



Factors influencing the adoption of sustainable land management strategies in Sedie District, northwestern Ethiopia

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Abstract

Sustainable Land Management (SLM) is a vital strategy for maintaining land productivity. Despite its benefits, the adoption of SLM practices remains uneven, largely due to localized socioeconomic and environmental constraints. This study aimed to assess the factors influencing the adoption of SLM strategies in the Sedie District. A purposive sampling technique was used to select the study area, and quantitative data were collected from one hundred twenty-eight systematically sampled household heads. Descriptive statistics were used to examine the extent of SLM adoption, while binary logistic regression analysis was employed to identify the determinants influencing farmers' decisions. The findings revealed high adoption rates of soil and water conservation practices (96.88%), agroforestry (92.97%), and organic inputs such as compost and manure. However, the adoption of practices like irrigation (59.38%) and crop residue retention (41.41%) was comparatively lower. The regression results identified lack of extension services, input shortages, land scarcity, and water scarcity as statistically significant factors associated with SLM adoption. In contrast, variables such as access to information, knowledge level, labor availability, and market access were not found to have a statistically significant effect. Addressing these challenges through targeted, context-specific interventions is essential for scaling up SLM practices.

Keywords: adoption, driver, sustainable land management, land productivity, Sedie District

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Article information

Received: 18Nov, 2025

Revised: 17Jan, 2026

Accepted: 19Feb, 2026

Available online: 31March, 2026

Doi: <http://doi.org/10.20372/ajids.2026.2784>

1. Introduction

Sustainable Land Management (SLM) encompasses a broad range of agricultural and environmental practices (Bwalya *et al.*, 2023) aimed at protecting, rehabilitating, and enhancing the productive capacity of land resources (Sanz *et al.*, 2017) while ensuring ecological balance and long-term food security (Haregeweyn *et al.*, 2023). These practices include soil and water conservation, agroforestry, composting, improved soil fertility techniques, and climate-smart cropping systems (Hussain *et al.*, 2024; Nebere & Afework, 2025). In the context of smallholder farming systems, especially in vulnerable regions such as Ethiopia's highlands, SLM is not only a technical solution but also a critical adaptation strategy for climate resilience, sustainable livelihoods, and ecosystem restoration (Abera *et al.*, 2023).

Land degradation, driven by soil erosion, declining soil fertility, and unsustainable land-use practices poses a significant threat to agricultural productivity and rural livelihoods in Ethiopia (Abebaw, 2019). It affects an estimated 50% of the total arable land, resulting in reduced crop productivity and heightened food insecurity (Gebreselassie *et al.*, 2016). This problem is particularly acute in the highland regions, where population pressure, steep terrain, and intensive cultivation accelerate the loss of productive land (Solomon *et al.*, 2024). In response, the Ethiopian government, in collaboration with international development partners, has implemented various SLM programs aimed at restoring degraded land and enhancing farm resilience (Schmidt & Tadesse, 2019).

Previous research on SLM adoption in Ethiopia (Bayisa *et al.*, 2025; Alemu *et al.*, 2023; Agidew & Singh, 2023; Nigussie *et al.*, 2017) has provided important insights; however, much of it relies on broad regional analyses. These studies often overlook the nuanced, site-specific realities such as local resource availability, institutional dynamics, and socio-cultural factors that critically shape farmers' decisions to adopt or reject particular SLM interventions.

Despite widespread recognition of the benefits of SLM, the actual adoption of these strategies by smallholder farmers remains uneven and insufficiently understood at the local level (Salaisook, 2019; Adimassu *et al.*, 2016). Addressing these limitations through localized, strategy-specific analysis is crucial for developing targeted policies and extension approaches that effectively promote sustainable land-use (Hernández, 2018). In response to this gap, the present study investigates the factors influencing the adoption of sustainable land management strategies in Sedie District, northwestern Ethiopia.

