

Soil and water conservation practices: effectiveness and determinants of adoption among smallholder farmers

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Abstract

This research scrutinized the effectiveness of soil-water conservation (SWC) techniques and the determinants of their adoption by smallholder farmers in Southwest Ethiopia. A total of 36 soil samples were collected from preserved and non-preserved plots, and a household survey was conducted with 332 randomly selected respondents. Soil physical and chemical properties were analyzed using standard laboratory techniques, while mean differences were tested through one-way ANOVA. In addition, binary logistic regression was employed to identify factors influencing the adoption of SWC practices. Results revealed that preserved plots had higher soil fertility indicators associated with non-preserved plots, including soil pH (6.17 vs. 5.83), organic carbon (1.85% vs. 1.77%), available phosphorus (10.92 ppm vs. 9.93 ppm), and cation exchange capacity (37.3 vs. 30.3 cmol (+)/kg), while bulk density was lower (0.42–0.69 g/cm³ vs. 1.22 g/cm³). Adoption rates, however, remained limited to 53.9% of households. Regression results showed that adoption was positively influenced by education, farm size, livestock ownership, land slope, and farmers' perception of erosion, while land tenure insecurity and credit access negatively affected adoption. The findings underscore that although SWC practices significantly improve soil fertility, socio-economic and institutional constraints hinder their wider uptake. Strengthening extension services, providing tenure security, and designing targeted interventions are recommended to enhance sustainable adoption.

Keywords: Conservation techniques, Farmers' adoption, Soil and water conservation, Southwest Ethiopia

Article Type: Research Article

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Citation: Masha, M., Borku, A.W., Mengiste, W. (2025). Soil and water conservation practices: effectiveness and determinants of adoption among smallholder farmers, *Water and Soil Management and Modeling*, 5(4), 240-253. doi: 10.22098/mmws.2025.18283.1673

Received: 19 August 2025, Received in revised form: 12 September 2025, Accepted: 14 October 2025, Published online: 07 November 2025

Water and Soil Management and Modeling, Year 2025, Vol. 5, No. 4, pp. 240-253.

Publisher: University of Mohaghegh Ardabili

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1. Introduction

The majority of the Ethiopian population relies heavily on agriculture as their primary source of livelihood (Masha et al., 2021; Borku et al., 2024b). This dependence has heightened vulnerability to land degradation, which threatens both agricultural productivity and rural livelihoods (Holmatov et al., 2017). Land degradation in Ethiopia arises from factors such as inappropriate agricultural practices, steep and undulating terrain, erratic rainfall, low vegetation cover, severe water erosion, and weak land resource management (Borku et al., 2024a; Muche and Molla, 2024; Tadesse et al., 2024; Reta et al., 2025). These processes reduce the productive potential of farmland, making it challenging for farmers to achieve sufficient crop yields (Masha et al., 2021).

Agricultural practices in southwest Ethiopia are characterized by small and fragmented landholdings, outdated production technologies, unpredictable rainfall patterns, high rates of soil erosion, and the prevalence of tropical diseases (Arega et al., 2013). Despite these challenges, the government and development partners have invested heavily in promoting SWC measures to support sustainable intensification of agriculture (Haregeweyn et al., 2015). Proven interventions include structural and vegetative measures, minimum tillage, reduction in livestock numbers, and establishment of enclosures to allow natural vegetation recovery (Ebabu et al., 2018, 2019; Fenta et al., 2016, 2017b; Sultan et al., 2018), which improve soil fertility and mitigate erosion (Borku et al., 2024c).

Despite national-level efforts, adoption rates of SWC measures remain uneven and often low, influenced by household livelihoods, socio-economic status, institutional support, and agroecological conditions (Gebregzibeh et al., 2016; Berhanu et al., 2016; Misganaw et al., 2017). Prior studies have provided insights into SWC adoption across Ethiopia; however, the southwest region, particularly Gesha district, is underexplored. Few studies have specifically examined the agroecological determinants of

adoption, sustained use, and household-level effectiveness of SWC measures in this area.

In the Gesha district, SWC structures such as soil bunds, fanyajuu, check dams, stone bunds, micro-basins, and tree plantations have been implemented through campaigns. Yet, these efforts have not fully engaged all households, and reported impacts on soil fertility and livelihoods are mixed, with no consensus on effectiveness (Fenta et al., 2016, 2017b; Sultan et al., 2018). Home-grown evidence from the Gesha district Agricultural office indicates that although the district aimed to implement SWC measures on all farmland between 2010 and 2022, actual achievements were substantially below the targets, and soil erosion continues to threaten land resources.

