ORIGINAL ARTICLE

Determinants of the Adoption of Improved Soil and Water Conservation Structures among Smallholder Farmers' in Amhara Region, Ethiopia: Gubalafto and Were'elu Watersheds in focus

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Abstract

This study seeks to analyze the determinants to the adoption of improved soil and water conservation structures among smallholder farmers in the Gubalafto and Were'elu watersheds of the Amhara region, Ethiopia. A comprehensive methodology involving household surveys, focus group discussions and key informant interviews and field observations were employed to gather both quantitative and qualitative data. Quantitative data were obtained from 348 randomly selected household heads while qualitative data were derived from focus group discussion , key informant interview and field observation. The results of the logit model reveal that Adoption of Soil and Water Conservation (SWC) practice is significantly and positively related to farm size (significant at P<0.05), slope (significant at P<0.10), credit access (significant at P<0.05), gender (significant at P<0.05) and land tenure security (significant at p<0.10) while age and farming experience with negative coefficient is (significant at p<0.10). Furthermore, the logit model predictions show that a higher percentage of farmers (74.7%) choose not to adopt the most recommended SWC practices such as stone bunds, soil bunds, stone terracing, and cut-off drains. Consequently, it is evident that interventions aimed at enhancing farmers' capacity to adopt improved SWC techniques should prioritize addressing these disparities from a livelihood perspective. In end, this study recommends the imperative need for targeted interventions that address the identified challenges, thereby fostering the adoption of improved SWC structures among smallholder farmers in the Ethiopian highlands.

Keywords: Adoption, non-adoption, logistic regression, determinant factors, rural livelihood, SWC technologies , Amhara region

Introduction

Agriculture plays a pivotal role in societal well-being. It utilizes approximately 40% of the land surface and about 70% of global water resources. Ethiopia heavily relies on agriculture to meet the demands for food and other essential goods and services. However,

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in developing countries, including rural Ethiopia, land degradation emerges as a critical factor contributing to low productivity and food insecurity (Abebe and Bekele, 2014). The significance of agriculture in alleviating poverty and ensuring food security is compromised due to land degradation issues such as soil erosion and nutrient depletion (Hurni, Berhe et al. ,2016) leading to a decline in crop and livestock productivity (Belayneh, Abera and Tadesse , 2017). Furthermore, the deterioration of natural resources and land degradation poses severe challenges, particularly in the Ethiopian highlands (Hurni ,1998; Asnake and Elias, 2017; Teshome, Rolker and de Graaff, 2013; Belay and Bewket, 2015). The Ethiopian highlands, covering more than 56% of the land mass, are experiencing severe degradation, progressively rendering them unsuitable for cultivation (Tesfaye, Brouwer et al.,2016). Scholars such as (Temesgen, 2012; Adams and Eswaran, 2000 and Teka et al., 2019) have highlighted that land degradation ranks among the major environmental concerns in Ethiopia. The rate of land degradation in Ethiopia is alarming, presenting a significant social and economic challenge (Temesgen ,2012,Teshome, Rolker and de Graaff , 2013; Gebremeskel , 2019 ,Teka et al. ,2019).

