SLMPs for decades. As defined by WOCAT (2021), SLMP refers to both technologies and an approach. However, there has been little systematic documentation of the successes or associated challenges. Monitoring and evaluation, in particular at the household level, have received insufficient attention (Studer et al., 2016). Hence, the choices of SLMPs must be documented and shared to provide options for better land use management under varying conditions, to promote practice upscaling and sharing, and to design a sustainable and inclusive policy environment (Mudhara et al., 2016).

Moreover, top-down planning methodologies, a lack of community input, weak institutional frameworks, and a lack of local implementation capacity all contribute to the ineffectiveness of land management practices in achieving the desired results (Tongul & Hobson, 2013). There are also issues with policy enforcement that have contributed to the failure of sustainable land management efforts in various parts of the country to achieve their intended goals. According to the findings of Nkonya et al. (2013) and von Braun et al. (2013), a lack of strong policy action and a low level of evidence-based policy framework are critical challenges to the effectiveness of SLMPs.

To combat and mitigate the interconnected effects of land degradation, the government and non-governmental organizations (NGOs) promoted the SLMP program to reverse the negative effects of land degradation, though progress and success varied across the countryside (Zerihun et al., 2017). This demonstrates and emphasizes the fact that household participation in SLMP is influenced by their geographical location as well as their understanding of the extent of land degradation trends (Tesfa & Mekuriaw, 2014).

Land management practices in Ethiopia, according to studies such as those conducted by Abebaw et al. (2011) and Befikadu & Frank (2015), have fallen far short of expectations, and land degradation, primarily due to soil erosion, remains widespread. Other recent empirical studies in Ethiopia have looked at the adoption of SLMPs and their impact on land degradation in various parts of the country, including Haftu et al. (2019), Senbetie et al. (2017), Paulos and Belay (2017), Tesfaye (2017) and Schmidt & Tadesse (2017). Their findings show that farmers’ use of SLMPs remains low, and the country is losing a significant amount of fertile topsoil.

Furthermore, empirical studies have demonstrated the benefits of SLMPs, in increasing productivity and improving smallholder livelihoods (e.g., Haregeweyn et al., 2015; Karidjo et al., 2018). However, the effectiveness of the government’s actions to support the scaling up of SLMPs in the country’s various agroecological zones requires comprehensive studies conducted in different locations over time. As a result, a more in-depth investigation is required to better understand the factors influencing households’ decisions to participate in SLMPs in these various socioeconomic settings: economic, ecological, geographical, and livelihood perspectives.

Typically, a combination of environmental, social, economic, and political factors that are extremely particular to households and the context in which they are implemented have created barriers for smallholder farmers to engage in SLMPs (Bisaro et al., 2011; Cordingley et al., 2015). Due to the failure of one-size-fits-all solutions to address, particularly at the local level, the current study’s focus on the factors that influence farm households’ participation in SLMPs is very crucial. To this effect, it is critical to investigate what specifically influences households’ decisions to adopt SLMPs in the west Wollega zone, Oromia region of Ethiopia, to develop policy options and support systems that could improve smallholder farmers’ adoption level to enhance agricultural production and productivity by rehabilitating the degraded lands.

2. Methods

2.1 Description of the Study Areas

This study was conducted in the West Wollega zon

e, which is one of the 20 administrative zones of the Oromia region of Ethiopia. Administratively, the zone has 21 districts, of which 19 are rural and two of them are urban administrations which were further subdivided into 543 kebeles 489 peasant associations, and 54 urban dweller associations. The population size of the zone is estimated as 1,741,567 out of which 864,277 or 49.6% are male, while 877,290 or 50.4% are female (WWZARDO, 2021). The total household size of the sampled districts was about 97,5offrom which 69571 are male and 27,928 are women heads.

West Wollega zone is located between 8^{0}12’-10^{0}03’N latitudes and 34008 -36^{0}10’E longitudes, located in the western part of the Oromia region, bordered by Benishangul Gumuz regional state in the North West and North East and Kelem Wollega Zone in the West. In the east it is bordered by East Wollega zone while in the south it is bordered by Gambela Regional state and Illubabor zone. West Wollega zone is found at an altitude ranging from1300 - 2,600 meters above sea level.

The zone has three agro-ecological zones which comprise 15.5% highland, 65.4% midland, and 19.1% lowland. The zone has a bimodal type of rainfall and receives an annual rainfall which ranges between 300 to 2,000 mm, while the average temperature is between 10 ℃ and 30 ℃. The area of the Zone is estimated to be 1,274,501 hectares (West Wollega Zone, Statistics Office Report, 2021). The total population of the five districts is estimated as 564538 (32.4%) of the total population out of which 287520 are males and 277,018 are females.

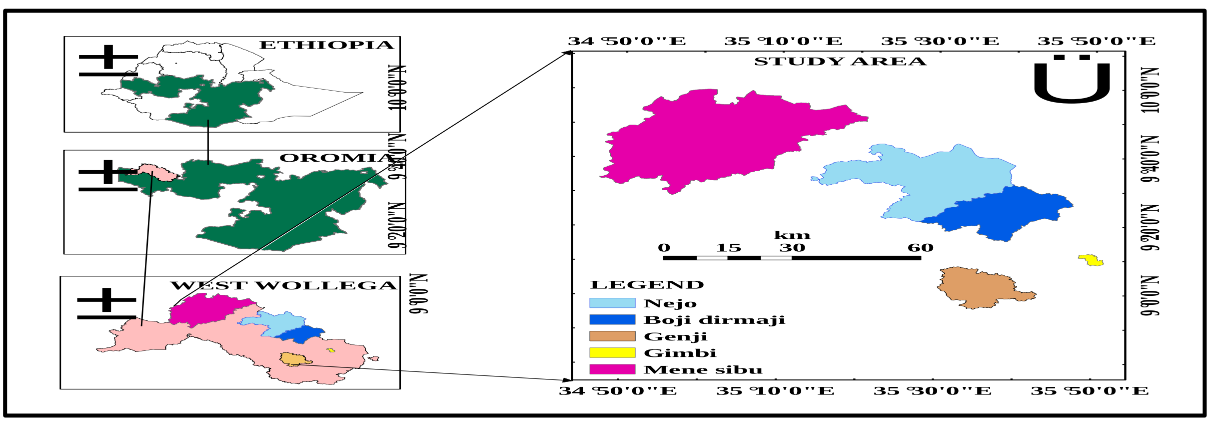

Figure 1. Geographical location of the study area and districts

2.2 Data Types, Sources, Sampling, and Data Collection Methods

2.2.1. Data Types, Sources, and Methods of Collection

The data from primary source were collected from sampled farm household heads using structured questionnaire, key interview and focus group discussion while secondary data were collected from various published documents, zonal agricultural offices, websites, etc through desk review

2.2.2. Sampling Design

A multi-stage sampling technique was used to randomly select 426 households from five districts. The data for this study was gathered using a multi-stage sampling technique to select the study districts, kebeles (It refers to the smallest administrative unit in Ethiopia), and sample households for the study. In the first stage, the zone was stratified based on agro-ecologies and five districts (three from midland and one each from low and highland), namely Ganji, Gimbi, Boji Dirmaji, Nejo, and Mana-Sibu were randomly selected based on probability proportional to size. In the second stage, 15 kebeles were randomly and proportionally chosen from the sample districts those have practices of the SLMP technology. Likewise, the households in each sample kebele were divided into two groups (adopters and non-adopters of SLMPs). In the third stage, using proportionate probability sampling based on the size of the households in each kebele, 426 farm households (201 adopters and 225 non-adopters) were randomly selected from both strata. For this study, the sample size of 426 households was determined using the Cochran (1963) formula.