This scenario highlights the need for an agroecology-specific assessment of SWC effectiveness and adoption barriers. Understanding the socio-economic, institutional, and political factors influencing SWC uptake is critical for improving program outcomes and supporting sustainable agricultural development. To fill the study gaps, the current study examines the long-term impact of SWC measures on particular properties of soil and identifies the determinants of adoption in the Gesha district, bridging key knowledge and implementation gaps in southwest Ethiopia.

2. Materials and Methods

2.1. Study area setting

The research was conducted in the Gesha district, located within the Kaffa Zone in southwestern Ethiopia. The Kaffa Zone comprises twelve districts and five administrative states. The capital of Gesha district, Deka town, is situated 571 km from Addis Ababa and 124 km from Bonga town, the zone's administrative center. Geographically, the Gesha district is surrounded by the Saylem district to the northern part, the Bita district to the south, the Sheka district to the west, and the Gawata district to the east. Positioned at a latitude of 7°39'60"N and a longitude of 35°49'60"E (Figure 1), the district encompasses a total area of 705.20 km square.

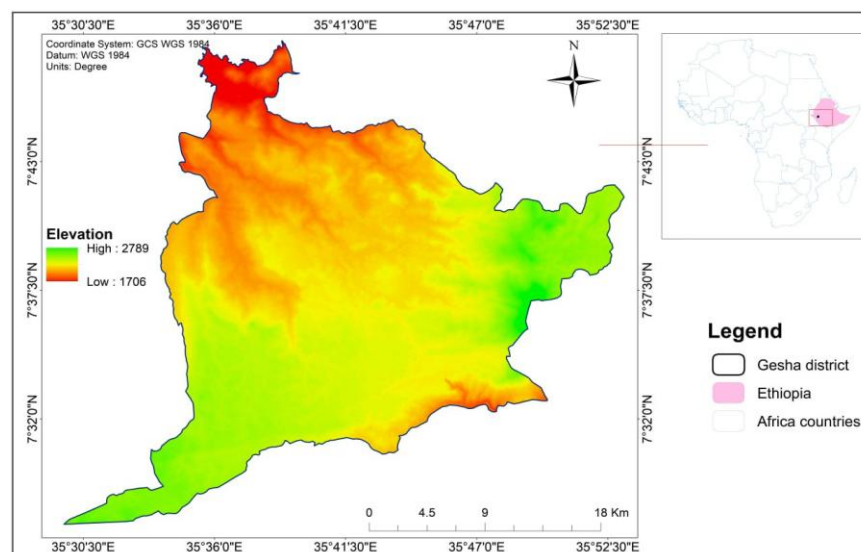


Figure 1. Location of the study area in Gesha District, Kaffa Zone, Southwest Ethiopia

2.2. Procedures for soil data

Soil samples were obtained from both preserved plots incorporating soil bunds, stone bunds, fanyajuu, and micro-basins, and adjacent non-preserved plots. A stratified random sampling approach was adopted to ensure representative coverage across different landscape positions, including upper, middle, and lower slopes. Within each stratum, sampling points were selected randomly. Using a 15 cm depth auger and a 294.375 cm³ core sampler, soil samples were collected from the 0–30 cm layer. In total, 36 disturbed soil samples were collected from preserved plots, with four samples obtained from each type of conservation structure across the three landscape positions, and replicated three times. Additionally, nine disturbed soil samples were collected from non-preserved plots following the same stratified random sampling procedure, resulting in 45 disturbed soil samples for laboratory analysis. For the determination of bulk density, an additional 45 undisturbed soil samples were collected following the same stratified random sampling design.

2.3. Soil-lab analysis

The collected soil samples were thoroughly homogenized in a tray to form composite samples for laboratory analysis. These composites were air-dried, ground, and passed through a 2-mm sieve before analysis at the Bedele Soil Laboratory, Southern National Regional State Agriculture Office. A range of physical and

chemical soil properties was assessed, including soil texture, pH, and bulk density, following standard laboratory procedures. Using the core sampler method, Bulk density was determined and described through (Black et al., 1965). Soil particle size distribution was measured via the hydrometer method (Sakar & Halder, 2005), and soil texture was classified according to the USDA soil texture triangle (Osman, 2013). Soil pH was measured in a 1:2.5 soil-to-water suspension using a pH meter (Van Reeuwijk, 2002). SOC was analyzed using the Walkley–Black rapid titration method, and TN was determined through the modified Kjeldahl procedure (Sakar & Halder, 2005). Available phosphorus was assessed using the Olsen extraction technique (Van Reeuwijk, 2002). Exchangeable bases and CEC were measured using the ammonium acetate method (Sakar & Halder, 2005), while calcium (Ca²⁺) and magnesium (Mg²⁺) concentrations were quantified by atomic absorption spectrophotometry, and sodium (Na⁺) and potassium (K⁺) were determined using a flame photometer.