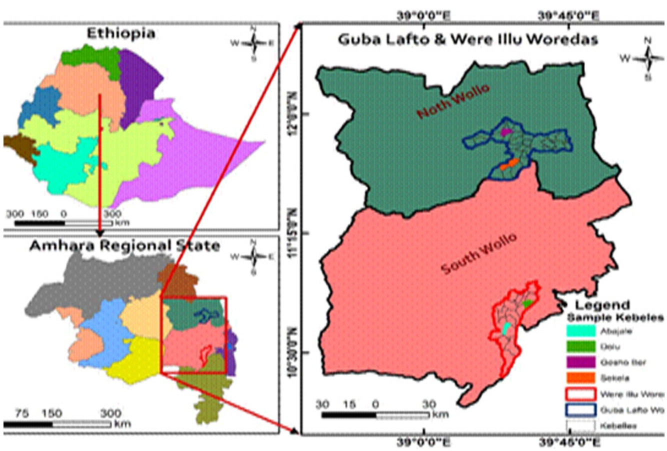
Review of Related Literature

Bekele (2003) reported that in the endeavor to mitigate degradation, the Ethiopian government, in collaboration with international organizations, has initiated and been implementing a comprehensive afforestation, soil, and water conservation program since the 1970s. The primary goal of this is to enhance agricultural production and uplift rural livelihoods (Campbell ,1991; Keeley and Scoones , 2000; Abebe and Bekele , 2014; Hunegnaw et al. , 2017). While the practice was not extensively adopted before 2010, it has garnered attention from both federal and regional governments, with the Amhara National Regional State demonstrating notable commitment and progress in the rehabilitation of degraded lands through soil and water conservation (SWC) structures (Engdayehu, Fisseha et al.,2016). In addition to this (Adimassu, Mekonnen et al.,2014) reported that various SWC technologies, such as stone and soil bunds, bench terraces, cut-off drains, waterways, check dams, and grass strips, are prominently utilized in the region. Empirical studies have identified impediments to the adoption of SWC practices, categorized into personal and household attributes, farm/plot factors, socio-economic considerations, and institutional aspects (Knowler and Bradshaw,2007;Abebe and Bekele,2014). Notably, there exists a positive correlation between household literacy levels and the adoption of SWC practices, emphasizing the significance of formal education as a determinant of farmers' adoption behavior (Anley; Bogale and Haile, 2007;Abebe and Bekele, 2014). Furthermore, research by (Shiferaw and Holden , 1998; Asrat; Belay and Hamito, 2004, and Gidey ,2015) in Ethiopia, along with Krishna et al. (2008) in Nepal, has indicated a negative relationship between farmers' age and the adoption of soil and water conservation practices. A study conducted by Gidey (2015) revealed a significantly negative relationship between family size and the adoption of certain SWC adoption packages. These packages consist of physical conservation or structural measures aimed at improving land management. On farm lands, they include practices such as tied ridges, soil or stone bunds, and various types of terraces. For grazing land, the conservation methods combine area closure with re-vegetation by incorporating fodder trees or shrubs. Additionally, farm size was found to have mixed effects on the adoption of soil and water conservation practices. Notably, studies by (Ersado, Amacher and Alwang 2004, Aklilu 2006 and Ahmed 2014) reported a positive relationship between the adoption of conservation measures and farm size. Conversely, (Deininger, Jin and Yadav 2013) suggested that land tenure security provides incentives for farmers to apply for and continue using land to enhance their plots. However, (Hagos and Holden, 2006 ; Abebe and Bekele ,2014) argue that land tenure is not a robust indicator of adoption behavior. Despite the numerous empirical studies on soil and water conservation adoption, a clear understanding of the challenges faced by farmers in adopting recommended soil and water conservation practices remains elusive. This gap underscores the need to investigate the determinants of farmers' interests and their evaluation of soil and water conservation practices in diverse settings. For instance, rural communities in the study area have made concerted efforts over the past few decades to construct stone terraces, soil bunds, cut-off drains, establish enclosures, and actively participate in tree planting programs (Abebe and Bekele, 2014) . However, past remedial measures have primarily focused on the physical aspects of land rehabilitation, such as the construction of structural interventions. Policy, institutional, and participatory issues have often been overlooked in these efforts as they were not adequately addressed in the remedial strategies (Berry, 2003). Thus, the objective of this study is to analyze the determinants of the adoption of improved soil and water conservation structures among smallholder farmers in the Amhara region, Ethiopia, specifically focusing on Gubalafto and Were'elu watersheds..

MATERIALS AND METHODS

Description of the study area

The study was conducted in the North and South Wello zones of the Amhara Region, specifically in the Gubalafto and Were'elu watersheds.



Source: Own computed GIS based on literature review, 2024

Fig 1. Map of the study area

Guba Lafto District, located in the northern Wollo Zone of the Amhara region, lies between 39°06′9″ and 39°45′58″ East longitude, and 11°34′54″ and 11°58′59″ North latitude. Were'elu District, on the other hand, is located in the South Wollo Zone of the Amhara Region. It has coordinates of 10°36′N, 39°26′E, and experiences three distinct seasons: *Bega* (dry season) (October-January), *Belg (like autumn)* (mid-February to mid-May), and *Kiremt (wet season)* (mid-June to mid-September) (Hurni, 1998). The mean annual temperature ranges from 14°C to 20°C, with rainfall varying between 680 mm and 1,200 mm (Hurni, 1998). This climatic diversity shapes the study areas environmental conditions. Topography, including flat and hilly landscapes, requires different farming methods, while soil types demand specific management practices. Steep slopes (>30%) with erodible soils, combined with high rainfall and low vegetation cover, significantly influence farmers' perceptions and behaviors regarding soil erosion and the adoption of soil and water conservation practices.