Table 1. Distribution of sample farm households by districts and kebeles

Districts	Total population	Total number of households	Adopters	Non-Adopters	Sample size
Najo	30,211	2666	63	69	132
Gimbi	18081	1591	36	43	79
Ganji	9842	874	20	23	43
Boji-Dirmaji	10299	918	22	23	45
Mana-Sibu	29067	2577	60	67	127
Total	97,500	8626	201(47.18%)	225(52.82%)	426

Source: Own survey data (2021)

2.3 Data Analysis

Household survey data were first into STATA version 15 and then coded for descriptive and inferential statistics. Descriptive statistics such as frequency, mean and standard deviation were used to describe households' socio-economic, demographic, and institutional characteristics whereas the multivariate probit (MVP) model was used to identify determinants that are likely to influence farmers' choices of SLMPs. MVP model was selected with the justification that the SLMPs themselves and the unobserved error terms might depend on each other and that a household may adopt more than one practice (Yu et al., 2008).

Following Greene (2003), the MVP regression model is specified as:

$$Y^*_{hpj} = X_{hpj}\beta_j + U_{hpj} \qquad j = 1,2,\cdots,m$$

$$Y_{hpj} = \begin{cases} 1 \; if Y^*_{hpj} > 0 \\ 0 \text{ otherwise} \end{cases} \tag{1}$$

Where j=1, 2 …, m denotes the SLMPs available, X_{hpj} is a vector of explanatory variables, β_j denotes the vector of the parameters to be estimated, and U_{hpj} are random error terms distributed as a multivariate normal distribution with zero mean and unitary variance. It was assumed that a rational farmer has a latent variable, Y^*_{hpj} which captures the unobserved preferences or demand associated with the j^{th} choice of SLM strategies. This latent variable is assumed to be a linear combination of observed household and other characteristics that affect the adoption of SLMPs, as well as unobserved characteristics captured by the stochastic error term. Given the latent nature of the variable Y^*_{hpj} the estimation is based on the observable variable Y_{hpj} which indicates whether or not a household adopts a specific SLMP. Since the adoption of several SLMPs is possible, the error terms in equation (1) are assumed to jointly follow a multivariate normal distribution with zero conditional mean and variance normalized to unity.

The off-diagonal elements in the covariance matrix represent the unobserved correlation between the stochastic component of the j^{th} and m^{th} type of SLMPs. This assumption means that equation (1) gives a MVP model that jointly represents the decision to adopt a particular SLMP.

Table 2. Summary statistics and definition of variables used in MVP model

Variable	Description of variables	Mean	S.D
Dependent variable			
Sustainable Land Management Practices (SLMPs)	Adopted SLMPs (1 = yes; 0 = otherwise)	0.47	0.50
Organic fertilizer (OF)	Adopted organic fertilizer (1 = yes; 0 = otherwise)	0.33	0.47
Area closure (AC)	Adopted area closure (1 = yes; 0 = otherwise)	0.32	0.47
Soil and water conservation (SWC)	Adopted soil and water conservation practice (1 = yes; 0 = otherwise)	0.44	0.50
Crop rotation (CR)	Practice crop rotation (1 = yes; 0 = otherwise)	0.41	0.49
Compost (C)	Adopted compost (1 = yes; 0 = otherwise)	0.40	0.49
Independent variables			
Age	Age of the head (years)	43.07	11.17
Family size	Number of members in the household	5.86	0.13
Perceived costs of inputs	1 if fair, 0 if otherwise	0.42	0.49
Farming experience	Number of years into farming	16.00	0.55
Farm size	Size of farmland (ha)	2.12	1.69
Non-farm income	Annual non-farm income in Birr	6568.33	9077.72
Level of education	Years of education of the head	3.91	3.83
Extension contacts	Frequency of contacts per year	5.44	5.95
Access to information	1 if head has access to information, 0 otherwise	0.75	0.43
Access to credit	1 if head has access to credit, 0 otherwise	0.43	0.50
Training	1 if head received training, 0 otherwise	0.28	0.45
Model farmer contact	Number of contacts that the head made with the model farmers per year	8.30	7.82
Social capital	1 if the head has network, 0 otherwise	0.74	0.44
Land slope	1 if flat, 0 otherwise	0.24	0.43
Perceived soil erosion hazards	1 if yes, 0 otherwise	0.34	0.48
Membership in cooperative	1 if yes, 0 otherwise	0.45	0.50
Access to NGOs	1 if NGOs are available in the area, 0 otherwise	0.69	0.46
Livestock	Livestock owned in TLU	11.12	8.39

Source: Authors computation.

Table 3. Test for multicollinearity and heteroscedasticity

Multicollinearity	VIF	
Livestock	4.36	
Model farmer	3.56	
Farm experience	3.20	
Coop membership	3.07	
Access to credit	2.84	
Education level	2.47	
Non-farm income	2.19	
Training	1.85	
Perceived costs of inputs	1.58	
Land size	1.55	
Age	1.49	
Slope type	1.47	
Access to information	1.28	
Access to NGOs	1.27	
Perceived soil erosion	1.22	
Social capital	1.22	
Family size	1.17	
Mean VIF	2.11	
Heteroscedasticity		
Test	χ^2-value	P-value
Breusch-Pagan (BP) test	120.76	0.00

3. Results of the Study

3.1 Descriptive Statistics Results

Descriptive statistics results of the smallholder farmers in the study area are presented in Table 2. Results show that 33% of the farmers have adopted Organic Fertilizer (OF), 32% have adopted Area Closure (AC), 44% have adopted Soil and Water Conservation (SWC), and 41% have adopted Crop Rotation (CR) while 40% of the farmers have adopted Compost (C) as SLMPs in the study areas to reverse effect of land degradation and rehabilitate the degraded farmlands.

3.2 Econometric Model Results

3.2.1 Test for Multicollinearity and Heteroscedasticity

Multicollinearity refers to the presence of linear relationships among the explanatory variables included in the model. In the presence of multicollinearity (independent variables in a model are correlated), the model results in wrong signs of coefficients, high standard errors of coefficients, and high R^2 value even when the parameter estimates are not significant (Wossen et al., 2017). The variance inflation factor (VIF) for each variable was evaluated to check for multicollinearity. If the VIF exceeds 10, that variable is said to be highly collinear and can be excluded from the model. The results of the multicollinearity test are presented in Table 3 above. Results show that the mean value is 2.11 and none of the variables included in the model has VIF greater than 10. This indicates that there is no multicollinearity problem in the dataset and hence all the explanatory variables are included in the model. The result of the heteroscedasticity test is also presented in Table 3. The χ^2-value (120.76) is statistically significant at a 1% probability level, indicating that there exists heteroscedasticity in the dataset. Hence, the robust standard error is used in the analysis.