2.4. Data sources and types

The study targeted smallholder farmers residing in the Gesha District of the Kaffa Zone. Data were collected from both primary and secondary sources to meet the research objectives. Primary data were obtained through household surveys using structured questionnaires, KII, FGD, and direct field observations. Secondary data were

sourced from online resources, scholarly journals, reports from governmental and non-governmental organizations, and other relevant literature. Household surveys were administered by trained enumerators, with three enumerators assigned to each kebele based on their educational qualifications. To foster trust and cooperation, participants were fully briefed on the study's objectives and the rationale for their selection. Subsequently, key informant interviews and focus group discussions were conducted jointly by the enumerators and the principal researcher. Upon completion of the survey, final consultations were held with enumerators, community leaders, and development agents to review the findings and resolve any remaining issues.

2.5. Sample size determination and techniques

A multi-stage sampling approach was employed to select the study area and respondents. The Gesha District was purposively chosen due to its highland agroecology and the observed inefficiency in SWC practices. Within the district, three kebeles were purposively selected based on

their agroecological characteristics. Finally, a simple random sampling technique was applied to select 332 respondents from a total of 1,966 households in the selected kebeles. The sample size was initially determined using Yemane's formula, assuming a proportion of 0.5, a 95% confidence level, and a 5% margin of error, as expressed in the equation.

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

To ensure the adequacy of the sample for logistic regression with 14 predictor variables, a rule-of-thumb check was conducted based on Peduzzi et al. (1996), which recommends a minimum of 10 events per predictor variable (EPV). Assuming a binary outcome with approximately 50% prevalence, the most conservative scenario, the required minimum sample size was calculated. Given that the final sample size of 332 exceeds this threshold, it is statistically sufficient to support logistic regression analysis with 14 predictors.

Table 1. Sample size selection of the study

Kebeles		Total Households			Sample size		
		Adopt	Not	Over-all	Adopt	Non	Over-all
1	Nechiti	342	300	642	58	51	109
2	Gaweti	320	260	580	54	44	98
3	Meshami	398	346	744	67	58	125
Total		1060	906	1966	179	153	332

Source: field survey 2023

2.6. Analysis method

In order to assess the influence of SWC measures on soil physical and chemical properties, one-way analysis of variance (ANOVA) was employed to test for mean differences between preserved and non-preserved plots. When the assumption of homogeneity of variances was violated, as checked by Levene's test, Welch's ANOVA was applied to provide robust results. Post-hoc mean separation was carried out where necessary to identify significant differences among conservation structures. For the socioeconomic survey, descriptive statistics (frequencies, percentages, and means) were used to summarize household characteristics, and an applied to identify factors influencing adoption of

SWC, the study employed regression model. All statistical analyses were performed using IBM SPSS Statistics version 27.

Moreover, a binary logistic regression model, as outlined by Alemu (2007), Gujarati and Porter(2009), and Tabachnick and Fidell (2013), was used to identify the key factors influencing smallholder farmers' adoption of SWC activities. In this model, the dependent variable represents SWC program participation status, where, P_i is the probability of adoption and probability that a household belongs to non-adoption of soil and water management activities is: the odds ratio, $Z_i = \beta_1 + \beta_2 X_i + U_i$, where z_i = is the probability of participation, 1= intercept, β_2 = regression coefficients to be estimated and U_i = a

disturbance term. The independent (explanatory) variables presumed to influence the implementation of (SWC) measures are taken from several existing literatures.

3. Results and discussions

Local governments and development partners have invested substantial resources in promoting and implementing SWC practices and technologies to sustainably enhance livelihoods. Consequently, this study examined the impact of conservation practices, which were executed through community participation, on selected soil physical and chemical properties. These properties were examined by evaluating mean differences through one-way ANOVA. To verify the assumption of equal variances, Levine's test was performed. Certain soil parameters, including soil reaction, exchangeable Na^+ , Ca^{2+} , Mg^{2+} , and K^+ , exhibited significant deviations ($p \leq 0.05$) when comparing adopted and non-adopted cultivated plots. Therefore, the Welch test was applied, as it is particularly effective for controlling Type I errors in cases of unequal variances, ensuring the robustness of the results (Liu, 2015)

3.1. SWC measure and its impact on soil physical properties

Soil texture is a critical indicator of soil physical properties. In this study, preserved plots exhibited a clay loam texture, whereas non-preserved plots were predominantly clay, indicating generally fine-textured soils across the study area. The mean clay content was higher in preserved plots (53.5%) compared to non-preserved plots (38%)