Study Design, Sample Size Determination and Sampling techniques

The study used a cross-sectional design to collect data at a single point in time, allowing for the analysis of patterns or associations across multiple variables (Bryman, 2016; Oppenheim, 2000). A mixed-methods approach was employed, integrating both quantitative and qualitative data through household surveys, key informant interviews (KIIs), focus group discussions (FGDs), and field observations. The two study districts, the South and North Wollo, were selected through a multi-stage sampling procedure, and with an input from agricultural experts. In the first stage, selection was based on factors like SWC adoption, topographical diversity, and farming practices. In the second stage, the selection of two districts, Were'eluWere'elu in South Wollo and Gubalafto in North Wollo, was made based on the specific criteria mentioned above. In the third stage, four *kebeles* were purposefully chosen: Dolu and Aba Jel from Were'eluWere'elu, and Sekela and Geshober from Gubalafto. Selection was based on the prevalence of soil and water conservation (SWC) adoption and farming system diversity. A stratified random sampling method was used to select households from each *kebele*, dividing them into adopters and non-adopters of SWC practices like stone bunds, soil bunds, stone terracing, and cut-off drains.

The determination of the sample size followed a simplified version of (Yamane ,1967) method, resulting in a sample size of 348 households for the survey. The sampling frame consisted of 2,691 households. In conclusion, this rigorous sampling approach aimed to provide a comprehensive understanding of through soil and water conservation (SWC) adoption, considering geographical variations and farming practices within the selected districts.

$$n = \frac{N}{1 + N(e)2}$$

n = Determined sample size the research uses
N= Total number farm households practicing soil and water conservation (SWC)in the study area (2691 HHHS)

e= margin error (5%)

$$n = \frac{2691}{1 + 2691(0.5)2}$$

$$n = \frac{2691}{1+2691 * 0.0025} = 348$$

Household heads were the respondent of this study. To this end, 174 adopters and 174 non adopters of recommended SWC practices was considered for this study.

Table 1. Distribution of sample households proportionally distributed across the study kebeles

Zone	District	Kebele Sample Kebeles	HHh size (Ni)	Gender		Formula for Stratified sample HHHs ni=□.Ni ∑Ni	Gender based Sample hhhs	
				M mi	fi		Mhhh	Fhhh
South Wollo	Were'elu	Dolu	790	550	240	102	71	31
	Were'elu	Aba jel	530	369	161	69	48	21
Total		1,320		919	401	171	119	52
North Wollo	Gubalafto	Sekela	641	446	195	83	58	25
		Geshober	730	508	222	91	65	29
Total			1371	954	417	177	123	54
Grand Total			2,691 Hhh	∑i= 1873	∑ fi 818	∑ ni= 348	∑MHHhs= 242	∑fHHhs 106

Source:Field survey .2024

Data Sources and Data collection techniques

The study, therefore, generated primary data through information gathering from a wide sector involving survey rural households, Key Informants, and government and non-government staff working at local levels and field observations. This was again be complemented by gathering secondary data from relevant literature and government and non-government reports. Capturing the required data and generating valuable information demands profound understanding of the theoretical grounds of the research design and methodology and clearly defining the dependent and independent variables.

DATA ANALYSIS

Based on the nature of the variables measured to analyze the collected data, both descriptive and inferential statistics were employed. The data gathered through the survey questionnaire was coded, edited and entered into a statistical package for social science (SPSS version 26 software). Accordingly, frequency distribution, percentage, mean and standard deviation were used to describe the household characteristics. With regard to inferential statistics, t-tests were employed to compare mean differences between adopters and non-adopters, and chi-square tests were used for analyzing categorical data. Binary logistic regression was applied to examine the degree of relationship between independent and dependent variables influencing the adoption of soil and water conservation practices.

BINARY LOGISTIC REGRESSION MODEL

In this study, binary logistic regression models were employed to analyze the likelihood of adopting soil and water conservation practices. The choice of these models is driven by the dichotomous nature of the dependent variable, representing a binary response. Notably, the independent variables encompass a combination of continuous and categorical factors. It is crucial to emphasize that the logistic econometric model, chosen for its suitability in handling binary outcomes, operates as a non-parametric regression. Unlike ordinary least squares regression, it does not adhere to the typical assumptions associated with such models. To ensure the robustness of the analysis, various diagnostic tools were employed, including the Hosmer and Lemeshow tests for assessing goodness of fit. Regarding model specification, the economic model adopted in this study was empirically specified as follows:

SWC adoption = f (AGE, SEX, education – Family size, farm size, access to extension, land tenure security, training, livestock, off farm income, distance, farming experience, credit service and slope .) The specification of these variables is based on their strong support in existing literature. Various studies (Bekele 2003; Ersado, Amacher and Alwang, 2004; Abebe and Bekele 2014; Gebremeskel, Teka et al., 2019) have consistently identified these variables as the most significant determinants influencing the adoption of improved soil and water conservation (SWC) practices.