3.2.2 Model Fitness, Probabilities, and Correlation Matrix from MVP Model

The correlation coefficient among the SLMPs (ρ_{ij}) was determined to assess if these practices are complementary and/or substitutable. The results show that the correlation coefficients of six combined practices, namely ρ_{21} (area closure and organic fertilizer), ρ_{31} (SWC and organic fertilizer), ρ_{41} (crop rotation and organic fertilizer), ρ_{51} (compost and organic fertilizer), ρ_{42} (crop rotation and area closure), and ρ_{43} (crop rotation and SWC) were positive and statistically significant at less than 10% probability levels indicating the complementarity of these practices and that farmers implement multiple SLMPs at a time in the study areas. The rest of the combinations of SLMPS, on the other hand, have proved neither complementarity nor substitutability in their application. Farmers usually construct physical structures on highly depleted land and apply an organic fertilizer to rehabilitate soil fertility (Samuel et al., 2022).

Results presented in Table 4 further assessed the chance of farmers adopting these SLMPs. As a result, the likelihood of implementing organic fertilizer, area closure, SWC, crop rotation, and compost preparation are 37.2%, 35.3%, 40.5%, 38.2%, and 38.5% respectively, indicating the importance of all these practices in choosing to the impacts of land degradation.

Table 4. Model fitness, probabilities, and correlation matrix of SLMPs

Variables	Organic Fertilizer	Area closure	SWC	Crop rotation	Compost
Predicted probability	0.372	0.353	0.405	0.382	0.385
Joint probability of success	0.230				
Joint probability of failure	0.496				
Estimated correlation of SLMPs (Pair-wise correlation coefficients)					
ρ_{21}	0.298**				
ρ_{31}	0.343**				
ρ_{41}	0.344***				
ρ_{51}	0.267*				
ρ_{32}	0.163				
ρ_{42}	0.317***				
ρ_{52}	0.180				
ρ_{43}	0.239**				
ρ_{53}	0.114				
ρ_{54}	0.134				
Likelihood ratio test of $\rho_{21} = \rho_{31} = \rho_{41} = \rho_{51} = \rho_{32} = \rho_{42} = \rho_{52} = \rho_{43} = \rho_{53} = \rho_{54} = 0$:					
chi2(10) = 23.3156 Prob > chi2 = 0.0096					
Number of draws = 5					
Number of observations = 426					
Log likelihood = -492.0966					
Wald chi2(85) = 578.46					
Prob > chi2 = 0.0000					

3.2.3 Parameter Estimates of the MVP Model on the Determinants of Adoption of SLMPs

According to the model results, 13 explanatory variables had a statistically significant effect on SLMPs (use of fertilizer, area closure, SWC, crop rotation, and compost). These include cooperative membership, non-farm income, model farmer contact, perceived costs of inputs, credit access, farming experience, social capital, livestock holding, the slope of the farmland, access to information, and NGO intervention in the village have a significant positive influence in the participation of SLMPs in the study area. However, the age of the household head, and household size, have a significant negative influence. The results on the significant variables are presented below.

Age of the household head: This is an important variable hypothesized to influence the choice of SLMPs in the study area. Age has a significant negative influence on the adoption of SLMPs such as area closure and compost at less than 5% probability levels.

Family size: It has a negative and significant effect on the likelihood of choosing area closure and crop rotation at less than 10% significant levels.

Membership in cooperative: This variable has a positive and statistically significant effect on the adoption of area closure, crop rotation, and compost at less than a 1% significance level and a significant positive impact on SWC at a 10% significance level.

Non-farm income: The total income generated from non-farming activities has a positive and significant effect on the adoption of organic fertilizer and SWC at less than a 1 % significance level while it affects crop rotation at a 10 % level of significance.

Perceived costs of inputs: It is one of the primary factors that are positively impacting the adoption of compost as SLMP for sustaining and reversing the adverse effects of land degradation in the study area.

Access to information: It has a significant positive effect on crop rotation as SLMP at less than 5% significance level. Access to high-quality, relevant, and up-to-date information is critical in the adoption of different agricultural technologies.

Model farmer contact: Model farmer contact has a positive and significant effect on the adoption of organic fertilizer at less than one percent significance level.

Credit access: Credit access by farm households significantly and positively affects the choices of organic fertilizer, area closure, and SWC, at less than 10% significance levels. This finding suggests that farm households with access to credit are more likely to implement these SLMPs for soil fertility management and improved crop production.

Farming experience: It is another important factor related to farm households' choice of SLMPs in the study area. In this study, the household head's farming experience had a positive and significant influence on the adoption of fertilizer, area closure, SWC, crop rotation, and compost at less than 10% significance levels.

Social capital: It is affecting the choice of SLMPs, particularly the use of organic fertilize at less than 1% significance level. Belonging to a specific social group is crucial in a circumstance where there is asymmetric information about various agricultural production and agricultural productivity methods.

Livestock holding: It is used as a proxy for measuring wealth or household asset possession and found to have a positive and significant effect on the decision to adopt area closure, SWC, crop rotation, and compost as SLMPs at less than 1% significance level.

Farm slope: Keeping all other variables constant in the model, the slope of the farmland has a positive and significant influence on the likelihood of adoption of compost as SLMP at 1% level of significance.

Access to NGOs: It has a significant positive impact on the adoption of compost, organic fertilizer, and area closure at less than 10% significance levels. An NGO intervention in the community helps to raise awareness about the importance and role of soil fertility management practices in agricultural productivity improvement.

4. Discussions of the Results

4.1 Descriptive Statistics Results Discussions

The empirical results of the current study demonstrate that a variety of factors affect farmers' decisions regarding the adoption of SLM practices The following discussion examines the key predictors that account for the factors that influence household adoption of SLM practices in the study area. The descriptive statistics results in Table 2 confirmed that the adoptions of organic fertilizer and area closure are the least adopted practices while the remaining three practices received similar attention from the adopters. The mean age of the farmers was found to be 33 years indicating that they are still active and productive. We also found that the average family size, farming experience, size of farmland, income from non-farm activities, years of formal education, extension contacts, contacts with model farmers, and livestock owned are 5.86, 16 years, 2.12 ha, 6568.33 Birr, 5.44, 8.30 and 11.2 TLUs respectively. About 42% of the farmers perceived the costs of inputs are fair, 75% had access to information, 43% had access to credit from formal sources which might have contributed to the adoption of SLMPs, only 28% had received training on natural resource management, 74% had some form of social networks, only 24% had farmland with flat slope, 34% had perceived soil erosion on their lands, about 45% of the farmers belonged to farmers cooperatives, while 75% of them had access to NGOs.

4.2 Econometric Model Results Discussions

The variance inflation factor (VIF) for each variable was evaluated as shown in the table 3 above to check for multicollinearity. And the mean value is 2.11 and none of the variables included in the model has VIF greater than 10. This indicates that there is no multicollinearity problem in the dataset and hence all the explanatory variables are included in the model. The result of the heteroscedasticity test is also presented in Table 3. The χ^2-value (120.76) is statistically significant at a 1% probability level, indicating that there exists heteroscedasticity in the dataset. Hence, the robust standard error is used in the analysis.

The joint probabilities of success or failure of adopting the five types of SLMPs suggested that households were likely to adopt the SLMPs jointly. As indicated in Table 3, the probability of farmers adopting the five SLMPs is 23% indicating that households were less likely to succeed to choose all the selected practices at the same time. That means farmers were unlikely by 73% to succeed in choosing all five SLMPs. The model results of the study on the significant variables are presented and discussed in Table 4 below.