(Table 1). This increase in clay content in preserved plots is likely due to the trapping of fine particles by SWC structures, which reduces soil erosion. Although direct erosion rates were not measured, these findings are consistent with previous studies in Ethiopian watersheds, which reported higher clay retention in areas protected by conservation interventions (Mengistu et al., 2016; Belayneh et al., 2019). ANOVA results confirmed that preserved plots had significantly higher clay content than adjacent non-preserved plots, suggesting that SWC measures effectively reduce the removal of fine particles. In contrast, non-preserved plots experienced greater soil erosion, resulting in the loss of clay and organic matter. Non-preserved soils also showed relatively higher sand (39%) and silt (37%) fractions, likely due to the selective removal of finer particles, consistent with observations by Belayneh et al. (2019). Bulk Density: The mean bulk density in preserved plots was significantly lower than in non-preserved plots ($P \leq 0.01$), with values of 0.42, 0.43, 0.69, and 0.61 g cm^{-3} for micro-basins, fanyajuu, soil bunds, and stone bunds, respectively, compared to 1.22 g cm^{-3} in the control plots. The elevated bulk density in non-preserved plots may be attributed to soil compaction from intensive grazing and erosion, which results in a denser soil structure. Conversely, lower bulk density in preserved plots can be linked to reduced erosion due to SWC structures and higher soil organic matter content. These results align with previous studies in Ethiopia, which reported significantly lower bulk density in soils treated with SWC measures compared to untreated soils (Selassie et al., 2015; Challa et al., 2016; Husen et al., 2017).

Table 2. Comparisons of means of sand, silt, clay, and Bulk density with conservation structures

Treatments	Physical properties of the soil				
	Sand (%)	Clay (%)	Silt (%)	Textural class	Bulk density (%)
	Mean	Mean	Mean	-	Mean
Soil bund	35.27e	53.52e	36.64e	Clay loam	0.69e
Stone bund	38.11d	47.85d	36.74d	Clay loam	0.61d
Fanyajuu	36.36c	51.10c	36.51c	Clay loa	0.43c
Micro basin	35.01b	50.64b	36.69b	Clay	0.42b
Control	37.89a	38.00a	37.66a	Clay	1.22a
F- ratio	2.86	3.87	4.58	-	4.2
P value	0.035*	0.003**	0.004**	-	0.006**

*Sig. at ($p \leq 0.05$), ** Sig. at ($p \leq 0.01$), and means within a column followed by different letters are significantly different at ($p \leq 0.05$) and ($p \leq 0.01$).

3.2. Impacts of SWC practices on soil chemical properties

Soil pH: Soil pH, an indicator of acidity or alkalinity, is influenced by a combination of chemical, mineralogical, and biological factors. In this study, soil pH was significantly affected by SWC practices ($P \leq 0.01$). The pH values ranged from 5.83 to 6.17, with preserved plots exhibiting slightly acidic conditions, while non-preserved plots were more strongly acidic (Tekalign, 1991). Specifically, preserved plots had a higher mean pH of 6.17 compared to 5.83 in non-preserved plots (Table 3). The lower pH in non-preserved plots is likely attributable to enhanced leaching from rainfall, which depletes essential soil nutrients, whereas the relatively higher pH in preserved plots may result from the retention of base-forming minerals due to reduced erosion. These findings are consistent with previous studies indicating that heavy rainfall can leach soluble bases and increase soil acidity (Amare et al., 2013; Osman, 2013). The outcomes also correspond with Getachew et al. (2007), who investigated the effects of rangeland management on soil characteristics in Yabelo, Southern Ethiopia. **Soil organic carbon (SOC):** The concentration of soil organic carbon (SOC) showed a statistically significant difference ($P \leq 0.01$) within the conservation structures, with mean values being lower than expected (Landon, 2013). This could be attributed to the acidic nature of the soil, soil erosion through runoff, and the influence of eucalyptus trees, all contributing to the limited availability of SOC. However, preserved plots exhibited relatively higher mean values of SOC compared to non-preserved plots (Table 3). This variation is primarily due to the effects of SWC on reducing soil erosion, as SWC helps minimize the loss of fine soil particles and organic residues (Husen et al., 2017; Mengistu et al., 2016; Sinore et al., 2018). These findings align with those of Tadele et al. (2013), Abay et al. (2016), and Lemma et al. (2016) in the Anjeni Watershed in the Central Highlands of Ethiopia, where soil organic carbon content was higher in terraced sites compared to their non-terraced counterparts. Similarly, non-preserved sites showed significantly lower SOC compared to preserved sites with various conservation measures. **Total nitrogen (TN):** It was not significantly influenced by SWC practices. This

suggests that while conservation measures may contribute to TN retention, the observed variation in this study cannot be confirmed as a significant effect (Table 3), which aligns with the findings of Cottenie (1980). This result is consistent with Hishe et al. (2017), who also reported no significant variance in TN content across treated plots. The variation between preserved and non-preserved plots is largely attributed to the impact of SWC on soil erosion, as conservation measures help reduce the loss of fine soil particles and organic residues (Husen et al., 2017; Mengistu et al., 2016; Sinore et al., 2018). This, in turn, enhances the concentration of soil organic carbon (SOC), which ultimately leads to an increase in TN content in the soil (Belayneh et al., 2019).