2. Materials and methods

2.1. Description of study area

Sedie District is located within the East Gojjam Administrative Zone of the Amhara Region, Ethiopia. Geographically, Sedie District lies between latitude $10^{\circ} 56' 59''$ N and longitude $37^{\circ} 52' 59''$ E. It is situated 137 km south of Bahir Dar and 370 km northwest of Addis Ababa. The elevation ranges from approximately 1,950 to 4,082 m above sea level (Figure 1).



Figure 1. Location and elevation map of the study area

2.2. Land-use and slope classes of Sedie District

Figure 2 illustrates the spatial distribution of land-use/land cover (LULC) classes derived from 2024 Sentinel-2 imagery, together with slope classes delineated according to the FAO classification scheme for Sedie District. The LULC analysis identifies five major land-use categories: cultivated land, forest land, built-up areas, grassland, and water bodies, each exhibiting distinct spatial patterns shaped by both biophysical conditions and human activities. As shown in Table 1, cultivated land overwhelmingly dominates the landscape, covering 35,313.82 ha (79.52% of the total area), clearly indicating a highly agriculture-dependent land system in which most available land resources are intensively used for crop production.

Grassland and built-up areas constitute moderate proportions of the district, accounting for 7.50% and 6.88% of the total area, respectively. Forest land covers only 2,689.42 ha (6.06%) and appears fragmented, and largely confined to topographically constrained areas, highlighting critically low forest cover and raising concerns regarding ecosystem stability and long-term environmental sustainability in the district.

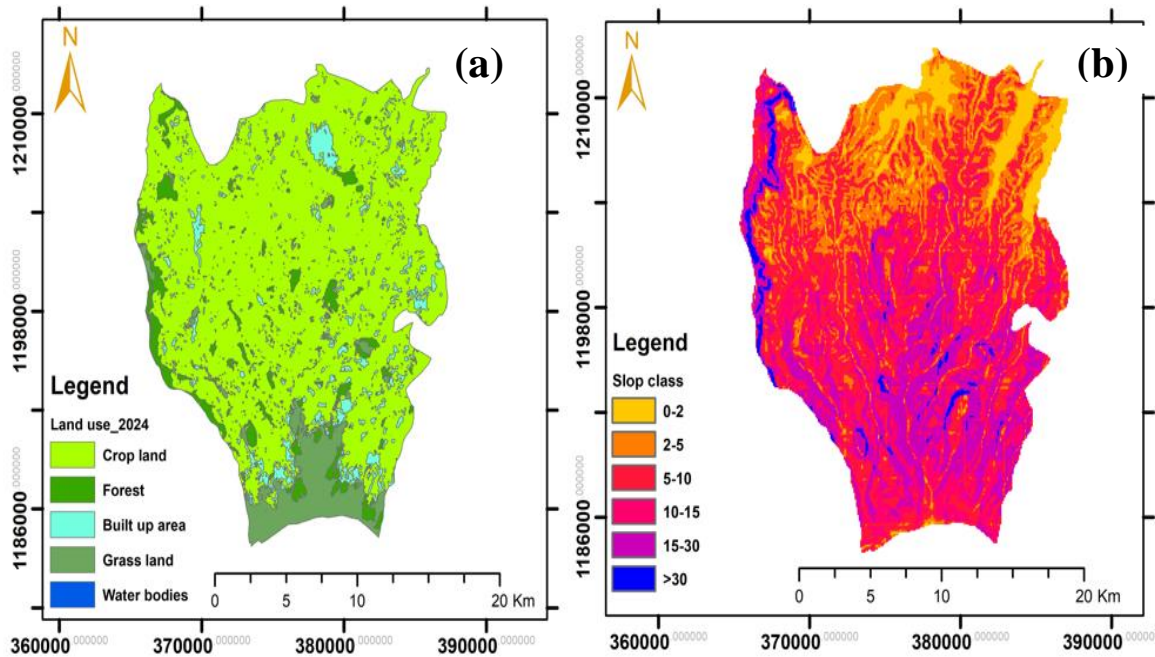


Figure 2. Spatial distribution of land-use/land cover (LULC) classes derived from 2024 Sentinel-2 imagery (a) and slope classes classified according to the FAO slope classification scheme (b) for the study area.