In this particular study, age has a significant negative influence. This means more likely due to the fact that older farmers are more risk averse and young farmers are more willing to seek knowledge from a variety of sources and had long-term plans to preserve SLMPs. This result is consistent with studies conducted by many scholars (Awotide et al., 2014; Milkias & Abdulahi, 2018; Simtowe et al., 2016) who confirmed that older farmers have less updated information on agricultural technologies than younger farmers. This could also be explained by the fact that younger farmers were more likely employed due to better education, greater access to information, and a longer planning horizon for the reasons that some of the SLMPs are more likely to take time labor.

On the contrary, studies such as Beshir (2014), Feyisa (2020), and Amanuel et al. (2018) found a positive and significant effect of age on the adoption of SLMPs and argue that older farmers are better at evaluating the pros and cons of agricultural technologies compared to younger farmers and that younger farmers do not put in more effort, while older farmers with more experience are more likely to adopt the technology.

Different study finding shows that the adoption of SLM practices has been positively correlated with the availability of labour, indicating that households with larger family sizes are more likely to adopt more than their counterparts. However, this current study shows that in the study area, there is a circumstance in which the majority of household members may be responsible for a higher proportion of dependents, primarily children and elders. Therefore, households with larger family sizes but a lower labour force may prefer to spend the majority of their time generating daily income, such as from off/non-farm jobs, in order to pay for their daily needs rather than devoting their time and labour to SLMPs.

Further, this implies that the probability of adoption of these SLMPs decreases with the size of the household members. These results might be related to the fact that households with large family members outlay their income more on consumption rather than investing in SLMPs (Challa & Tilahun, 2014). However, this result contradicted the conducted in Ethiopia who claimed that household size has a positive significant influence on SLMPs (Gebrelibanos & Abdi, 2012; Haftu et al., 2019).

The association cooperative membership variable has a statistically significant positive impact on the adoption of SLMP. This suggests that SLMP-adopting households have higher association membership rates. The association's adoption of SLMP can help farmers who use it by providing them with access to better land fertility maintenance, as would be expected. This outcome is consistent with the conclusions made by Bakhsh et al. (2012).

Hence, the decision of households to adopt SLMP is influenced by their participation in cooperative membership-holding. Households in cooperative groups were discovered to be more likely to adopt SLM practices than non-member households. This result suggests that households that are members of farmers' agricultural cooperatives are more likely to adopt these SLMPs than their counterparts due to the fact that farmers have developed into a vital network that offers different types of assistance to farmers, including financing and technical assistance. This finding is consistent with the findings of Ogada et al. (2014) and Ojo et al. (2019), who discovered that membership in farmers' associations, facilitated the adoption of agricultural technology in Kenya.

Participating of households in off-farm or non-farm activities has an impact on households' decision to adopt SLMP. This could be because households who earn more money from sources other than agriculture are more likely to use SLMPs as they are more likely to overcome the financial barriers required to undertake practices (Ponguane & Mucavele, 2018; Kousar & Abdulai, 2016; Challa & Tilahun, 2014). However, the findings of this study contradict with those of Mekuriaw *et al.* (2018) and Asfaw & Neka (2017), who discovered that participation in non-farm activities have a negative impact on households' willingness to implement SWC on their farmlands.

One of the important factors that restrict the adoption of agricultural technology is the cost of inputs for the adoption of SLMPs. Clearly, the high cost of agricultural technology is a major barrier to adoption, according to many studies. Djibo & Maman's (2019) .Hence, in line with different studies' results to study the determinants of agricultural technology adoption, improved seed adoption is negatively impacted by high input costs while organic fertilizer use is positively impacted. Challa & Tilahun (2014) discovered that household heads' attitudes towards the fairness of the cost of inputs specifically, the cost of improved seed are influenced by the adoption of modern agricultural technology in west Wollega, Gulliso district, Ethiopia.

The perception of the cost of inputs in regard to its affordability and accessibility affects household adoption decisions in the study area. This is more likely because of cost of materials for making compost is less as compared to other inputs like commercial fertilizer for land fertility maintenance. Hence, increased technology adoption suffers as a result of high agricultural input prices, according to Djibo & Maman's (2019) study on factors influencing the use of agricultural technology in Niger.

Access to high-quality, relevant, and up-to-date information is critical in the adoption of different agricultural technologies. This could be because farmers who have regular access to information from a variety of sources are more likely to be informed about potential SLMPs, success stories, and how to overcome land degradation challenges over time (Adjepong et al., 2019; Bekele & Drake, 2003; Mekuriaw et al., 2018).

Model farmer contact has a positive and significant effect on the adoption of SLMPs among households in the study area. This is because model farmer contact increases sharing with practically tested practices, experiences, skills, knowledge, and information that could easily facilitate in promoting perception and the choice of options to look after their plot to reduce hazards of land degradation effectively (Belay et al., 2017). Further, this could be explained by the fact that as farmers to farmers' contact increases their understanding of indigenous knowledge to evaluate their land degradation status and to use SLMPs to improve land fertility maintenance and crop production over time (Alhassan et al., 2018a).

The adoption of SLMPs is more likely promoted as a result of credit services to address any financial constraints for the adoption of these practices. This conclusion is supported by the findings of Haftu et al. (2019), Adeyemo et al. (2017), and Zemenu & Minale (2014) in their respective studies who argue that financial support is an important factor that encourages smallholder farmers to adopt land management practices. On the contrary, to this finding Eleni (2008) and Berhanu et al. (2016) discovered that access to credit hurts the adoption of SWC practices. This further implies that adopting a different SLMP will be more likely if it has financial support or backup. Due to the high capital requirements of implementing SLMP on a farm, having access to financial assistance will motivate the farmers to make investments and adopt sustainable land management practices. The findings of Adeyemo et al. (2017), who discovered that accessing credit facilities encourages the adoption of land management practices, are consistent with this outcome.

Households with years of experience are more likely to have found success with a variety of SLMPs, leading to the adoption of numerous sustainable land management techniques. The result suggests that more experienced farmers understand the value of SLMPs and adopt them more than less experienced farmers. According to Shiferaw & Holden (2008) and Yenealem et al. (2013) experienced farmers are better equipped to identify soil erosion problems than less experienced farmers and have a higher likelihood of taking part in land management initiatives. This finding is also consistent with the findings of Aminu et al. (2018) and Mugisha & Alobo (2012) who discovered that having a substantial level of experience always helps smallholder farmers devise a strategy to deal with land degradation problems through the use of various land management practices.

Being a part of different social groups positively and statistically significantly affected the adoption of all agricultural technologies covered in the study, demonstrating that belonging to different social groups raises the likelihood of adoption. Participation in social groups can improve societal ties. This is because it helps farmers to share information and learn from one another (Feyisa, 2020; Ketema et al., 2016).

In this particular study, it was discovered that livestock ownership as a proxy for wealth or household asset possession measured using TLU had a favorable and significant impact on the choice to adopt the dominant SLM practices. Compared to households with small livestock units, those with large livestock units are more likely to adopt technology. This is so that households with a lot of livestock will be better able to afford and have access to new agricultural technologies. The research by (Abay et al., 2016; Feyisa, 2020) found the same conclusion regarding conformity using technology This further illustrates that households who own large herd sizes have the chance of overcoming the costs of adopting SLMPs as compared to their counterparts. The likelihood of adopting area closure, SWC, crop rotation, and compost is higher for households owning large herd sizes as compared to households owning small herd sizes. This is because households having large livestock will have better financial standing to afford and possess new agricultural technologies (Abay et al., 2016; Feyisa, 2020; Tesfaye & Brouwer, 2016; Senbetie et al., 2017). This was also raised during the focus group discussions, and they confirmed that households with larger sizes of livestock have a greater willingness to adopt SLMPs.

