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Original Paper

Adoption of Sustainable Land Management Practices among Smallholder Farmers in Sekota District, North-eastern Ethiopia

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Abstract*— Despite the promotion of sustainable land management practices to enhance agricultural productivity by the government and non-governmental organizations, the adoption rate of these practices among smallholder farmers remains low. The present study aims to analyze the determining factors influencing the adoption of these practices and to identify the major challenges in adopting these practices. The data was collected from 267 households using a multistage sampling technique, which included a household survey, key informant interviews, and focus group discussions during the 2024 production season. Descriptive, inferential statistics and multinomial logit models were used to analyze the quantitative data, while the qualitative data was analyzed by narrations and conceptual generalization. The multinomial regression result shows that the adoption of livestock manure was positively influenced by household age, education, livestock holdings, and income (P ⩽ 10%), while the slope and farm size negatively influenced the adoption of livestock manure. Compost adoption was positively allied to education, livestock holdings, credit access, and training (P ⩽ 10%). The adoption of inorganic fertilizer was influenced by education, farm experience, credit access, and income (P ⩽ 10%), whereas age, slope, and farm size negatively influenced the adoption of compost and inorganic fertilizer. Integrated methods were positively influenced by education, livestock holdings, family size, credit access, and training (P ⩽ 10%), while the slope of farmland negatively affected the adoption of integrated methods. The majority of respondents expressed that changes in the price of agricultural inputs (44.94%), a lack of capital (19.1%), tenure security (16.1%), small livestock units (14.61%), and labor intensiveness (5.24%) were the major factors influencing their decisions. Consequently, boosting access to training, extension services, and credit, improving land productivity per unit area, and addressing the significant challenges specific to each practice are important for encouraging sustainable land management in the district.

Keywords*— Adoption, Land degradation, Land management, Multinomial logit, Sekota

I. INTRODUCTION

Land degradation and declining soil fertility are serious global problems particularly whose economies depend on agriculture. These problems lead to losses in food production and endanger food security worldwide, particularly in developing countries [1] & [2]. Currently, land degradation caused by human activities is negatively affecting the well-being of over 3.2 billion people, driving the planet towards a sixth mass extinction of species and resulting in the loss of more than 10% of the global annual GDP due to loss of biodiversity and ecosystem services [3]. It is growing in both severity and scale across many regions of the world. Over 40% of cultivated lands, 30% of forests, and 10% of grasslands are experiencing degradation [4]. Likewise, millions of hectares of land are degraded each year across all climate zones. In Sub-Saharan Africa, land degradation has become a major challenge to agricultural productivity and food security, where the livelihoods of the majority of the rural poor largely depend on rain-fed agriculture. It is widely recognized as a major threat to sustainable development and food production [5]. This has led smallholder farmers to experience very low incomes, trapping them in a cycle of permanent poverty. Moreover, the main driver of land degradation in Sub-Saharan Africa is the expansion and intensification of agricultural activities to feed its rising population [6].

In Ethiopia, agriculture remains a leading sector, contributing significantly to 35.45% of the country's total domestic output and playing a significant role in the country's economic development [7]. However, the agriculture sector faces persistent challenges related to soil degradation and erosion, leading to declines in both crop and livestock productivity [8]. Land degradation is a major cause for declining crop productivity, food insecurity, and extreme poverty, all of which directly influence the agricultural sector. Additionally, negatively affects the health, well-being, and livelihood opportunities of individuals [9]. The total estimated annual soil loss from Ethiopia's cultivated lands, rangelands, and pastures ranges from 1.3 to 7.8 billion metric tons per year [10]. Additionally, in the Amhara region, land degradation is a major threat resulting in the reducing agricultural productivity, food insecurity, poverty, and social conflict [11]. Like other areas of the Amhara region, Sekota district is also a highly vulnerable area to the problem of land degradation.

Therefore, to avert this problem the government of Ethiopia and developmental agencies have implemented various sustainable land management initiatives aimed at rehabilitating degraded farmlands and improving soil fertility and agricultural productivity. Sustainable land management has the potential to enhance agricultural productivity and soil health while also mitigating environmental impacts [12]. Adopting sustainable land management provides benefits such as ensuring environmental services, enhancing food security, and reducing poverty [13]. One of the key components of this strategy involves the use of land management practices across the country such as composting, livestock manure, inorganic fertilizers, crop rotation, integrated methods, Etc. These practices are effective in enhancing soil fertility [14]. However; the adoption rate of these practices among smallholder farmers remains alarmingly low, this low adoption is hindered by a range of demographic, socio-economic, institutional, and biophysical [14]. Moreover, Sekota district is one of the areas where land management practices have been practiced. Although various efforts have been conducted to improve agricultural productivity and soil fertility through enhanced environmental conditions, the adoption of sustainable land management practices on the household level has not yet been systematically investigated. Therefore, the purpose of this study is to analyze the determinant factors influencing their adoption decisions and identify the major challenges in adopting sustainable land management practices in the Sekota district.

A. Conceptual Framework of the Study

Though reviewing the previous studies, it is attempted to develop the following conceptual framework. The framework considers the influence of different factors on the adoption decision of sustainable land management practices. In which the adoption of sustainable land management practices is viewed as a dependent variable. The decision of a household to adopt sustainable land management can be driven by demographic, institutional, socioeconomic, and physical factors as indicated in Fig I below. It is important to know the relationship between these factors and the process of adoption of new technology to improve agricultural productivity and sustainable land management. It is assumed that the farmers will compare the advantages and appropriateness of different soil management technologies. These four factors listed above can positively or negatively influence the decision of farmers to adopt sustainable land management practices. Therefore, the conceptual framework of the adoption of land management practices in this article is based on the principle of absolute and comparative advantage to farmers in combination with some influence of demographic, socioeconomic, institutional, and biophysical factors.