This follows a logistic regression model that can be expressed mathematically below as:

$$Y* = \beta o + \beta 1Agei + \beta 2sexi + \beta 3tuni + \beta 4frmsi + \beta 5crdi + \beta 6frmexpi + \beta 7slovi + Ui$$

WHERE Y*= decision to adopt (1, if household is adopter; 0, if household is non-adopter) is the dichotomous dependent or response variable and U_i is the stochastic error term that takes care of all the unaccounted factors, β_0 is the intercept or constant term and β_1 to β_7 are the slopes or the coefficient estimates of all the major independent variables influencing the SWC practices adoption. To avoid over-parameterization and ensure model adequacy, only key variables were included in the model. Based on a review of relevant literature, thirteen commonly used explanatory variables were identified: sex of the household head, age, farming experience, family size, education status, training, number of livestock, farm size, access to credit, access to extension services, off-farm income, distance to farmland, and slope. This study aims to examine the determinants of adopting improved Soil and Water Conservation (SWC) structures, with these variables providing a comprehensive analysis of adoption patterns in the study area.

Table 1: Summary and hypothesis list of independent explanatory variables for adoption of SWC practice

Variables	D	Variable type	Value	Anticipate ted sign
Dependent variable		Dichotomous	0 if non-adopter 1 if adopter	
Independent Variables				
(Demographic Factors)				
Sex		Dummy	1 if male;0 if female	+
Farming experience		Continuous	0number of	+/-
Age		Continuous	Years	+/-
Family size		Continuous	AE	+
Institutional Factors				
Education		Dummy	1 literate 0 if illiterate	+
Tenure		Dummy	1 if yes 0 if no	+
Access to extension		Dummy	1 if yes 0 if no	+
Access to credits		Dummy	1 if yes 0 if no	+
Training		Dummy	1 if yes 0 if no	+
Socio Economic Factors				
Livestock		Continuous	TLU	+
Off-farm income		Continuous	Birr	+
Biophysical				
Slope		Continuous	0 if Flat 1 if medium 2 if steep	+
Distance		Continuous	Km	+

Source: own computation for survey data, 2024

RESULTS AND DISCUSSION

Description of demographic, institutional, socio-economic and bio-physical variables of respondents

Sex of the household head: Table 1 shows that of the 174 respondents, 48 (27.58%) were female-headed households and 126 (72.42%) were male-headed. Significant disparities were observed between adopters and non-adopters of improved SWC structures, with a chi-square test (x2) revealing a statistically significant difference (P < 0.05) related to household headship. This highlights the importance of gender in SWC adoption, aligning with findings from Nigussie, Tsunekawa et al. (2017) who have reported that higher participation of male-headed households. Focus Group Discussions (FGD) also confirmed that many female-headed households managed land through sharecropping or renting, often hiring male labor for tasks like plowing.

Household Size: The results of field survey presented in **Table 1** shows that, out of 174 respondents, 9 (5.1%), 76 (43.6%), and 89 (51.1%) non-adopters reported family sizes of three, four, and five or more, respectively. Among adopters, 25 (14.3%), 138 (79.3%), and 11 (6.3%) had family sizes of three, four, and five or more. The t-test revealed a statistically significant difference in family size (P < 0.05) between adopters and non-adopters of improved SWC structures. This finding aligns with research by Teshome et al. (2013) and Bekele and Drake (2003), which suggested that larger households are more likely to invest in and maintain SWC practices. The statistically significant difference highlights the importance of family size in influencing the adoption of improved SWC structures, contributing to the growing literature on the link between household demographics and sustainable agricultural practices.

Table 1. Summary of demographic variables

Variables		non-Adopter (n=174)	%	Adopter (n=174)	%	Total	P- value
Sex	Female	48	27.58	18	10.34	66	0.000
	Male	126	72.42	156	89.66	282	
	Total	174	100	174	100	348	
Family size	Three	9	5.17	25	14.37	34	0.000
	Four	76	43.68	138	79.31	214	
	Five and above	89	51.15	11	6.32	100	
	Total	174	100	174	100	348	

Source: Field survey, 2024

Age of the household: Table 2 shows that the mean age of adopters was 44.60 years, while for non-adopters, it was 44.60 years. The standard deviation for adopters was 1.11, and for non-adopters, it was 1.12. The mean age difference was -0.022 years (44.6207 - 44.5977). The t-test revealed a statistically significant difference (P < 0.05) between adopters and non-adopters of SWC practices. This finding contradicts Aklilu (2006), who reported a positive link between age and the adoption of water and soil conservation practices among Ethiopian farmers.