One of the critical factors that affect farmers' choice of adoption of SLMP is limited by slope types among households in the study area. The results imply that owners of gentle farmland are more likely to adopt compost than owners of flat plots. This might be related to the fact that plots with a steeper slope have more runoff water and are therefore more likely to be prone to land degradation. This finding is in line with the findings of Wagayehu (2003) and Haftu et al. (2019), who discovered that gentle slope plots have a significant positive effect on the adoption of various SLM technologies. However, it contradicted, the studies by Asrat & Simane (2017b), Kassie et al. (2009), and Wossen et al. (2015) suggested that farmers invest in adoption strategies in plots with a relatively plane slope than likely to be more vulnerable to any development practices.

The availability and interventions of NGOs in the study area influence the adoption of SLMP among households in the study area. This could be because NGOs provide farmers with training as well as resources on SLMPs in particular, capacitating households through experience sharing and frequent and site-specific extension services.

As a result, because most NGOs provide practical training and materials provision, households will have the opportunity and capacity to participate in the management of their agricultural land by implementing organic fertilizer, area closure, and compost. According to Assefa & Hans-Rudolf (2016), farmers who participated in NGOs' training on NRM projects were more knowledgeable about soil erosion and conservation than those who did not.

Table 5. Multivariate probit simulation results on the determinants choice of SLMPs

Variable	Organic fertilizer		Area closure		SWC		Crop rotation		Compost	
	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.
Age	-0.006	0.009	-0.022**	0.009	-0.020	0.015	-0.015	0.010	-0.027***	0.011
Education level	-0.004	0.034	0.013	0.034	0.023	0.048	0.029	0.039	0.023	0.038
Family size	-0.053	0.034	-0.072**	0.034	-0.075	0.051	-0.077*	0.040	0.002	0.041
Model farmer	0.048***	0.017	0.022	0.017	0.013	0.023	0.028	0.020	0.020	0.023
Land size	0.025	0.065	-0.052	0.062	0.161	0.112	-0.065	0.069	0.060	0.075
Access to information	-0.078	0.275	-0.453	0.301	-0.628	0.406	0.728**	0.366	0.429	0.332
Perceived cost of input	-0.070	0.206	0.317	0.209	-0.194	0.348	0.322	0.235	0.541**	0.239
Coop membership	0.218	0.273	1.267***	0.271	0.759*	0.391	0.807***	0.289	0.896***	0.300
Access to credit	0.557**	0.240	0.460*	0.247	1.020***	0.313	0.443	0.286	0.219	0.300
Farm experience	0.024*	0.013	0.033**	0.014	0.040**	0.018	0.036**	0.017	0.002	0.013
Access to NGOs	0.409*	0.239	0.571**	0.251	-0.289	0.376	-0.131	0.262	0.693***	0.253
Training	0.017	0.222	0.338	0.223	0.542	0.341	0.118	0.254	0.214	0.287
Non-farm income	0.000***	0.000	0.000	0.000	0.000***	0.000	0.000*	0.000	0.000	0.000
Soil erosion hazard	0.147	0.192	0.096	0.197	-0.040	0.294	0.085	0.226	-0.242	0.240
Social capital	0.771***	0.256	-0.118	0.258	0.125	0.331	-0.104	0.298	-0.224	0.309
Livestock	0.015	0.012	0.031***	0.012	0.051***	0.018	0.047***	0.014	0.056***	0.014
Slope type	0.208	0.198	0.001***	0.191	0.278	0.298	0.324	0.230	0.715***	0.243
Constant	-2.275***	0.475	-0.954**	0.452	-1.804**	0.733	-1.163**	0.511	-2.176***	0.541

5. Conclusion and Recommendations

Land degradation is the most critical environmental problem limiting agricultural productivity in Ethiopia in general and in the west Wollega zone in particular. Even though. SLMPs contribute significantly to the reduction of land degradation, but farmers' adoption of these practices is low in the study area. Moreover, very limited studies have been conducted on household-level determinants of choice of SLMPs in general and the study area in particular. This shows that in biophysically and socioeconomically diverse countries like Ethiopia, local specific studies provide more information for policymakers to design effective interventions demanded as policy frameworks to minimize the blanket recommendations.

Therefore, this study examined factors that influence the adoption of SLMPs by farm households in the study area. The study used primary cross-sectional data collected from 426 farm households using multistage random sampling methods from five randomly selected districts and fifteen kebeles of the west Wollega zone, Oromia region, Ethiopia. Both quantitative and qualitative data were gathered from household surveys and FGDs respectively. Data were analyzed using descriptive statistics and a Multivariate Probit model. Results show that the rate of adoption of organic fertilizer, area closure, SWC, crop rotation, and compost as SLMPs were 33, 32, 44, 41, and 40% respectively. MVP model results showed a strong correlation between the various SLMPs, demonstrating that households adopted a variety of interdependent SLMPs. The practices were therefore complementary rather than supplementary or having a synergetic effect on one another. Model results also show that the predicted probabilities of adopting organic fertilizer, area closure, soil and water conservation, crop rotation, and compost were 37.2, 35.3, 40.5, 38.3 and 38.5% respectively showing similarity of the importance of these SLMPs to reverse the impact of land degradation and rehabilitate the degraded lands in the study area. Also, the output of the MVP model indicates that the probability that farm households choose all the SLMPS is 23% which is lower.

Further, the results of the MVP model show that 13 explanatory variables had a significant effect on the choice of SLMPs. Family size, agricultural cooperative membership, non-farm income, model farmer contact, credit access, farming experience, social capital, livestock holding, slope of the farmland, access to information and access to NGOs have a significant positive influence while age of the household head and perceived costs of inputs have a significant negative influence on the adoption of SLMPs in the study area.

As a result, the study recommended that local and regional governments develop specific programs to address the constraints, thereby scaling up and encouraging the adoption of SLMPs in the study area. This could be achieved by policy and development interventions that focus on all socio-economic, demographic and institutional factors that influence SLMPs in response to reversing the significant impacts of land degradation in the study area.

Households should use of labor-saving technologies and adopt modern livestock production systems to enhance their adoption rate and reduce the impact of land degradation. Households' access to non-farm income-generating activities and credit has to be prompted through policies strengthening the services of rural microfinance and establishing formal and informal saving institutions for different provision options. In addition, community-based organizations like farmer cooperative groups, NGOs, and different experience-sharing modalities such as model farmers' contacts through preparing different forums like field days should be promoted to improve their adoption rates. Special focus should be given to middle-aged farmers with reach experience in farming will enhance the adoption of SLMPs in the study area. Furthermore, it is critical to advance and update natural resource management and usage regulations by articulating land use and management directives and strengthening the current extension services.