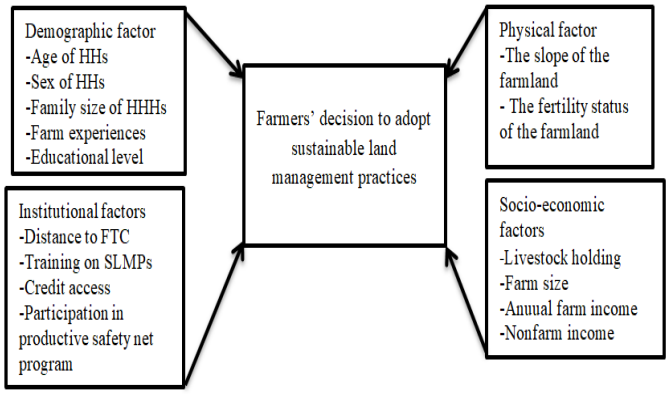

Fig. 1. Conceptual framework on land management practices
Source: Own sketch based on literature review, 2024

II. RESEARCH METHODOLOGY

A. Description of the Study Area

This study was carried out in the Sekota district, located in northeastern Ethiopia. Sekota is one of the seven districts in the Waghimra administrative zone of the Amhara region, situated at a latitude of 12° 37′ 31″ N and a longitude of 39° 02′ 06″ E. The elevation of the district is 2119 meters above sea level. It is surrounded by Gazgibla to the south, Dehana to the west, Ziquala to the northwest, Abergele to the north, and the Tigray region to the east. The district contains 25 rural kebeles and spans an area of 167,156. 07 hectares. Approximately 112,259 people live within this district. The average maximum temperature annually ranges between 23. 1°C and 28. 6°C and the area experiences an unpredictable rainfall pattern, with annual rainfall averaging between 329mm and 833mm. Most of the precipitation occurs between the fourth week of June and the end of August. Rainfall in the district is typically inconsistent and uneven, lasting no more than two months each year, primarily from late June to late August. This short rainy season often leads to dry spells, recurrent droughts, and unreliable rainfed farming within the district. Mixed agriculture is the primary economic activity in the area. Crop cultivation and livestock raising are both practiced as vital sources of income. The district is particularly recognized for its potential in goat and cattle farming, as well as honey production. Commonly cultivated crops in Sekota include sorghum, teff, wheat, barley, and faba beans. Natural tragedies frequently impact the area, affecting the agricultural output of local smallholder farmers. The main challenges faced comprise drought, shortage of rainfall, and intimidations from crop pests and diseases that hamper both agricultural production and livestock health.

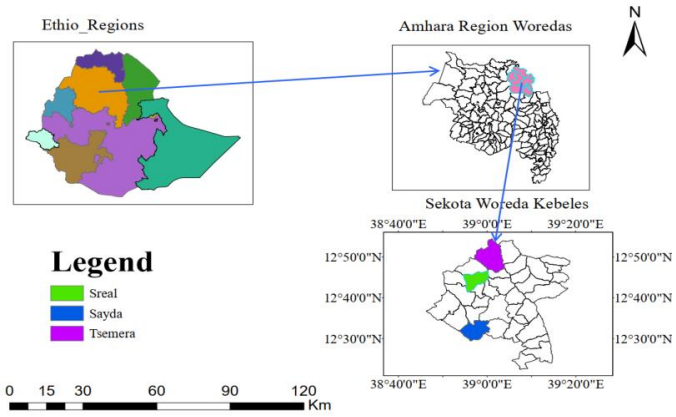

Fig. 2. Map of the study area

Source: Own sketch (GIS, 2024)

B. Data Types, Sources and Data Collection

In the study, to meet the objectives of the study both quantitative and qualitative data was gathered from primary and secondary sources. The primary quantitative data from the household survey was collected using structured questionnaires. To improve the questions and eliminate ambiguities these questions were pre-tested with thirty farmers outside the sample kebeles. The household survey is attentive to the respondents' demographic, socioeconomic, institutional, and biophysical features in nature expected to represent the entire population concerning the study objectives. In addition to structured questionnaires, focus group discussions (FGDs), key informant interviews (KIIs), and field observation were carried out to gather additional information regarding major encounters in adopting sustainable land management practices. Furthermore, the secondary data for the study was collected from zonal and district agricultural office reports, journal articles, books, and proceedings. The survey was conducted in March and April 2024. Finally, to prevent potential harm and confidentiality respondents were given reference codes instead of names.

C. Sampling Methods and Sample Size Determination

The study used a multistage sampling technique to select the sample households. In the first stage, Sekota district was selected purposively due to the prevalence of land degradation problems, soil fertility losses, and a variety of sustainable land management practices introduced in the district besides its accessibility. In the second stage, three representative kebeles (Tsemera, Sayda, and Sireal) were selected by using random sampling from 25 rural kebeles in the Sekota district. Finally, a total of 267 household heads were selected using a simple random sampling technique based on the size of each kebeles. The sample size was determined through the Cochran formula (1963) described in [15] & [16].

$$n = \frac{Z^2 Pq}{e^2} \quad \text{.....(1)}$$

$$n = \frac{1.96^2 (0.5\ x\ 1-0.5)}{(0.06)^2} \quad \text{.....(2)}$$

Where:- **n** is the number of samples, **Z** is the confidence level related to the risk of error, which equals 1.96 for an error risk of 5% level of significance; **P** is the proportion of total farmers adopter of land management practices, in this case, it was assumed to be 0.5 because 50% of the smallholder farmers are user/adopter land management practices; **q** equals (1-p) representing the showing the proportion of farmers who do not use land management practices among the total number of farmers while **e** is the precision level, set at 0.06.

D. Method of Data Analysis

In this study, both descriptive and inferential statistics were employed to analyze the quantitative data. Descriptive statistics such as mean, standard deviation, percentages, and frequencies were used to describe various aspects of households and sustainable land management practices implemented by farmers. Inferential statistics such as (a t-test for continuous variables and a chi-square ($\chi 2$) test for dummy/categorical variables) were employed to compare the mean/association of socioeconomic characteristics between adopters and non-adopters of sustainable land management practices. The multinomial logit model was used to analyze determinant factors influencing the adoption decision of sustainable land management practices. Qualitative data obtained from focus group discussions and key informant participants were analyzed by summarizing, interpreting, and narrating.