Farming experience of households: **Table 2** shows that adopters have an average farming experience of 10.64 years while non-adopters have 9.67 years. The standard deviations for farming experience are 3.11 for adopters and 3.31 for non-adopters. The mean difference between the two groups is 0.97 years. A t-test revealed a statistically significant difference in farming experience (P < 0.05). These findings align with previous studies (Thomas & Hartmann, 1998; Anley et al., 2007; Boyd et al., 2000; Simon et al., 2018), which found that farmers with less than five years of experience are more likely to adopt improved SWC practices.

Table 2. Independent-test between ages and farming experience of households

Decision to adopt		N	Mean	Std. Deviation	Std. Error Mean	P- value
Age	Adopter	174	44.5977	1.11178	.08428	. 848
	non-Adopter	174	44.6207	1.11988	.08490	
Household farming experience	Adopter	174	10.6379	3.11271	0.23597	0. 005
	non-Adopter	174	9.6667	3.31459	0.25128	

Source: Field survey, 2024

Households' tenure security: The field survey findings, as presented in **Table 3**, reveal a notable disparity in the perception of land loss between non-adopters and adopters. Specifically, 116 individuals (66.6%) among non-adopters and 169 individuals (97.1%) among adopters acknowledged the potential loss of land. Conversely, 58 non-adopters (33.3%) and only 5 adopters (2.9%) did not anticipate future land loss. The justification for this result lies in the fact that possession of a legal title to land is not necessarily required to ensure land tenure security. Land security encompasses more than just formal certification; the adoption of these technologies is also influenced by a range of additional factors such as strong enforcing institutions that contribute to overall security and sustainable land management. A rigorous statistical analysis employing the chi-square test (x2) underscored a statistically significant difference (at $P < 0.05$) in tenure security between adopters and non-adopters regarding the adoption of improved Soil and Water Conservation (SWC) structures. This observation underscores the critical role of tenure security in influencing farmers' decisions to embrace and sustain investments in land-improving practices.

Credit access of Households: The survey results indicate that 51 (29.3%) of non-adopters and 123 (70.6%) of adopters lack access to credit services. Conversely, 36 (20.6%) of adopters and 138 (79.3%) of non-adopters have access to credit services (see Table 4). This suggests that adopter of SWC practices have received less credit access than non-adopting households in the context of enhancing Soil and Water Conservation (SWC) structures. From this, it is possible to understand that credit institutions were not exclusively encouraging farmers who have interest in adopting SWC practices. The chi-square test (x2) demonstrated statistical significance at P=0.063 which is insignificance (at $P < 0.05$) level. Regarding the accessibility of credit services among adopters and non-adopters of improved SWC structures, these finding is in agreement with Hagos and Holden (2006) assertion that credit access can decrease conservation investment by allowing farmers to mitigate the short-term impacts of land degradation.

The study's findings are further corroborated by insights from Focus Group Discussions (FGD), which revealed that farmers with access to credit are less likely to adopt soil and water conservation (SWC) practices compared to those without access. Discussants highlighted that some farmers who did not utilize credit may not have had access to it in the first place. This suggests that the decision to use credit may not be a clear indicator of access, as some farmers may choose not to take credit due to concerns about affordability or perceived risks, even when credit is available. As a result, it is apparent that adopter households received less credit than non-adopters, particularly in relation to improving SWC structures.

Household's access to extension service: As shown in **Table 3**, 37 non-adopters (21.26%) and 7 adopters (4.02%) have access to extension services while 137 non-adopters (78.73%) and 167 adopters (95.9%) do not. Although both adopter and non-adopter households receive agricultural advice from extension agents, this relationship is statistically insignificant (P = 0.052). The analysis suggests that extension services may not sufficiently promote SWC practices, as the impact on adoption behavior is limited. This contrasts with Nyairo et al., (2021), who found a positive correlation between frequent extension interactions and adoption of new technologies. Therefore, refining extension services to focus on SWC structures may not significantly influence adoption behaviors.

Household Training access: The field survey findings in **Table 3** show that 37 non-adopters (21.26%) and 7 adopters (4.02%) reported having access to training services. The chi-square test revealed that the difference in access to training between adopters and non-adopters was statistically insignificant (P = 1.12). This result contrasts with Abebe and Bekele (2014), who emphasized that access to training on agricultural inputs is crucial in encouraging farmers to adopt more effective Soil and Water Conservation (SWC) practices.

Off farm activity of households: The survey results in **Table 3** show that 103 non-adopters (59.1%) and 100% of adopters were engaged in off-farm activities, while 71 non-adopters (40.8%) and none of the adopters were involved in off-farm work. The chi-square test revealed a statistically insignificant difference (P > 0.05) between adopters and non-adopters. This finding is consistent with Abebe and Bekele (2014), who observed that off-farm employment could incentivize farmers to adopt more effective soil and water conservation (SWC) practices.