Available Phosphorus (Av.P): SWC practices significantly affected soil phosphorus availability ($P \leq 0.01$) across the different conservation structures. In this study, the mean available phosphorus ranged from 9.93 to 10.92 mg kg⁻¹, indicating a medium concentration (Cottenie, 1980). The relatively higher phosphorus levels in preserved plots compared to non-preserved plots (Table 3) suggest that SWC measures help retain phosphorus in the soil, potentially enhancing fertility. This may also be influenced by the ongoing application of phosphorus-based fertilizers by local farmers. Similar trends have been reported by Fisseha et al. (2014), Hishe et al. (2017) in the Middle Silluh Valley, Northern Ethiopia, Mengistu et al. (2016), Selassie et al. (2015), and Belayneh et al. (2019), who observed higher available phosphorus in preserved soils. However, Nega and Heluf (2013) noted that in some tropical soils, available phosphorus does not always decrease in soils with low organic matter content.

Cation Exchange Capacity (CEC): A significant difference ($P \leq 0.01$) was also observed in soil cation exchange capacity (CEC) between preserved and non-preserved plots. According to Landon (2013), the CEC in the study area was classified as high, ranging from 30.33 to 33.22 cmol(+) kg⁻¹. The elevated CEC in preserved plots is likely due to higher clay content and the effect of SWC measures in reducing soil erosion, as soils with more clay generally retain more positively charged ions (Selassie et al., 2015; Sinore et al., 2018). These findings are consistent with previous studies by Abay et al. (2016),

Challa et al. (2016), Mengistu et al. (2016), Selassie et al. (2015), and Belayneh et al. (2019),

all of which reported higher CEC values in preserved soils compared to non-preserved plots.

Table 2. Comparison between means of the control plots with conservation structures

Treatments	pH	OC	TN	Av. P	CEC
	Mean	Mean	Mean	Mean	Mean
Soil bund	6.17e	1.83d	0.17e	10.92e	33.22e
Stone bun	6.12d	1.84b	0.10d	10.75d	36.11d
Fanyajuu	6.11c	1.85c	0.09c	10.66c	37.33c
Micro basin	6.11b	1.84b	0.08b	10.77b	39.00b
Control	5.83a	1.77a	0.04a	9.93a	30.33a
F-ratio	5.3	4.56	1.42	5.21	3.23
P value	0.0002**	0.004**	0.214ns	0.002**	0.022*

* Significant at ($p \leq 0.05$), ** Significant at ($p \leq 0.01$), ns: not significant at ($p \leq 0.05$), and means within a column followed by different letters are significantly different at ($p \leq 0.05$) and ($p \leq 0.01$)

Exchangeable basic cations (Na^+ , K^+ , Ca^{2+} , and Mg^{2+}): The current study found that conservation measures had a significant effect ($P \leq 0.01$) on exchangeable basic cations (Na^+ , K^+ , Ca^{2+} , and Mg^{2+}) (Table 3). The observed cation concentrations were dominated by calcium (11.44), magnesium (11.85), potassium (0.47), and sodium (0.58) (Table 4). These variations are influenced by particle size distribution and soil management practices (Heluf and Wakene, 2006). Additionally, the higher concentrations of calcium (11.44) and magnesium (11.85) may be due to the formation of the soils from young parent rocks and the impact of conservation measures on the levels of these cations. This

aligns with Asmamaw and Mohamed (2012), who reported that high calcium and magnesium content are characteristics of soils derived from basaltic parent rocks. One-way ANOVA also revealed numerical mean variations between preserved and non-preserved lands (Table 4). This difference may be attributed to the removal of cations through overgrazing, erosion, and nutrient loss in non-preserved areas. In this context, Belayneh et al. (2019) found differences in exchangeable basic cations between preserved and non-preserved plots, noting that conservation practices improved infiltration and reduced runoff accumulation.