E. Econometric analysis

In this study, both descriptive and inferential statistics were employed to analyze the quantitative data. Descriptive statistics such as mean, standard deviation, percentages, and frequencies were used to describe various aspects of households and sustainable land management practices implemented by farmers. Inferential statistics such as (a t-test for continuous variables and a chi-square ($\chi 2$) test for dummy/categorical variables) were employed to compare the mean/association of socioeconomic characteristics between adopters and non-adopters of sustainable land management practices. The multinomial logit model was used to analyze determinant factors influencing the adoption decision of sustainable land management practices. Qualitative data obtained from focus group discussions and key informant participants were analyzed by summarizing, interpreting, and narrating.

The multinomial logit model delivers a convenient closed form solution for the underlying choice probabilities without any prerequisite of multivariate integration. Therefore, choice situations characterized by many alternatives can be treated in a computationally convenient way [17]. When the dependent variable has more than two alternatives, the appropriate econometric model would be either a multinomial logit or a multinomial probit model. The multinomial logit regression model was used to express the probability of a farmer being in a particular category chosen [18].

Before running the model diagnostic tests are carried out to check the problem of multicollinearity and heteroskedasticity in the data. A variation inflation factor (VIF) test is carried out to check multicollinearity issues in the data. Similarly, both Breusch-Pagan/Cook-Weisberg and

White's test is tested to check the problem of heteroskedasticity issue in the data.

TABLE I. DESCRIPTION OF EXPLANATORY VARIABLES AND EXPECTED RELATIONSHIPS

Outcome Variables			
1.	Compost	If 1, the household adopts sustainable land management practices, & 0, don't adopt.	
2.	Livestock manure		
3.	Integrated methods		
4.	Inorganic fertilizer		
Explanatory Variable	Type of Variable	Expected Relationship	Description of the Variable
SexHH	Dummy	+	A value of 1 if the household head is male and 0 for Female
AGEHH	Continuous	+/-	The age of the household is measured in years.
FamSize	Continuous	+	Family size measured in the adult equivalent
EduStat	Dummy	+	A value of 1 if the household head is literate & 0 otherwise
TLU	Continuous	+	The number of livestock owned by the household
PSNP	Dummy	+	A value of 1 if the household participates in a productive safety net program & 0 otherwise
FarmSize	Continuous	+/-	The total farm size measured in minutes
FarmExp	Continuous	+	Farming experience of the household
SlopLand	Categorical	-	If, 1= the slope of land is flat, 2= moderate, 3 gentle slope
DistFarm	Continuous	-	Distance to farmland measured in minutes
DisFTC	Continuous	-	Distance to farmer training center measured in minutes
ExtServ	Dummy	+	A value of 1 if the household had accessed extension service & 0 otherwise
TrainAcc	Dummy	+	A value of 1 if the household had accessed training & 0 otherwise
CreditAcc	Dummy	+	1 if the household had accessed credit & 0 otherwise

III. RESULT AND DISCUSSION

A. Descriptive Statistics

1) Demographic characteristics of the households

The result of descriptive analysis of the demographic, socio-economic, physical, and institutional characteristics of the sampled farm households is given in Table II. From the total respondent samples, 82.4% and 17.6% were male-headed and female-headed households, from this 96.3%, 2.6%, and 1.1% are married, divorced, and widowed respectively. The average age of the sample respondent farmers was 49.76. this result indicated that most of the household heads were relatively young and belonged to the economically active age and productive labor forces. Moreover, the education status of farmers is assumed to increase their ability to be aware of the consequences of land degradation and use information relevant to the use of improved agricultural technologies. In the present study, about 62.6% of the sample respondents were illiterate, while only 37.4% of the respondents have various education levels ranging from the ability to read and write up to diploma completion. From the total respondent samples average family size of respondents was 5.83 in adult equivalent. The average farm experience of the sample household in land management was 25.71 years with a standard deviation of 8.7 which was enough to perceive sustainable land management practices. Therefore, the two-group comparison (t-test) result indicated significant differences between adopter and nonadopter households ($P \leqslant 10\%$) among groups in terms of age, family size, and farming experience. Similarly, the chi-square ($\chi 2$) test revealed significant differences among groups in their gender and education status.

TABLE II. DEMOGRAPHIC CHARACTERISTICS OF THE SAMPLE HOUSEHOLDS (N=267)

Variables		Adopter	Non-adopter	Overall	t-value
Age	Mean	48.8	50.72	49.76	13.79***
	SD	9.3	9.31	9.3	
Family size	Mean	5.9	5.76	5.83	2.66**
	SD	1.6	1.31	1.5	
Farm experiences	Mean	26.63	24.8	25.71	9.86***
	SD	9.1	8.33	8.7	
	Dummy/categorical			Percentage	$\chi 2$
Sex	Male	58.1	24.3	82.4	7.7958*
	Female	11.2	6.4	17.6	
Marital status	Married	66.7	29.6	96.3	7.3861
	Divorced	2.2	0.4	2.6	
	Widowed	0.4	0.7	1.1	
Education	Illiterate	36	26.6	62.6	36.141***
	Literate	33.3	4.1	37.4	

***, ** and * significant at 1%, 5% and 10% respectively, n = total samples
Source: Own survey computation (2024)

2) Socio-economic characteristics of the households

From the total samples, the average farm size was 0.913 hectares with a standard deviation of 0.3, this implies that farmers with higher capital assets could easily afford to adopt land management practices. In addition, the average size of the households in tropical livestock units was 6.74 with a standard deviation of 4.5, this could contribute to the household's overall resource base for adopting land management practices, the average annual farm income of respondents farmers was ETB 11,034.44, this annual farm income mainly comes from the selling of livestock and their products, crops, and fruits and vegetables. The annual average off-farm income of the sample respondents was ETB 13,777 ETB. Hence, involvement in remittance (productive safety net program and short relief) (18%) followed by labor employment in any private enterprises (16.9%), seasonal trade (7.5%), and employment in governmental work opportunities (1.5%) were identified as the main sources of off-farm income. Likewise, the average distance of the farmer training center was 41.5 minutes with a standard deviation of 18.84, this implies that farmers who are located far from the farmer training center were less likely to adopt land management practices, and the average distance of farmland was 34.43 minutes with a standard deviation of 14.21. Furthermore, the t-test result indicated a significant difference between adopter and non-adopter households in most continuous socio-economic variables except off-farm income and distance to farmland ($P \leqslant 5\%$).