Table 3. Summary of institutional categorical variables

Variables	non-Adopter	%	Adopter	%	Total of (No & yes)	P- value
Tenure security						
No	58	33.3	5	2.87	63	0.000***
Yes	116	66.7	169	97.13	285	
Total	174	100	174	100	348	
Credit access				36	20.68	0.063
No	51	29.31	36	20.68	87	
Yes	123	70.69	138	79.31	261	
Total	174	100	174	100	348	
Access to xtension service						
No	137	78.73	167	95.97	304	0.052
Yes	37	21.26	7	4.02	44	
Total	174	100	174	100	348	
Training						
No	97	55.74	38	21.83	135	1.12
Yes	77	44.25	136	78.16	213	
Total	174	100	174	100	348	
OFF_FARM						
No	103	59.9	0	0	103	0.065
Yes	71	40.80	174	100	245	
Total	174	100	174	100	348	

Source : Field survey,2024

Educational status of the household head: The field survey findings presented in **Table 4** below show that 133 adopters (76.43%) and 91 non-adopters (52.3%) were illiterate while 41 adopters (23.6%) and 83 non-adopters (47.7%) were literate. This indicates that adopter households had lower educational levels compared to non-adopters, suggesting a negative correlation between education and the adoption of improved Soil and Water Conservation (SWC) structures. The chi-square test on literacy status revealed no statistical significance (P > 0.05), implying that literacy does not significantly influence the adoption of improved SWC practices. Interestingly, illiterate farmers were found to be more likely to adopt new technologies than their literate counterparts. Key informants suggested that this might be due to literate individuals engaging more in off-farm activities, such as petty trading, rather than focusing on agricultural practices. This finding contrasts with Orinda (2013), who argued that higher literacy levels correlate with greater access to knowledge and a higher likelihood of adopting improved SWC practices.

Farm size (hac): The descriptive analysis revealed that average cultivable land for all households in the study area ranged from 0.48 to 1.0 hectares, with a minimum size under 0.48 hectares and a maximum exceeding 1.1 hectares. A significant disparity in land size emerged between adopter and non-adopter households, as indicated by a t-test. Specifically, 8 (4.6%) non-adopters and 7 (4.02%) adopters had farms of 0.48 hectares, while 12 (6.9%) adopters and 81 (46.6%) non-adopters managed farms between 0.48 to 1.0 hectares. Additionally, 155 (89.1%) adopters and 85 (48.85%) non-adopters had farms larger than 1.1 hectares. The t-test revealed a significant difference in farm size (P < 0.05) between adopters and non-adopters of improved SWC structures. This supports previous findings by Aklilu (2006) and Gidey (2015), who reported mixed effects of farm size on SWC adoption. Larger landholdings are often linked to greater adoption of soil and water conservation practices.

Distance from homestead: The time required for farmers to travel from their homestead to their farm is a key factor influencing the adoption of improved Soil and Water Conservation (SWC) structures. **Table 4** shows that 8.6% of adopters and 18.4% of non-adopters travel 30 minutes or less, 49.42% of adopters and 25.9% of non-adopters travel 31 to 60 minutes, and 41.9% of adopters and 55.7% of non-adopters travel over 60 minutes. Despite adopters generally having closer farmland, the Pearson t-test did not show a statistically significant difference in travel time between adopters and non-adopters of improved SWC structures. In practical terms, the adoption of the improved Soil and Water Conservation (SWC) structure was adversely affected by the distance from farmland. This finding contradicts Gidey (2015) assertion that farmers with plots in close proximity to homesteads are more inclined than their counterparts to adopt SWC methods.

Slope of the land: The survey results showed that 22 non-adopters (12.6%) and 50 adopters (28.7%) implemented Soil and Water Conservation (SWC) structures on flat-sloped plots. On medium-sloped plots, 102 non-adopters (58.6%) and 53 adopters (30.5%) adopted SWC structures, while on steep-sloped plots, 50 non-adopters (28.7%) and

71 adopters (40.8%) did so. Most SWC structures were found on flat or moderately sloped plots. The Pearson t-test revealed a significant influence of plot slope on adoption behavior (P < 0.05), which contrasts with previous studies (Shiferaw & Holden, 1998; Bekele, 2003; Berhanu et al., 2003; Aklilu, 2006) that focused on steep slopes for SWC adoption. This study presents a different perspective on the influence of plot slope on SWC adoption.