Table 3. Comparison between means of the control lands with Exchangeable Basic Cations

Treatment	Mg ⁺	Na ⁺	K ⁺	Ca ²⁺
	Mean	Mean	Mean	Mean
Soil bund	11.85	0.58e	0.47e	11.44e
Fanyajuu	10.429	0.42d	0.50d	10.08d
Stone Bund	9.46c	0.53c	0.56c	11.23c
Micro Basin	11.40b	0.56b	0.52b	12.57b
Control	9.54a	0.38a	0.40a	8.99a
F-ratio	3.84	2.96	5.05	3.89
P value	0.010**	0.031*	0.002**	0.01**

*Significant at ($p \leq 0.05$), ** Significant at ($p \leq 0.01$), and means within a column followed by different letters are significantly different at ($p \leq 0.05$) and ($P \leq 0.01$).

One of the key factors discouraging farmers from adopting SWC practices is their perception of these measures. According to the focus group discussions, some farmers reported removing conservation structures from their plots, believing that the structures attracted rodents. Participants also noted that the SWC structures were

implemented without proper training on technical aspects, and were primarily constructed for the purpose of reporting the hectares covered, rather than addressing the technical needs of the land. As a result, the structures were ineffective. This finding aligns with Bekele et al. (2018). Additionally, the discussions highlighted that the

training provided to farmers by extension agents in the study area was inadequate. This was attributed to extension workers being involved in other activities such as collecting loans, taxes, and addressing other agricultural issues. Belayneh et al. (2019) found similar results, indicating that agricultural extension services were more focused on crop and livestock production than on SWC practices, which led to farmers reducing their investments in SWC due to limited interaction with extension agents.

3.3. The factors affecting farmers' adoption of SWC measures

Sex: this was found to have a significant impact on the adoption of SWC measures at the 5% level, with a negative correlation. Specifically, female-headed households were 10% less likely to adopt SWC practices than male-headed households (Table 5). This disparity may be attributed to several socio-cultural and institutional factors. In many rural settings, women often have limited access to critical resources such as land, credit, and agricultural inputs, which constrains their ability to implement labor-intensive conservation measures. Cultural norms may also restrict women's participation in decision-making processes related to land management, while male-headed households typically have greater influence and access to extension services, technical advice, and community-based support networks. Furthermore, institutional programs and training on SWC may inadvertently target male farmers more frequently, creating additional barriers for women. These findings align with Daniel and Mulugeta (2017), who also reported gender-based disparities in SWC adoption and highlighted that women face systemic barriers, including restricted resource access and lower participation in agricultural development programs.

Age: The analysis revealed a positive and statistically significant relationship between the age of the household head and the adoption of SWC practices at the 5% significance level (Table 5). This indicates that older household heads are more likely to implement SWC measures. Specifically, each additional year in age increases the probability of adoption by 1.07%. Contrary to the expectation that younger farmers may be

more receptive to innovative agricultural practices, these results are consistent with the findings of Misganaw et al. (2015) and Berhanu et al. (2016), who reported that older farmers tend to commit more time and resources to SWC activities. This tendency may be attributed to their greater awareness of the long-term advantages of conservation practices and the risks associated with soil degradation. Moreover, older farmers often possess more land and resources, which may facilitate their participation in SWC initiatives. **Education:** As hypothesized, the level of education of the household head positively affected the likelihood of adopting SWC practices (Table 5). The marginal effect of 1.94 indicates that each additional year of schooling increases the probability of adopting SWC measures by 19.4%, assuming other factors remain constant. This suggests that educated household heads are more cognizant of the importance and benefits of SWC. Furthermore, higher education enhances the ability to comprehend technical information and engage effectively with extension services, thereby promoting the adoption of sustainable agricultural practices.

Family Size: Although household size exhibited a positive effect on the adoption of SWC practices, this was significant ($p \leq 0.05$) (Table 5). Larger households typically provide more available labor, which can facilitate the implementation of labor-intensive SWC measures, as noted by Misganaw et al. (2015) and Berhanu et al. (2016). The marginal effect of 1.22 suggests that each additional household member increases the likelihood of adopting SWC measures by 1.22 times. This finding implies that while a larger family may contribute labor capacity, other factors likely influence adoption decisions, reducing the statistical significance of household size in this context.

Farm Size: Farm size had a significant positive effect on the adoption of SWC measures ($p \leq 0.01$) (Table 5). Specifically, a one-unit increase in farm size increased the odds of adopting SWC practices by a factor of 3.03, with significance at the 10% level. This finding is consistent with the study by Belay & Bewket (2012), which suggests that larger farms are more likely to invest in SWC practices due to better access to capital. Larger

farms may have more resources to implement and maintain conservation measures, including the financial capacity to invest in necessary inputs and the labor needed for such practices. This suggests that farm size is a crucial determinant in the adoption of SWC measures, with larger farms having a greater capacity to integrate such practices into their operations.