TABLE III. SOCIO-ECONOMIC CHARACTERISTICS OF THE HOUSEHOLDS (N=267)

Variables		Adopter	Non-adopter	Overall	t-value
Farm size	Mean	0.91	0.92	0.915	4.31***
	SD	0.3	0.34	0.3	
TLU	Mean	8.4	4.81	6.6	13.18***
	SD	3.1	5.94	4.5	
Annual farm income	Mean	15764	6304.88	11034.44	2.55**
	SD	27271.56	11729.13	29448.57	
Off-farm income	Mean	13407.7	14146.34	13777	0.91
	SD	35843.4	55975.11	40460.624	
Distance to FTC	Mean	33.73	49.27	41.5	17.354***
	SD	15.33	22.36	18.84	
Distance to plot	Mean	33.8	35.06	34.43	2.566
	SD	15	13.435	14.21	

***, ** and * significant at 1%, 5% and 10% respectively, n = total samples
Source: Own survey computation (2024)

3) Institutional characteristics of the households

Institutional characteristics of the households were expected to influence the adoption decisions of sustainable land management practices either positively or negatively. Credit is one of the institutional variables, it is important to resource-poor farmers who cannot finance agricultural input purchases from their savings. From the total respondent samples, about 31.1% of respondents had accessed credit from formal and informal institutions whereas 68.9% of the households did not have credit access. Almost 85% of the sample households accessed credit from formal institutions like Tsedey Bank, while the other nearly 15% of the sample households had accessed credit from informal institutions; for example, from Mahiber, Equb, and Edir. Also, training is another institutional variable that has significant importance for the capacity building of farmers about land management practices. In the study, 56.2% of households had access to training related to land management practices, while the other 43.8 of respondents did not have training access to land management practices. The provided training was mainly on compost preparation, fertilizer utilization, applying full technology package, and disease and pest management. In addition, extension service is one of the important parameters for disseminating a particular technology within heterogenous societies so in the study area 49.4% of respondents had received extension service once a month, 15% twice a month, and 6% three times a month, while 29.6% of respondents did not access any extension service in a month. Likewise, in terms of land allocation 11.9% of respondents were inherited from

parents, 65.4% were allocated by Kebele, 17.7 % through sharecropping, and 4.9% through renting. From the total sample of respondents, 42.3% of households were engaged in productive safety net programs and short relief the remaining 57.7% of sample households were not engaged in productive safety net programs and short relief. Furthermore, the χ2- test indicated a significant difference between adopter and non-adopter households in most institutional characteristics of the households (P ⩽ 10%).

TABLE IV. INSTITUTIONAL CHARACTERISTICS OF THE HOUSEHOLDS (N=267)

Variables	Description	Percentage		Overall	χ2
		Adopter	Non-adopter		
Credit access	No	41.9	27	68.9	29.7045***
	Yes	27.3	3.7	31.1	
Training	No	30.7	13.1	43.8	41.6230 ***
Access	Yes	38.6	17.6	56.2	
Productive safety net program	No	35.2	22.5	57.7	22.6683***
	Yes	34.1	8.2	42.3	
Land allocation	Inherited from parents	5.6	7.1	11.9	30.4559***
System	Allocated by *Kebele*	45.3	19.1	65.4	
	Sharecropping	9.4	4.1	17.7	
	Renting	1.5	0.4	4.9	
Extension contact	No contact in a month	22.1	7.5	29.6	20.316*
	Once in month	34.8	14.6	49.4	
	Twice in month	8.6	6.7	15	
	Three times in month	3.7	3.7	6	

***, ** and * significant at 1%, 5% and 10% respectively, n = total samples
Source: Own survey computation (2024)

Participation in local community institutions was the other institutional characteristic that could influence the adoption of land management practices among smallholder farmers, in the study area; almost 100% of the sample household respondents were members of at least one of the informal institutions. Thus, 5.6%, 29.2%, 4.1%, 44.6%, and 16.5% of sample households were members of mahiber, zikir, debo, mahiber+zikir, and mahiber+zikir+debo respectively. These informal institutions have a significant role in the technology adoption process to discuss issues regarding to land management practices in the periodic meetings of the event. Mahiber and Zikir are monthly Orthodox Christian gatherings honoring Angels or Saints, where farmers pray, share food, drink Tela, and discuss agricultural issues. Debo or Webera are rotational working groups in rural communities of Ethiopia particularly in the study area, based on relationship and nearness, focusing on shared labor to address issues related to land degradation and agricultural challenges [19].

TABLE V. HOUSEHOLD PARTICIPATION IN INFORMAL INSTITUTIONS

Informal community institutions	Frequency	Percentage (%)
Mahiber	15	5.6
Zikir	78	29.2
Debo	11	4.1
Mahiber & Zikir	119	44.6
Mahiber, Zikir & Debo	44	16.5

4) Physical characteristics of the sampled plots/farmlands

The physical characteristics of farm plots are indicated in Table VI. From the total sample households, 90.3% of respondents have their own farmland, while the other 9.7% of the households do not own farmland and they are participating in sharecrops and renting of lands. Respondents classified each farm plot into flat, moderate slope, and gentle slope. From the total sample farmers only 23.6%, 48.6%, and 27.7% of the land was flat, moderate slope, and steep slope respectively. Respondents have also identified their plot's fertility status into three categories very fertile, medium, and poor. Based on this classification, from a total of 267 farm plots 6%, 43.8%, and 50.2% were considered very fertile, medium, and poor respectively. The descriptive result indicated that from the total respondents, 78.3% of smallholder farmers perceived that the current status of the soil fertility of the farmland was decreasing, while 12.7% and 9% of respondents perceived it as having no change and increasing respectively. Therefore, the x 2- test indicated a significant difference between adopter and non-adopter households in the slope of the land and the current soil fertility status of the land (P ⩽ 10%).