Livestock holding: The survey results show a mean difference in livestock units between adopters and non-adopters of SWC practices. Non-adopters have an average of 3.18 livestock units while adopters have a mean of 3.17. The standard deviation for non-adopters is 1.112, and for adopters, it is 1.113. The mean difference between the two groups is 0.01 (3.18 – 3.17). This difference is statistically significant at P < 0.05. The study also explores whether TLU per household varies across the sample areas and its relationship with SWC adoption. These findings contradict the research by Tenge et al. (2011) and Abebe & Bekele (2014), who suggested that livestock availability encourages SWC adoption. Key informants in the study area noted that farmers with larger livestock herds often prioritize collecting fodder over engaging in SWC activities.

Table 4. Summary of Institutional, socio-economic and biophysical continuous variables

Variables	Non-adopters n =174		Adopters n =174	%	Total	p-value
Institutional categorical variable						
Education status of the household head						
Illiterate	91	52.29	133	76.44	224	0.000
Literate	83	47.71	41	23.56	124	
Total	174	100	174	100	348	
Socio-economic variables						
FARM SIZE(ha)						
<0.5	8	4.6	7	4.0	15	
0.6-1.0	81	46.55	12	6.9	93	0.000
>1.1	85	48.85	155	89.1	240	
Total	174	100	174	100	348	

	Non adopter	%	Adopter	%	Total	
Biophysical continuous variables						
Distance to farmland (in minute						
30 minute and less than	15	8.6	32	18.3	47	0.052
	86	49.4	45	25.8	131	
30 to 60 minutes	73	41.9	97	55.7	170	
	174	100	174	100	348	
Above 60 minute						
SLOPE CATEGORY						
Flat (3-15%)	22	12.6	50	28.74	72	0.000
Medium (15-30%)	102	58.62	53	30.46	155	
Steep >30%	50	28.74	71	40.8	121	
	174	100	174	100	348	

Independent-test between livestock number and adoption of SWC practice

Decision to adopt		N	Mean	Std. Deviation	Std. Error Mean	P- value
Livestock in TLU	Non Adopter	174	3.18	1.112	.0840	0.001
	Adopter	174	3.17	1.113	.0841	

source :Field survey ,2024

Factors determining the adoption of improved SWC technologies

This section outlines the determinants of adopting improved Soil and Water Conservation (SWC) technologies based on a logistic regression model (Table 5). Only significant variables were included to avoid over-parameterization, following the literature's preference for a parsimonious model. Insignificant variables, like training, distance, off-farm income, household size, and livestock, were excluded to ensure valid results. The selection of explanatory variables was based on theoretical reasoning and prior studies. The model's goodness-of-fit was evaluated using the Log Likelihood Ratio (LR) test, which yielded a chi-square value of 4.572 ($p = 0.802$), suggesting a reasonable fit. The Nagelkerke R Square of 0.324 indicates the model explains a substantial portion of the variation in SWC adoption. The model was significant at $P < 0.10$, $P < 0.05$, and $P < 0.01$ levels, confirming its adequacy in estimating the influence of key variables. Out of the 13 explanatory variables included in the model, notably, seven (age, Sex of the household head, Farming experience, Access to credit, Tenure, Farm size, and Slope of the plot) were found to be statistically significant and influence the adoption of improved SWC in the study area. Conversely, the remaining six explanatory variables that did not show statistical significance in the model (Distance from homestead, Extension service, Education, Training, Livestock availability, Household size) were not incorporated into the model to avoid over-parameterization.

The age of the household head was initially expected to influence the adoption of improved Soil and Water Conservation (SWC) practices either positively or negatively;however, the logit model results indicate a significant negative relationship at the $P = 0.038$ level. Specifically, the model reveals a negative coefficient of -0.098 for age, suggesting an inverse relationship between age and the adoption of improved SWC structures. The odds ratio of 0.906 indicates that for each one-unit increase in age, the likelihood of adopting improved SWC practices decreases by a factor of 0.906, maintaining all other variables constant. Consequently, younger farmers are more inclined to adopt SWC technologies compared to their older counterparts. This finding can be explained by the fact that older farmers are less likely to adopt innovations, possibly due to shorter planning horizons and reduced capacity to invest the necessary labor for implementation. This aligns with previous research on technology adoption for instance that of Gebremeskel, Teka et al., (2019).

The logit regression model shows a statistically significant difference at $P < 0.10$ between adopters and non-adopters of improved SWC structures based on the sex of the household head. The results indicate that male-headed households are more likely to adopt improved SWC practices, with an odds ratio of 7.101, meaning male-headed households are 7.1 times more likely to adopt SWC technologies than female-headed households. These findings align with Nigussie et al. (2017), who found that male-headed households were more likely to engage in SWC activities. Focus Group Discussions (FGD) revealed that many female-headed households rented or sharecropped land managed by male heads and hired labor for tasks like plowing.