Agro-Ecology: The perception of agro-ecological conditions had a positive influence on the adoption of SWC measures, with statistical significance at the 5% level (Table 5). Farmers in highland areas, particularly in the Dega zone, were more likely to adopt SWC practices, as they perceive their lands to be more susceptible to soil erosion. Specifically, farmers in the Dega zone had 1.35 times higher odds of adopting SWC measures compared to their counterparts in lowland areas, holding all other factors constant. This suggests that farmers' awareness of their land's vulnerability to erosion plays a significant role in motivating them to adopt conservation practices to protect their soil and maintain productivity. The perception of land degradation risk, especially in areas more prone to erosion, can drive greater engagement in conservation efforts (Adimassu et al., 2013).

Extension Services: This refers to a positive and statistically significant impact on the adoption of SWC measures, with a significance level of 1%. Households that received advice and guidance from development agents were 12.3% more likely to adopt SWC practices. This finding aligns with previous studies, such as those by Misganaw et al. (2015) and Daniel and Mulugeta (2017), which also reported a positive relationship between extension services and the adoption of SWC measures. However, a contrasting finding was observed in the study by Berhanu et al. (2016), which identified a negative correlation. The positive influence of extension services highlights the importance of providing technical support and information to farmers, which can significantly enhance their willingness and ability to implement conservation practices.

Farmland Distance: The variable had a significant positive effect on the adoption of SWC measures at the 1% level (Table 5). Surprisingly, the results revealed that households with farmland located closer to their homes were more likely to adopt

SWC practices, contrary to prior expectations. Specifically, households with shorter distances between their homes and farm plots were 1.23 times more likely to implement SWC measures. This finding supports the research by Wagayehu (2003), which proposed that when farmland is closer to the household, it allows for more frequent and effective supervision and management. This increased proximity enables farmers to monitor the land more closely, ensuring that conservation practices are consistently maintained and that any issues are addressed promptly (Belay & Bewket, 2012). Furthermore, it suggests that easier access to the farmland may facilitate better maintenance of conservation structures and more proactive interventions, enhancing the overall effectiveness of SWC practices.

Land Slope: As anticipated, the slope of the farmland had a significant positive effect on the adoption of SWC practices at the 1% level. Households with steeper land slopes were 12.41 times more likely to adopt SWC measures. This result aligns with the findings of previous studies by Wagayehu (2003), Berhanu and Swinton (2003), which indicated that farmers with steeper slopes are more likely to perceive soil erosion as a serious threat to their land. Consequently, these farmers are more inclined to implement preventive measures such as SWC practices to mitigate the risks of erosion and maintain soil fertility. The greater awareness of erosion risks in such areas often leads to a heightened sense of urgency, prompting farmers to adopt conservation strategies to protect their land from further degradation.

Perception of Soil Erosion: The perception of soil erosion as a significant problem had a strong and statistically significant impact on the adoption of SWC practices ($p \leq 0.001$). Farmers who viewed soil erosion as a threat to their land were more likely to implement SWC measures. Specifically, households that considered soil erosion a major issue were 6.25 times more likely to adopt SWC practices. This finding highlights the critical role that farmers' awareness of environmental risks plays in their decision to adopt conservation techniques. When farmers recognize the direct threat that soil erosion poses to their land's productivity and sustainability, they are more

motivated to take preventive actions to safeguard their soil and improve long-term land management.

Livestock Numbers: Livestock holdings had a significant and positive impact on the adoption of SWC practices at the 1% significance level. Specifically, households with greater livestock numbers were 1.41 times more likely to adopt SWC measures. This finding is consistent with the work of Wagayehu (2003), who highlighted that livestock can enhance soil fertility through the use of manure, which improves soil quality and supports sustainable agricultural practices. Additionally, livestock serve as an important source of income, enabling farmers to invest in SWC measures that help protect their land from degradation. The presence of livestock thus plays a dual role in facilitating both the financial capacity and ecological sustainability required for successful SWC adoption.

Credit Access: Contrary to initial expectations, access to credit had a negative influence on the adoption of SWC practices. Households with access to credit were less likely to implement SWC measures, with the likelihood of adoption decreasing by a factor of 0.45 when credit was accessed. Focus group discussions revealed that

credit was typically used for other priorities, such as purchasing seeds or constructing houses, rather than investing in SWC practices. This observation is consistent with the findings of Berhanu et al. (2016), who also reported that access to credit negatively impacted the adoption of SWC practices. This suggests that credit, while providing financial resources, may not always be allocated toward long-term environmental conservation investments, reflecting a shift in immediate priorities over sustainable land management.