B. Farmer Implemented Sustainable Land Management Practices

The survey result indicated that farmers implement a variety of sustainable land management practices such as crop rotation, livestock manure, integrated methods, and the use of inorganic fertilizers. Among these, crop rotation was most widely used by smallholder farmers in the district which accounts for, followed by livestock manure, integrated method, and inorganic fertilizer respectively, and compost was the least implemented land management practices by the farmers.

C. Determinants of Adoption of Sustainable Land Management Practices

The multinomial logit model estimation gave rise to a Pseudo R2 = 0.3509 implying that most of the independent variables were relevant to the model. The likelihood ratio test was significant at 1% with a chi-square test statistic (219.03) as shown in (Table VII). The base category was crop rotation of any of the practices of which the farmers commonly used this practice in the study area. One crop rotation adopter was sampled from each community for the base outcome requirement of the multinomial logistic regression. Given the above measures, it is determined that the applying Multinomial logit model was appropriate for evaluating the smallholder farmers' adoption decision on land management practices. As per the regression rule before running the model, diagnostic tests were carried out to check the problem of multicollinearity and heteroskedasticity in the data. A variance inflation factor

(VIF) test was carried out to check multicollinearity issues in the data. According to [20], if the VIF is greater than the critical value of 10, then multicollinearity is a major problem. Therefore, in our study, the VIF value was 1.43, which is below 10 suggesting that multicollinearity among the variables did not exist. Likewise, both Breusch-Pagan/Cook-Weisberg and White's test was also conducted for the outcome equation to test for possible heteroscedasticity in the model. The chi-square test statistic for the test was statistically significant at the 1% level, which indicates that in the data there was the existence of a heteroscedasticity issue. To resolve the presence of heteroscedasticity, the outcome equation was estimated with robust standard errors.

1) Factors influencing smallholder farmers' adoption of livestock manure

The age of the household positively and significantly affects the probability of smallholder farmers' decision to adopt livestock manure at a 10% significance level. This implies that a unit increase in the age of the household makes the selection of livestock manure more likely compared to crop rotation practices (base outcome). This suggests that as farmers become older they may give more emphasis on investing in livestock manure, as they tend to have larger livestock units and better farm experience, leading to a better understanding of the benefits of using livestock manure. The older farmers' were more likely to apply livestock manure in their farmlands than younger farmers. This study is consistent with the findings of [21] who found that the age of the household head increases their decisions to adopt land management practices also increases, as well as the age of households was found to have a positive and significant effect on the adoption of livestock manure [22].

Also, the education status of the household has a positive and significant effect on the probability of adoption decision of livestock manure at a 10% significant level. This implies that educated households were more likely to adopt livestock manure compared to crop rotation. This might be because the educated farmers may have good knowledge and a better understanding of the importance of land management practices, they believed that livestock manure has better qualities for soil fertility enhancement than crop rotation, this result is in line with the finding of [23], who stated that the level of education of households has positively and significantly affected the adoption of soil fertility management practices. This study contradicts the research conducted in Ethiopia, the educational status of the households negatively affects the adoption choice of livestock manure [24]. The farm size of the household negatively and significantly affects the probability of farmers' decision to adopt livestock manure at a 10% significance level. This implies that a unit increase in the farm size of the household makes the selection of livestock manure less likely compared to crop rotation. This is because a farmer who has a large farm size can't address all farms with livestock manure due to inadequate manure which hinders the adoption status of livestock manure. This result contradicts the findings conducted in Ethiopia, South Asia and Kenya, which suggested that the farm size of the households has a positive and significant relation with livestock manure, hence the likelihood of livestock manure adoption increased with farm size [7], [25] & [26].

Additionally, the number of years of farming experience significantly increased the probability of smallholder farmers' decision to adopt livestock manure at a 5% significant level. The results indicate that a unit increase in the farming experience of the household makes the selection of livestock manure more likely compared to crop rotation practices. This might be because more experienced farmers accumulate farm skills for several years of farming more knowledge over time which increases their likelihood of adopting soil fertility improvement practices. The result is consistent with studies by [27], who noted that more experienced farmers accrue more knowledge over time which increases their likelihood of adopting soil fertility improvement practices. The number of livestock a household owns is positively and significantly related to the probability of the farmers' decision to adopt livestock manure at a 5% significant level. This implies that a unit increase in the livestock unit of the household makes the selection of livestock manure more likely compared to crop rotation practices. Smallholder farmers may consider that using manure from their livestock is cheaper than purchasing other labor-intensive technologies. Hence, this may be the smallholder farmers with relatively higher ownership of assets and livestock holding tend more to livestock manure and have large flocks (herds) they can easily access and facilitate the livestock manure in their farmland. This finding is similar to studies in northwestern Ethiopia, which facilitate the disposal of dung matter for livestock manure application [28].

Whereas, the slope status of the plot negatively and significantly affects the adoption decision of livestock manure at 1% significant level. This implies that the slope of farmland becomes steeper makes the household less likely to adopt livestock manure compared to crop rotation. This might be because the sloppy farmland will be susceptible to erosion and washed organic matter of the livestock manure by runoff water due to this farmers are unwilling to adopt livestock manure on sloppy plots. This result is consistent with the findings conducted in Ethiopia that stated that the slope of the farmland negatively affected manure adoption [24]. This study contradicts the findings of [23] conducted in the Oromiya region, Ethiopia, positive and significant influence on the likelihood of adopting organic fertilizers. Besides, the distance of the farmer training center has negatively and significantly affected the probability of adoption decision farmers' decision to adopt livestock manure at a 1% significant level. The results indicate that the distance to the FTC increases and smallholder farmers are less likely to choose livestock manure as compared to crop rotation practices. This might be because the extension service center is far from the household residence makes it difficult to access and decreases their likelihood of adopting soil fertility improvement practices. This study is in line with the findings of [29] and [24] who stated that distance to extension service negatively and significantly affects the probability of adoption decision livestock manure.

2) Factors influencing smallholder farmers' adoption of livestock manure

The age of the household heads is negative and significantly affects the probability of adopting compost at a 10% significant level. The results indicate that an increase in the age of the household heads makes smallholder farmers less likely to choose compost as compared to crop rotation practices. The negative relationship between the age of the households and the use of compost can also be linked to the bulkiness and labor-intensive nature of the resource. It is also related to complex technology in terms of applicability than other land management practices so older farmers are reluctant to adopt compost. This result is reliable to the findings of [30], who found that the age of the household negatively affects the probability of adopting compost technology. This result opposes the findings conducted in Northern Ghana, which found that younger household heads are less likely to adopt compost than older farmers [31].