The logit model results show that farming experience significantly influences the adoption of improved SWC structures at the $P < 0.10$ level. The negative coefficient of -0.043 indicates an inverse relationship between farming experience and SWC adoption. The odd ratio of 0.958 suggests that a one-unit increase in farming experience decreases the likelihood of adoption by 0.958 times. This finding aligns with Simon et al. (2018), who found that farmers with less than five years of experience are more likely to adopt SWC practices. It also supports earlier studies by Thomas and Hartmann (1998), Anley et al. (2007), Boyd et al. (2000), and Simon et al. (2018), which observed that less experienced farmers are more likely to adopt improved SWC practices across their plots. The study found that access to credit significantly influences the adoption of improved SWC practices, with results from the logit model showing significance at $P < 0.01$. The odds ratio of 3.567 indicates that, keeping other factors constant, access to credit increases the likelihood of adoption by 3.567 times. This highlights that credit enables households to purchase inputs and adopt agricultural technologies. However, Focus Group Discussions (FGD) revealed that some farmers avoid credit due to perceived risks or unaffordability, even when it is available. This suggests that adopting households may have received less credit for SWC improvements than non-adopters, challenging the claim by Hagos and Holden (2006) that credit access reduces conservation costs.

Farm size of household heads: The logit model shows that farm size is significantly related to the adoption of improved SWC technologies ($P < 0.01$). With an odds ratio of 6.286, each unit increase in farm size increases the likelihood of adoption by a factor of 6.286. Households with larger farm sizes are more likely to adopt improved SWC technologies compared to those with smaller farms. These findings align with Aklilu (2006) and Gidey (2015), who reported mixed effects of farm size on SWC adoption. The positive influence may be due to larger farms being more likely to implement soil and water conservation practices.

Slope of the plot: The logit model results show a significant relationship ($P < 0.10$) between plot slope and the adoption of improved SWC technologies. Households with steeper slopes are more likely to adopt these technologies, with an odds ratio of 1.363. This means the likelihood of adoption increases by 36.3% for steeper plots. These findings align with Shiferaw and Holden (1998), Aklilu (2006), and Abebe and Bekele (2014), who linked steeper slopes to greater soil erosion severity.

Table 5. Logistic regression analysis (Major factors influencing the adoption of improved SWC structures)

Step 1[a]	Variable	Coefficient	S.E.	Z-value	df	P-value.	0dd ratio
	Age	-.098	.113	-0.87	1	.003	.906
	Sex	1.960	.392	5.00	1	0.000**	7.101
	Farming Experience	-.043	.111	.-0.38	1	0.05	.958
	Tenure	.074	.039	1.91	1	.005*	1.077
	Credit access	1.272	.319	3.98	1	0.000**	3.567
	Farm size	1.838	.281	6.54	1	.000**	6.286
	Slope	.309	.178	1.74	1	0.008*	1.363
	Constant	-4.337	5.155	-0.84	1	0.400	.013

Source: field survey,2024
Log likelihood function=385.606[a]
Cox & Snell R Square=0.243
Nagelkerke R Square=0.324

Number of observation =348 **Note** =*P <0.10; ** P <0.05; *** P <0.01, OR > 1 implies that the outcome is associated with predictor, and increases as the predictors increases, OR < 1 means that the relation is negative, OR = 1.0 implies no association between dependent and predictors. Nagelkerke R Square is normally higher than Cox & Snell R Square. In this study a p-value of 0.802 suggests that the estimated model has adequately fit.

Conclusions

The study identified key factors affecting adoption, including the age and sex of the household head, farm size, access to credit, tenure security, and plot slope. These factors were found to significantly influence the likelihood of adopting improved SWC practices and provide valuable insights for targeted intervention efforts. The findings emphasize the need for policies and strategies that address these determinants to enhance soil fertility and boost agricultural productivity.

These results have important implications for government agencies, development organizations, and other stakeholders in the agricultural sector. The findings also highlight the need to integrate these factors into policy frameworks and intervention strategies aimed at promoting sustainable farming practices and improving soil and water conservation efforts.

Recommendation

- To address the challenges mentioned in the findings of this study, it is essential to raise awareness about soil fertility issues amongst framers and emphasize the need for adopting improved SWC structures to mitigate their negative effects.
- Accurate and widespread information regarding the use of enhanced SWC structures should be shared with a broader group of smallholder farmers in the study area.
- Both local and national governments must prioritize the adoption of SWC structures to improve soil fertility and increase productivity.
- Interventions aimed at enhancing farmers' capacity to adopt improved SWC structures should focus on livelihood perspectives to win the motivation and confidence of farmers.

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