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Authors contributions

Professor Fekadu Beyene (Ph.D.), Professor Jema Haji (Ph.D.), and Assistant Professor Chanyalew Siyum (Ph.D.), all were accountable for the study's design from the outset to the final manuscript writing up. The manuscript was eventually made improvements after numerous revisions made by all authors. And lastly, the final manuscript was read and approved by all authors

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References

Abay, K. A., Berhane, G., Taffesse, A. S., Koru, B., & Abay, K. (2016). *Understanding Farmers' Technology Adoption Decisions: Input Complementarity and Heterogeneity.* ESSP Working Paper 82, Ethiopian Strategy Support Program (ESSP), Ethiopian Development Research Institute (EDRI), International Food Policy Research Institute (IFPRI).

Abebaw, S., Penporn J., & Vute W., (2011). Analysis of factors affecting adoption of soil conservation measures among rural households of Gursum district. *Kasetsart Journal of Social Sciences*, *32*(3), 503-515.

Abera, W., Tamene, L., Tibebe, D., Adimassu, Z., Kassa, H., Hailu, H., Mekonnen, K., Desta, G., Sommer, R., & Verchot, L. (2020). Characterizing and evaluating the impacts of national land restoration initiatives on ecosystem services in Ethiopia. *Land Degradation and Development, 31*, 37-52. https://doi.org/10.1002/ldr.3424

Abiye, W. (2019). Review on impacts of land degradation on agricultural production in Ethiopia. *Journal of Resources Development and Management*, *57*, 21-20.

Adeyemo, R. A., Oladoja, A. M., Famakinwa, M., & Alabi, D. L. (2017). Assessment of utilization of soil management practices among arable crop farmers in Ogun State: Implication for sustainable agriculture in Nigeria. *Economics, Engineering, Agriculture and Rural Development*, *17*(3), 37-46.

Adjepong, K., Deladem J., Agyire-tettey F., & Bruce D. (2019). Assessment of the determinants that influence the adoption of sustainable soil and water conservation practices in Techiman Municipality of Ghana. *International Soil and Water Conservation Research, 7*(3), 248-257. https://doi.org/10.1016/j.iswcr.2019.04.003

AGNES (Africa Group of Negotiators Experts Support). (2020). *Land degradation and climate change in Africa.* Policy Brief No. 2. Retrieved from https//agnes-africa.org/wp-content/uploads/07/Policy-brief-2Land-degradation_Final_09032020.pdf

Alhassan, S. I., Shaibu, M. T., Kuwornu, J. K. M., & Damba, O. T. (2018a). Assessing smallholder women farmers' adaptive capacity to climate change and variability in the Northern Region of Ghana: A Composite Index Approach. *Journal of Energy and Natural Resource Management*, *1*, 1-9.

Amanuel, W., Yimer, F., & Karltun, E. (2018). Soil organic carbon variation in relation to land use changes: The case of Birr watershed, upper Blue Nile River Basin, Ethiopia. *Journal of Ecology and Environment, 42*(1). https://doi.org/10.1186/s41610-018-0076-1

Aminu, F. O., Rosulu, H. O., Balogun, E. O. S., & Babawale, O. H. (2018). Analysis of adoption of sustainable land management practices for yam production in Osun State, Nigeria. *Journal of Agricultural Science Practices, 3*(6), 154-160. https://doi.org/10.31248/JASP2018.115

Asfaw, D., & Neka M. (2017). Factors affecting adoption of soil and water conservation practices: the case of Wereillu *Woreda* (District), South Wollo zone, Amhara region, Ethiopia. *International Soil and Water Conservation Research*, *5*(4), 273-279. https://doi.org/10.1016/j.iswcr.2017.10.002

Asrat, P., & Simane B. (2017b). Household- and plot-level impacts of sustainable land management practices in the face of climate variability and change: Empirical evidence from Dabus Sub-basin, Blue Nile River, Ethiopia. *Agriculture and Food Security, 6*(1). https://doi.org/10.1186/s40066-017-0148-y

Assefa, E., & Hans-Rudolf, B. (2016). Farmers' perception of land degradation and traditional knowledge in southern Ethiopia—Resilience and stability. *Land Degradation and Development, 27*(6), 1552-1561. https://doi.org/10.1002/ldr.2364

Awotide, B., Abdoulaye, T., Alene, A., & Manyong, V. (2014). Assessing the extent and determinants of doption of improved cassava varieties in South-West Nigeria. *Journal of Development and Agricultural Economics, 6*(9), 376-385. https://doi.org/10.5897/JDAE2014.0559

Bakhsh, K., Hassan, I., Khurshid, W., & Hassan, S. (2012). Econometric analysis of adoption of water conservation practices: a case of cotton crop. *Journal of Agricultural Research*, *50*(3), 445-455.

Befikadu, A., & Frank W. (2015). *Determinants of WTP and WTA in watershed management for a better PES intervention in the Blue Nile Basin, Ethiopia*. Paper prepared for presentation at the "2015 World Bank Conference on Land and Poverty". The World Bank - Washington DC, March 23-27, 2015.

Bekele, W., & Drake L. (2003). Soil and water conservation decision behavior of subsistence farmers in the Eastern Highlands of Ethiopia: a case study of the Hunde-Lafto area. *Ecological Economics, 46*(3), 437-451.

https://doi.org/10.1016/S0921-8009(03)00166-6

Belachew, A., Mekuria W., & Nachimuthu K. (2020). Factors influencing adoption of soil and water conservation practices in the northwest Ethiopian highlands. *International Soil and Water Conservation Research, 8*(1), 80-89. https://doi.org/10.1016/j.iswcr.2020.01.005

Belay, A., John, W. R., Teshale, W., & John, F. M. (2017). Smallholder farmers' adaptation to climate change and determinants of their adaptation decisions in the Central Rift Valley of Ethiopia. *Agriculture & Food Security, 6*(24), 1-13. https://doi.org/10.1186/s40066-017-0100-1

Berendse, F., van Ruijven, J., Jongejans, E., & Keesstra, S. (2015). Loss of plant species diversity reduces soil erosion resistance. *Ecosystems, 18*, 881-888. https://doi.org/10.1007/s10021-015-9869-6

Berhanu, A., Teddy, G., Dinaw, D., & Melese, B. (2016). SWC practices: Economic and environmental effects in Ethiopia. *Global Journal of Agricultural Economics and Econometrics, 4*(1), 169-177.

Beshir, H. (2014). Factors affecting the adoption and intensity of use of improved forages in North East Highlands of Ethiopia. *American Journal of Experimental Agriculture, 4*, 12-27. https://doi.org/10.9734/AJEA/2014/5481

Bisaro, A., Kirk, M., Zimmermann, W., & Zdruli, P. (2011). *Analyzing new issues in desertification: Research trends and research needs*. Institute for Cooperation in Developing Countries.

Bisht, I. S., Rana, J. C., & Ahlawat, S. P. (2020). The future of smallholder farming in India: Some sustainability considerations. *Sustainability, 12*(9), 3751. https://doi.org/10.3390/su12093751

Borrelli, P., Robinson, D. A., Panagos, P., Lugato, E., Yang, J. E., Alewell, C., Wuepper, D., Montanarell, L., & Ballabio, C. (2020). Land use and climate change impacts on global soil erosion by water (2015-2070). *National Liberary of Medicine, 117*(36), 21994-22001. https://doi.org/10.1073/pnas.2001403117

Brevik, E. C., Cerdà, A., Mataix-Solera, J., Pereg, L., Quinton, J. N., Six, J., & Van Oost, K. (2015). The interdisciplinary nature of Soil. *Soil, 1*, 117-129. https://doi.org/10.5194/soil-1-117-2015

Challa, M., & Tilahun, U. (2014). Determinants and impacts of modern agricultural technology adoption in West Wollega: The case of Gulliso district. *Journal of Biology, Agriculture and Healthcare, 4*(20), 63-77.