Moreover, the educational status of the household has a positive and significant effect on the adoption decision of compost at a 1% significant level. This implies that educated households were more likely to adopt compost over crop rotation. This is due to educated farmers having a better understanding and early adopters having the ability to perceive the new technology and have a good understanding about the benefits of the compost, hence educated farmers are adopting compost technology than non-educated. This result agrees with the findings of [30] suggest the education status of the households positively and significantly influenced the probability of adoption of compost in the farmlands. This result contradicts the findings of [32] which explain education status of the household has a negative influence on the adoption of compost (organic fertilizer). The regression analysis revealed that the number of livestock owned by farmers has positive and significant effects on the probability of adopting compost at a 10% significant level. This implies that a unit increase in livestock units of the household makes the selection of compost more likely compared to crop rotation practices. This is because livestock manure is one of the inputs used for compost application due to this farmer who has large livestock units adopting compost. This finding is reliable to the findings of [33], livestock ownership has a positive and significant effect on the adoption of compost, and this conforms with the findings of [27] studies, which reported that livestock ownership positively influences the adoption of compost in Ghana, and found that livestock ownership increases access to animal waste as well as the quantity of waste from the animals for compost preparation [27].

The slope of the land had negatively and significantly affected the adoption of compost at a 1% significance level. This implies that the slope of the land becomes steeper making the household less likely to adopt compost over crop rotation. This specifies that steep land is more exposed to erosion which led the washing out of compost from the farmland due to this farmers are reluctant to adopt compost for those who have sloppy farmland. This result meets the findings which found slope status of the land has negative and significant effects on the probability of adopting compost conducted in Amhara Region, Ethiopia [32]. The regression analysis of this study revealed that the participation of households in the productive safety net program positively and significantly affects the adoption decision of compost at a 5% significance level. This suggests that the households who participate in a safety net program are more likely to adopt compost over crop rotation practices. This implies households who participate in productive safety net programs easily access information and training from extension agents in addition to this they get direct and indirect incentives for their work because of this farmers adopt a compost technology. This result opposes the findings of [21], who found that it is negatively associated with the adoption of land management practices conducted in South Wollo zone, Ethiopia.

The training status of the household had a positive and significant effect on the probability of the adoption decision of compost at a 1% significance level. This infers that households who accessed training are more likely to choose compost compared to crop rotation. This infers that farmers were able to adopt the technology because they were advanced with information and captured more skills and knowledge about the technology. This result is in line with the finding that stated training positively and significantly influenced the adoption of compost [34]. On the other hand, access to credit for farmers is one of the most important sources of finance to address the constraints associated with the adoption of sustainable land management practices and to purchase agricultural inputs. Due to this credit access has a positive and significant influence on the adoption of compost at a 10% significance level. This suggests that a household who accessed credit is more likely to choose compost over crop rotation. This result confirms the findings of the [22] studies, which revealed a positive and significant effect on the adoption of sustainable agricultural practices in Ghana.

3) Factors influencing smallholder farmers' adoption of inorganic fertilizer

The age of the household head had a negative and significant effect on the adoption of inorganic fertilizer at a 1% significance level. The result implies the age of the household heads increases, smallholder farmers are less likely to choose inorganic fertilizers as compared to crop rotation practices; hence older farmers are less likely to adopt inorganic fertilizers rather than younger farmers. This contradicts the age of the households has a positive and significant relation with the adoption of inorganic fertilizer [35] & [22]. Also, the education status of the household head had positively and significantly affected the probability of adoption decision of inorganic fertilizer at 5% significance levels. The result implies that educated households were more likely to adopt inorganic fertilizer compared to crop rotation. This infers education is a powerful instrument for development so educated household heads are more likely to adopt inorganic fertilizers than non-educated household heads. This finding is similar to studies conducted in Oromiya region, Ethiopia [35], which found the education status of the household heads has positive and significant effects on the adoption probability of inorganic fertilizer. Similarly, research conducted in South Asia, found that the education status of the households is significant and positively influenced the adoption of inorganic fertilizer [25]. This result contradicts the findings of [31] found that educated households are less likely to adopt inorganic fertilizers.

The farming experience was significant and positively influenced the probability adoption decision of inorganic fertilizer at a 5% significance level. This entails that a unit increase in a household's farming experience makes the selection of inorganic fertilizer more likely compared to crop rotation. This denotes that more experienced farmers who have a good background and knowledge about inorganic fertilizers are more likely to adopt inorganic fertilizers than those who do not have experience. This is in line with the findings of [24], who found that inorganic fertilizer was positively influenced by farming experience. Additionally, the livestock holdings of the households had a positive and significant effect on the adoption of inorganic fertilizer used at a 5% significance level. The result implies that a unit increase in the livestock unit of the household makes the selection of inorganic fertilizer more likely compared to crop rotation. Livestock is one of the financial assets that can generate income to purchase inorganic fertilizer and other inputs. This result agrees with the finding that stated livestock units of the households affect adoption choices of inorganic fertilizer positively and significantly [35]. While this finding contradicts the study conducted in the Oromiya Region, Ethiopia stated that livestock ownership has a negative and significant effect on the adoption of inorganic fertilizer[36].

Having credit access as a farmer is not an easy opportunity to address developmental issues to satisfy the agricultural inputs and outputs in developing nations, like Ethiopia. Therefore, in this study access to credit to adopt inorganic fertilizer is significant to ensure food security in the study area. Hence, having credit access in either cash or kind has a positive and significant effect on the adoption of inorganic fertilizer at a 1% significance level. The result entails that households who access credit makes it more likely to choose inorganic fertilizer over crop rotation, so this result is comparable to the findings of [25], and [35], who suggest that having credit access positively and significantly influences the adoption probability of inorganic fertilizer. On the other hand, access to training related to sustainable land management is important for the capacity building of smallholder farmers. Thus the training status of the households has a positive and significant influence on the adoption of inorganic fertilizer at a 1% significance level. The result suggests that households who accessed training are more likely to choose inorganic fertilizer over crop rotation. This result is consistent with the training status of the households that had a positive and significant relation with the probability of adopting inorganic fertilizer which was conducted in South Asia [25].