Land Tenure Insecurity: As anticipated, land tenure insecurity had a negative impact on the adoption of SWC practices. Farmers lacking secure land tenure were less likely to engage in SWC measures, with the likelihood of adoption decreasing by a factor of 0.46. This finding is in line with the research of Gebremedhin and Swinton (2003), who argued that secure land tenure encourages farmers to invest in long-term land management practices, such as SWC, as they are more confident in the future stability of their land. The insecurity associated with unstable land tenure, on the other hand, discourages investment in conservation measures, as farmers may fear losing their land or the benefits derived from it.

Table 5. Likelihood estimates of the binomial logit model for determinants of SWC practices.

Variable	B	S.E.	Wald.	Sig.	OR
Sex	-7.03	6.75	1.08	0.044	0.01
Age	0.007	0.04	2.80	0.050	1.07
Agro ecology	3.75	1.69	4.91	0.027*	1.35
Family size	0.20	0.15	1.75	0.186	1.22
Marital status	-1.904	4.92	1.49	0.699	0.14
Education	0.54	0.106	0.25	0.611	1.94
Farm size	3.49	1.05	11.10	0.002**	3.03
TLU	0.350	0.091	14.86	0.001***	1.41
Extension	12.85	4.81	7.13	0.008**	1.23
Farm distance	4.82	1.28	14.14	0.001***	1.23
Credit access	-0.79	1.07	0.53	0.46	0.45
Land Slope	2.51	0.77	10.64	0.001***	12.41
Land insecurity	-0.75	0.86	0.76	0.38	0.46
Soil erosion	3.79	1.02	13.83	0.001***	6.23
Constant	-6.20	8.011	0.600	0.43	0.002

Obs=378; LR chi2 (23) =419.42; Prob>chi2 =0.001; pseudo-R2 =0.89, Log likelihood= 85.957; Significant at 10%, 5% and 1% probability level.

4. Conclusion

SWC methods play a crucial role in enhancing crop yields by improving soil moisture retention, conserving rainfall, and preventing erosion. However, their adoption remains limited due to

the interplay of complex socio-economic and institutional factors. Soil analysis revealed that most physical and chemical soil properties varied significantly based on management practices and slope positions. It was observed that farmlands

without conservation practices had higher bulk density compared to those with conservation measures, as these practices helped prevent soil erosion. Bulk density was significantly different ($P \leq 0.05$) between plots with and without conservation measures, with control plots showing the highest average bulk density, while plots treated with soil bunds and fanyaa juu had the lowest. The highest sand content was found in soil bund-treated plots, while the lowest was found in non-preserved farmlands. Binomial logistic regression analysis identified several significant factors influencing the adoption of SWC practices, including respondents' age, agro-ecological conditions, farm size, livestock ownership, interaction with extension workers, distance to farmland, perceptions of soil erosion, and the slope of the land. These factors significantly impacted the likelihood of adopting conservation measures at various significance levels (10%, 5%, and 1%). Specifically, variables such as the age of the household head, agro-ecology, and awareness of soil erosion all positively influenced the adoption of SWC practices. On the other hand, factors such as household gender, marital status, access to credit, and land insecurity were found to negatively affect the adoption of these practices.

4.1. Recommendations

Although local governments and NGOs have recently taken on important roles in managing soil and water resources, institutional focus on integrating SWC into broader development plans remains limited. It is highly recommended to design inclusive, participatory programs that engage all community members regardless of gender, age, or education to foster large-scale adoption of SWC practices. NGOs operating in rural areas should prioritize the integration of SWC into rural development and livelihood strategies to ensure sustainable and effective resource management.

Local stakeholders should focus on improving extension services, offering skill development training, strengthening local institutions, and adopting a participatory approach to encourage the adoption of SWC practices. Policies and programs should prioritize increasing farmers' involvement in both community and household

decision-making processes. This will help raise awareness and provide incentives to engage all household members in natural resource conservation, ensuring a more inclusive and effective conservation effort.

- The study found that access to credit and land tenure insecurity negatively affected the adoption of conservation practices. These results highlight the importance of developing comprehensive policies and programs that address these challenges. By improving access to secure land tenure and ensuring better credit facilities for farmers, it will be possible to encourage the adoption of SWC measures, ultimately supporting sustainable agricultural practices.

Author contribution

Mamush Masha: Original draft preparation, data collection, and analysis were performed.

Abraham Woru Borku: edited the manuscript and preparing suitable journals for publication.

Wasihun Mengiste: contributed review, and formatting issues.

Data availability: The data supporting this study's findings are available from first author upon reasonable request.

Competing interests: The authors declare no competing interests.

Funding Declaration: The author(s) declare that no funds, grants, or other financial support were received during the preparation or submission of this manuscript.

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