Collier, P., & Dercon S. (2014). African agriculture in 50 years: smallholders in a rapidly changing world? *World Development, 63*, 92-101. https://doi.org/10.1016/j.worlddev.2013.10.001

Cordingley, J. E., Snyder, K. A., Rosendahl, J., Kizito, F., & Bossio, D. (2015). Thinking outside the plot: addressing low adoption of sustainable land management in sub-Saharan Africa. *Current Opinion in Environmental Sustainability, 15*, 35-40. https://doi.org/10.1016/j.cosust.2015.07.010

Dixon, J. A., Gibbon, D. P., & Gulliver, A. (2001). *Farming Systems and Poverty: Improving Farmers' Livelihoods in a Changing World.* Italy: Food and Agriculture Organization of the United Nations

Djibo, O., & Maman, N. M. (2019). Determinants of agricultural technology adoption: farm households' evidence from Niger. *Journal of Development and Agricultural Economics, 11*(1), 15-23. https://doi.org/10.5897/JDAE2018.0998

Eekhout, J. P. C., & de Vente, J. (2022). Global impact of climate change on soil erosion and potential for adaptation through soil conservation. *Earth Science Review, 226*, 103921. https://doi.org/10.1016/j.earscirev.2022.103921

Eleni, T. (2008). *Determinants for continued use of SWC practices: The case of productive safety net program in Tulla district, Ethiopia*. Master thesis, SWC Group and Environmental Policy Group.

FAO and ITPS. (2015). *Status of the World's Soil Resources.* Retrieved from http://www.fao.org/3/a-i5199e.pdf

FAO. (2019a). *Soil erosion: the greatest challenge to sustainable soil management*. Rome. Licence: CC BY-NC-SA 3.0 IGO P.100. Retrieved from http:www._iam.it/uploads/attachments/794/web Sustainable_land_management_and_land Restoration pdf

Fenta, A. A., Tsunekawa, A., Haregeweyn, N., Poesen, J., Tsubo, M., … Kurosaki, Y. (2020). Land susceptibility to water and wind erosion risks in the East Africa region. *Science of Total Environment, 703*, 135016. https://doi.org/10.1016/j.scitotenv.2019.135016

Feyisa, B. W. (2020). Determinants of agricultural technology adoption in Ethiopia: A meta-analysis. *Cogent Food & Agriculture, 6*(1), 1. https://doi.org/10.1080/23311932.2020.1855817

FOA. (2019a). *Soil erosion: the greatest challenge to sustainable soil management*. Rome.

FSIN. (2018). *Global report on food security.* 2018, 1-195.

Gebrelibanos, G. G., & Abdi, K. E. (2012). Valuation of soil conservation practices in Adwa Woreda, Ethiopia: A contingent valuation study. *Journal of Economics and Sustainable Development, 3*(13), 22221700.

Gebreselassie, S., Kirui, O. K., & Mirzabaev, A. (2016). Economics of land degradation and improvement in Ethiopia. *Economics of Land Degradation and Improvement-A Global Assessment for Sustainable Development*. Springer, pp. 401-430. https://doi.org/10.1007/978-3-319-19168-3_14

Haftu E., Teklay N., & Metkel A. (2019). Factors that influence the implementation of sustainable land management practices by rural households in Tigriai Region, Ethiopia. *Journal of Ecological Processes, 8*(14), 1-16. https://doi.org/10.1186/s13717-019-0166-8

Haregeweyn, N., Tsunekawa, A., Nyssen, J., Poesen, J., Tsubo, M., Tsegaye, M. D., Schütt, B., Adgo, E., & Tegegne, F. (2015). Soil erosion and conservation in Ethiopia: a review. *Progresses in Physical Geography, 39*(6), 750-774. https://doi.org/10.1177/0309133315598725

Haregeweyn, N., Tsunekawa, A., Poesen, J., Tsubo, M., Meshesha, D. T., Fenta, A. A., Nyssen, J., & Adgo, E. (2017). Comprehensive assessment of soil erosion risk for better land use planning in river basins: case study of the upper Blue Nile River. *Science of Total Environment*, *574*, 95-108. https://doi.org/10.1016/j.scitotenv.2016.09.019

Karidjo, B. Y., Wang, Z., Boubacar, Y., & Wei, C. (2018). Factors influencing farmers' adoption of soil and water control measures in Keita valley, a semi-arid area of Niger. *Sustainability, 10*(288), 2e13. https://doi.org/10.3390/su100 20288

Kassie, M., Zikhali P., Manjur K., & Edwards S. (2009). Adoption of organic farming technologies: Evidence from semi-arid regions of Ethiopia. *Natural Resources Forum, 33*, 189-198. https://doi.org/10.1111/j.1477-8947.2009.01224.x

Ketema, M., Kebede, D., Dechassa, N., & Hundessa, F. (2016). Determinants of adoption of potato production technology package by smallholder farmers: Evidences from eastern Ethiopia. *Review of Agricultural and Applied Economics*, *19*(2), 61-68. https://doi.org/10.15414/raae.2016.19.02.61-68

Le, Q. B., Nkonya, E., & Mirzabaev, A. (2016). Biomass productivity-based mapping of global land degradation hotspots. *Economics of Land Degradation and Improvement-A Global Assessment for Sustainable Development*. Springer, pp. 55-84. https://doi.org/10.1007/978-3-319-19168-3_4

Mekuriaw, A., Heinimann, A., Zeleke, G., & Hurni, H. (2018). Factors influencing the adoption of physical soil and water conservation practices in the Ethiopian highlands. *International Soil and Water Conservation Research, 6*(1), 23-30. https://doi.org/10.1016/j.iswcr.2017.12.006

Mihertu, B. A., & Yimer, A. (2017). Determinates of farmers adoption of land management practice in Gelanasub-watershed of northern highlands of Ethiopia. *Ecological Processes, 6*(1), 1-11. https://doi.org/10.1186/s13717-017-0085-5

Milkias, D., & Abdulahi, A. (2018). Determinants of agricultural technology adoption: the case of improved highland maize varieties in Toke Kutaye district, Oromia Regional State, Ethiopia. *Journal of Investment and Management, 7*(4), 125-132. https://doi.org/10.11648/j.jim.20180704.13

Mudhara, M., Critchley, W., Di Prima, S., Dittoh, S., & Sessay, M. (2016). Community Innovations in Sustainable Land Management: Lessons from the Field in Africa. *Routledge/Earthscan Studies in Natural Resource Management*. https://doi.org/10.4324/9781315641003

Mugisha, J., & Alobo, S. (2012). Determinants of land management practices in theagricultural highlands of Uganda: A case of Kabale highlands in Western Uganda. In: Third RUFORUM Biennial Conference, 24-28 2012. Entebbe, Uganda.