The regression analysis result revealed that the participation of households in the productive safety net program positively and significantly influenced the probability of the adoption decision of inorganic fertilizer at a 5% significant level. The result indicates that a household that participated in the productive safety net program is more likely to choose inorganic fertilizer compared to crop rotation. This might be because households who participate in productive safety net programs get incentives for their work due to this farmers are motivated to apply agricultural technologies such as inorganic fertilizer. This result denies the finding conducted in the South Wollo zone, Ethiopia which found that a productive safety net program was negatively associated with the adoption of land management practices [21] and [25] reported that government subsidy plays a significant role in fertilizer adoption. In addition, institutional factors such as the distance of the farmer training center have negative and significant effects on the probability of adoption choice of inorganic fertilizer at a 5% significant level. The result entails that an increase in the distance to FTC makes the household less likely to choose inorganic fertilizer over crop rotation. This infers if the households are far from the extension service they do not access any information and knowledge regarding inorganic fertilizer due to this reason farmers are reluctant to adopt it. This finding in line with the distance of extension farmer training center service is significantly and negatively linked with the adoption of inorganic fertilizer [29] & [31]. Farmers located near agricultural extension agents are more likely to adopt each of the practices. The result is expected since the practices are knowledge-based technologies.

4) Factors influencing smallholder farmers' adoption of integrated methods (livestock manure + inorganic fertilizer)

The regression analysis result revealed that the family size of households has positively and significantly influenced the probability of the adoption decision of livestock manure + inorganic fertilizer at a 5% significant level. The result indicates that a unit increase in family size makes households more likely to choose integrated methods compared to crop rotation. This implies that a larger family size will make more labor available to adopt a new technology, which may require the farmer to carry out labor-intensive activities. It is expected that a farmer with a large family will eagerly adopt new technologies. This result agrees that family size had a positive and significant effect on the adoption of integrated practices [37], [38] & [26]. This result contrasts with the finding that family size has a negative and significant effect on the adoption probability of integrated practices [39]. The livestock ownership of the household positively and significantly affects the probability of adoption choice of int livestock manure + inorganic fertilizer at a 10% significant level. The result indicates that a unit increase in livestock units makes households more likely to select integrated methods over crop rotation. This entails that households with a large number of livestock units are more likely to adopt livestock manure + inorganic fertilizer to obtain more manure. Livestock serve as sources of labor and finance to purchase agricultural inputs. This finding is consistent with the research that stated livestock ownership of the households positively and significantly affects the adoption decision of livestock manure + inorganic fertilizer in Kenya [26], and in Amhara Region, Ethiopia [38].

Furthermore, credit access has a positive and significant influence on the adoption decision of livestock manure + inorganic fertilizer at a 1% significance level. The result implies that a household that accessed credit is more likely to choose manure + inorganic over crop rotation. This infers that farmers who have access a credit are more likely to adopt livestock manure + inorganic fertilizer than others. This result is similar to research that household access to credit positive and significant effect on the adoption decision of integrated practices in Kenya [26], Ghana [37], and Ethiopia [38] suggests farmers who willingly obtain credit will more likely

adopt integrated soil fertility management technologies than others. The education status of the household significantly affects the adoption decision of livestock manure + inorganic fertilizer at a 1% significance level. The result implies that educated households were more likely to choose livestock manure + inorganic fertilizer compared to crop rotation. Education is a human capital that enhances farmers' proficiency in acquiring and applying new information. Therefore, smallholder farmers who access education are more likely to adopt integrated technologies. This result agrees with the findings of [26], and [37] found that the education status of the household has positive and significant effects on the adoption decision of integrated practices.

Moreover, the training status of the household on land management practices positively and significantly affects the adoption decision of livestock manure + inorganic fertilizer at a 5% significant level. The result entails that a household that accessed training is more likely to choose manure + inorganic over crop rotation. Training related to land management practices is necessary for smallholder farmers to empower knowledge and skills. Therefore, farmers who access training are more likely to adopt livestock manure + inorganic fertilizer than others. This finding agrees with the findings of [26] and [40] that the training status of the household head on land management practices positively and significantly influenced the adoption probability of integrated practices. The slope of the farmland of the households had negatively and significantly affected the adoption probability of integrated methods at a 5% significant level. The result implies that households who had steep slope land were less likely to choose livestock manure + inorganic fertilizer over crop rotation. This implies a farmer who has steep slope farmland is less likely to adopt livestock manure + inorganic fertilizer than others because the steep land is vulnerable to runoff and the micronutrients are washed by water. This result contradicts the findings of [23] that the slope of farmland positive and significant effect on the adoption choice of land management practices choices.

TABLE VI. MULTINOMIAL LOGIT ESTIMATION OF THE FACTOR INFLUENCING THE ADOPTION OF SUSTAINABLE LAND MANAGEMENT PRACTICES (ROBUST STANDARD ERRORS)

Variables	Livestock manure	Compost	Inorganic fertilizer	Livestock manure + Inorganic fertilizer
Sex	0.47(0.73)	1.09(1.08)	0.46(0.71)	0.09(0.72)
Age	0.06(0.04)*	-0.09(0.06)*	-0.12(0.04)***	-0.05(0.04)
Education	0.98(0.54)*	2.35(0.91)***	1.17(0.57)**	1.81(0.53)***
Family size	-0.09(0.20)	0.20(0.36)	0.18(0.24)	0.46(0.21)**
Farm experience	0.11(0.05)**	0.07(0.06)	0.11(0.05)**	0.04(0.04)
PSNP	0.09(0.47)	2.33(0.99)**	1.29(0.52)**	0.57(0.47)
Farm size	-1.62(0.94)*	-0.11(1.53)	-1.50(1.09)	-0.12(0.90)
TLU	0.13(0.06)**	0.16(0.09)*	0.16(0.07)**	0.12(0.06)*
Distance plot	0.01(0.02)	-0.03(0.03)	-0.02(0.02)	-0.00(0.02)
Slope	-1.18(0.37)***	-2.07(0.67)***	-0.46(0.39)	-0.7(0.36)**
Distance FTC	-0.04(0.01)***	-0.03(0.02)	-0.04(0.02)**	-0.02(0.01)
Access extenservic	0.46(0.51)	-1.33(0.93)	0.66(0.65)	-0.12(0.54)
Credit	0.47(0.55)	1.47(0.85)*	1.70(0.57)***	1.65(0.54)***
Training	-0.70(0.52)	3.15(1.06)***	1.72(0.57)***	1.22(0.52)**
Constant	-2.81(2.29)	-0.49(4.10)	1.25(2.79)	-2.32(2.34)

Significant at *** p<0.01, ** p<0.05, * p<0.1

D. Figures and Tables

Most farmers articulated that the decline of soil fertility is a serious challenge in the districts due to the topography being highly vulnerable to soil erosion and farmers using poor management practices. The respondent farmers listed several factors related to soil fertility decline. These factors are mainly categorized into five. These are; tenure security (land ownership), lack of labor access, lack of capital, less livestock size, and change in price of agricultural inputs and outputs related to current price inflation Figure below.

In the study area, the majority of respondents indicated that changes in the price of agricultural inputs and outputs were the prior factor that retards the adoption of land management practices (44.94%) of the respondents indicated due to price inflation of agricultural inputs and outputs. This implies farmers have become too reluctant to implement the necessary sustainable land management practices due to the price inflation of sustainable land management technologies such as inorganic fertilizer. It was in agreement with FGD members' perspective as they explained farmers had been less motivated to implement the recommended land management practices because the change in agricultural input prices was a bottleneck for the adoption of soil fertility management practices in the land. The second factor was lack of capital access (19.10%), capital is one component of a factor of production, and hence to purchase agricultural inputs, oxen, and other materials, so capital was a determining factor in applying land management practices in the study area. Due to lack of capital farmers are less likely to adopt land management practices. Farmers cannot afford to buy personal farm implements for land management practices because it is expensive. If farmers do not have enough resources to invest in their farmland to provide enough amounts of inputs, the farmland soil fertility remains poor. Moreover, the third factor to use land management practices was ownership of land (16.10%) respondents like as capital; the land is one part of the factors of production. Some respondents stated that they did not have their own farmland to implement land management practices as the descriptive result indicated that about 18% of the respondent farmers did not have their own land, hence they engaged in sharecropping and renting the land for a given year. Therefore this is difficult to apply land

management practices in the future due to this farmer were reluctant to use land management practices in rented farmlands because they had no guarantee for the future. Land ownership and land management practices have a positive relationship [41].

The fourth factor in using land management practices was small livestock size (14.61%) livestock is one source of manures and compost so farmers had small livestock units due to this farmers' adoption status was becoming low. A farmer who has a large livestock size has more chance to implement land management practices. Hence livestock ownership has a direct relation to organic fertilizer [22]. The last factor mentioned by the sample respondent and FGD members was the lack of labor access (5.24%) of farm labor is also a challenge they experience in implementing land management practices. These farmers indicated that some land management practices are labor intensive and they require an additional labor force to cover a large portion of the farmland. This finding is similar to the research conducted in Kenya [42], and in Malawi [34].

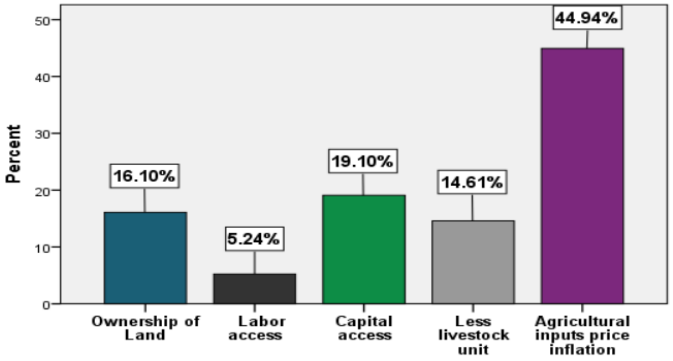

Fig. 3. The major challenges in sustainable land management practices
Source: Computed from own survey data of 2024

IV. Conclusion and Recommendations

The findings of this study suggest that sustainable land management practices are integral to the agricultural system in the study area, to improve the livelihood of smallholder farmers. The adoption of sustainable land management practices is influenced by demographic, socio-economic, institutional, and physical factors, which are linked to the different types of farming households and the various land management practices they use. Moreover, the major reasons that shape farmers' decision to adopt these practices are the economic benefits, ensuring food security, and a desire to sustain farmland productivity. This situation emphasizes the need for conditions that could allow for more profitable farming and enhanced income, while also boosting agricultural productivity and food output with a focus on economic, social, and ecological safety. Such circumstances can encourage the use of sustainable land management practices and sustain related land management initiatives. The major sustainable land management practices implemented by the smallholder farmers in the study area are as follows: crop rotation, livestock manure, inorganic fertilizer, compost, and integrated methods. These practices are used independently and partially, but not to the extent expected. The constraints hindering the adoption of sustainable land management practices among farmers in the study area are multifaceted, including fluctuations in the cost of agricultural inputs, limited access to labor and capital, concerns regarding land tenure security, and the small size of livestock. To address these challenges and enhance the adoption of sustainable land management practices, the district agriculture office should prioritize the expansion of educational initiatives and training programs on land management practices. These programs should be tailored for both farmers and development agents. The educational efforts should focus on raising awareness and providing technical guidance to facilitate the adoption of sustainable land management practices. In addition, policymakers should intervene in research to design farm implements that reduce physical effort and develop educational interventions to inform older farmers about livestock manure use, acknowledging their positive association with this practice. Younger farmers were found to be more adopters of compost and inorganic fertilizers. Furthermore, the government should develop strategies to improve land productivity per unit area rather than expanding farmland, especially for those who have larger farm sizes. The district office should construct easily accessible farmer training centers to increase the adoption of land management practices among farmers living farther away.

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