Nigussie, A., Adugna A., Ajema L., Shimber T., & Taye E. (2017a). Effects of planting density and number vertical on yield and yield component of south Ethiopia coffee selections at Awada, Sidama zone, Southern Ethiopia. *Academic Research Journal of Agricultural Science and Research, 5*(4), 313-319.

Nkonya, E., Von Braun, J., Alisher, M., Bao Le Q., Ho Young, K., Kirui, O., & Edward, K. (2013). Economics of land degradation initiative: methods and approach for global and National Assessments. ZEF- discussion papers on development policy no. 183, Bonn. https://doi.org/10.2139/ssrn.2343636

Ogada, M. J., Mwabu, G., & Muchai, D. (2014). Farm technology adoption in Kenya: a simultaneous estimation of inorganic fertilizer and improved maize variety adoption decisions. *Agriculture and Food Economics, 2*(12). https://doi.org/10.1186/s40100-014-0012-3

Ojo, T. O., Baiyegunhi, L. J., & Salami, A. O. (2019). Impact of credit demand on the productivity of rice farmers in South West Nigeria. *Journal of Economics and Behavioural Studies, 11*(1), 166-180. https://doi.org/10.22610/jebs.v11i1(J).2757

Paulos, A., & Belay, S. (2017). Household- and plot-level impacts of Sustainable land Management Practices in the face of climate variability and change: Empirical evidence from Dabus Sub-basin, Blue Nile River, Ethiopia. *Journal of Agriculture and Food Security, 6*(61), 1-12. https://doi.org/10.1186/s40066-017-0148-y

Pingali P., Schneider K., & Zurek M. (2014). *Poverty, agriculture and the environment: the case of Sub-Saharan Africa.* In: Marginality. Springer, Berlin. https://doi.org/10.1007/978-94-007-7061-4_10

Ponguane, S., & Mucavele, N., (2018). *Determinants of agricultural technology adoption in Chokwe district, Mozambique*. Munich Personal RePEc Archive, MPRA Paper No. 86284.

Prăvălie, R., Patriche, C., Borrelli, P., Panagos, P., Roșca, B., Dumitraşcu, M., Nita, I., Săvulescu, I., Birsan, M.V., & Bandoc, G. (2021). Arable lands under the pressure of multiple land degradation processes: A global perspective. *Environmental Research, 194*, 110697. https://doi.org/10.1016/j.envres.2020.110697

Salih, A., Ganawa, E., & Elmahl, A. (2017). Spectral mixture analysis (SMA) and change vector analysis (CVA) methods for monitoring and mapping land degradation/desertification in arid and semiarid areas (Sudan), using Landsat imagery. *Egyptian Journal of Remote Sensing and Space Science, 20*, S21-S29. https://doi.org/10.1016/j.ejrs.2016.12.008

Samuel, D., Agajie, T., & Beza, E. (2022). Determinants of adoption of climate-smart agricultural technologies and practices in the coffee-based farming system of Ethiopia. *Agriculture & Food Security, 11*(42), 1-14. https://doi.org/10.1186/s40066-022-00385-2

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

Senbetie, T., Tekle, L., & Sundaraa, R. D. (2017). Factors influencing the adoption of sustainable land management practices among farmers: The case of Boloso sore district in Wolaita zone, SNNPR, Ethiopia. *International Journal of Current Research, 9*(7), 5423624244.

Shiferaw, B., & Holden, S. (2008). Resource degradation and adoption of land conservation technologies in the Ethiopian high lands: a case study in Andit Tid, North Shewa. *Agricultural Economics, 18*(3), 233-247. https://doi.org/10.1111/j.1574-0862.1998.tb00502.x

Simtowe, F., Kassie, M., Diagne, A., Asfaw, S., Shiferaw, B., Silim, S., & Muange, E. (2011). Determinants of agricultural technology adoption: The case of improved pigeonpea varieties in Tanzania. *Quarterly Journal of International Agriculture, 50*(4), 325-345.

Studer, R. M., Providoli, I., & Liniger, H. (2016). Sharing knowledge to spread sustainable land management (SLM). In I. Chabay, M. Frick, & J. Helgeson (Eds.), *Land Restoration* (pp. 543-545). Academic Press. https://doi.org/10.1016/B978-0-12-801231-4.00035-5

Taddese, S. (2018). The impacts of land degradation on crop productivity in Ethiopia: A review. *Journal of Environment and Earth Science, 8*(11), 102-106.

Tesfa, A., & Mekuriaw, S. (2014). The effect of land degradation on farm size dynamics and crop-livestock farming system in Ethiopia: A Review. *Open Journal of Soil Science, 4*(1), 1-5. https://doi.org/10.4236/ojss.2014.41001

Tesfaye, A., & Brouwer R. (2016). Exploring the scope for transboundary collaboration in the Blue Nile River Basin: downstream willingness to pay for upstream land use changes to improve irrigation water supply. *Environment and Development Economics, 21*, 180-204. https://doi.org/10.1017/S1355770X15000182

Tesfaye, S. (2017). Determinants of adoption of Sustainable Land Management (SLM) practices among smallholder farmers' in Jeldu district, West Shewa zone, Oromia region, Ethiopia. *Journal of Science Frontier Research, 17*(1), 118-127.

Tongul, H., & Hobson M. (2013). *Scaling up an integrated watershed management approach through social protection programmers in Ethiopia: the MERET and PSNP schemes.* FAO, Sustainable Forest

Management (SFM) Toolbox.

von Braun, J., Gerber, N., Mirzabaev, A., & Nkonya, E. M. (2013). *The economics of land degradation* (No. 147910). University of Bonn, Center for Development Research (ZEF), Bonn. https://doi.org/10.2139/ssrn.2237977

Wagayehu, B. (2003). *Theory and empirical application to subsistence farming in the Ethiopian highlands*. PhD dissertation, Swedish University of Agricultural Sciences.

WOCAT. (2021). *The world overview of conservation approaches and technologies* [online]. Retrieved from https://www.wocat.net/en

Wossen, T., Berger, T., & Di Falco, S. (2015). Social capital, risk preference and adoption of improved farm land management practices in Ethiopia. *Agricultural Economics, 46*, 81-97. https://doi.org/10.1111/agec.12142

WWZARDO (West Wollgaga Zone Agricultural and Rural Development Office) (2021). *Annual report, Gimbi.*

Yenealem, K., Fekadu, B., Jema, H., & Belaineh, L. (2013). Impact of integrated soil and water conservation program on crop production and income in West Harerghe Zone, Ethiopia. *International Journal of Environment Monitoring and Analysis, 1*(4), 11-120. https://doi.org/10.11648/j.ijema.20130104.11

Yu, L., Hurley T., Kliebenstein J., & Orazen P. (2008). *Testing for complementarities and substitutability among multiple technologies: The case of U.S. hog farms*. Working Paper No. 08026. Ames, IA, USA: Iowa State University, Department of Economics.

Zemenu, D. A., & Minale, A. S. (2014). Adoption of soil conservation practices in North Achefer district, Northwest Ethiopia. *Chinese Journal of Population Resources and Environment, 12*(3), 261-268. https://doi.org/10.1080/10042857.2014.934953

Zerihun, N., Tsunekawa, A., Nigussie, H., Enyew, A., M., Nohmi, M., … Abele, S. (2017). Farmers’ perception about soil erosion in Ethiopia. *Land Degradation and Development,* 28, 401-411. https://doi.org/10.1002/ldr.2647