The slope analysis, based on the FAO classification, reveals pronounced topographic variability across Sedie District, ranging from flat and gently sloping terrain to steep slopes exceeding 30° . Moderately steep slopes ($15\text{--}30^\circ$) constitute the largest proportion of the district, covering 33.66%. This is followed by sloping ($5\text{--}10^\circ$) and strongly sloping ($10\text{--}15^\circ$) areas, which account for 19.73% and 18.40% of the total area, respectively (Table 1). Collectively, these three slope categories comprise more than 70% of the district, indicating that the landscape is predominantly hilly to mountainous in nature. Steep slopes greater than 30° cover 15.79% and represent areas highly susceptible to soil erosion, landslides, and land degradation if not properly managed. In contrast, flat to gently sloping land ($0\text{--}2^\circ$) occupies only 4.49% of the district, while gently sloping areas ($2\text{--}5^\circ$) account for 7.93% (Table 1). The limited availability of low-slope terrain suggests that land suitable for intensive and mechanized agriculture is scarce, increasing the likelihood that cultivation is expanding onto marginal and erosion-prone slopes. This pattern underscores growing pressure on fragile

landscapes and highlights the need for slope-sensitive land-use planning and sustainable land management interventions.

Table 1. Land-use/land cover and slope classes of Sedie District

No	Land-use/land cover classes	Coverage		Slope classes (Degree)	Characteristics	Coverage	
		ha	%			ha	%
1	Cultivated land	35313.82	79.52	0-2	Flat to Gently	1994.76	4.49
2	Forest land	2689.42	6.056	2-5	Gently	3521.01	7.93
3	Built up area	3054.88	6.88	5-10	Sloping	8760.58	19.73
4	Grass land	3331.07	7.50	10-15	Strongly Sloping	8172.38	18.40
5	Water bodies	21.34	0.05	15-30	Moderately steep	14947.41	33.66
6	Total	44410.53	100	>30	Steep	7014.40	15.79
				Total		44410.53	100

2.3.Sampling Design and Sample Size Determination

In this study, a combination of probability and non-probability sampling techniques was employed to ensure both representation and relevance. Sedie District was selected purposively based on its vulnerability to land degradation, agro-ecological characteristics, and the presence of ongoing or previous SLM interventions. This selection falls under non-probability sampling, specifically the purposive sampling technique, as it was based on predefined criteria rather than random selection.

To determine an appropriate sample size for the study, a two-step formula was used. First, the initial sample size (n) was calculated using the standard formula for estimating proportions:

$$n = \frac{z^2}{d^2} * p * q$$

Where:

- Z = the standard normal deviation,
- p = estimated proportion of the population,
- q = 1-p,
- d = level of precision (typically set at 0.05 or 5%).

However, since the population size less than 10,000, the finite population correction formula was applied to adjust the sample size. The total number of households (the sampling frame) in the study area was N=1764. The adjusted sample size (Fn) wascalculated using:

$$Fn = n / (1 + (n/N))$$

$$Fn = 138 / [(1 + (138/1764))] = 128$$

Where:Fn = desired sample size; N = sample frame of the study area

Systematic random sampling was employed to select households. The first household was selected randomly, after which every subsequent unit was selected using the calculated sampling interval. If there are N units in the population and n units are to be selected, then $R = N/n$ (the R is known as the sampling interval). The first number is selected at random out of the remainder of this R (Sampling Interval) to the previously selected number, and this interval is used. During this process, the list of households in each kebele was used to make a selection of the households randomly.

2.4. Data analysis

The data collected from the closed-ended questionnaires were analyzed quantitatively. Descriptive statistical analyses were performed using SPSS version 22.0, while Python 3.12 was employed for graphical visualization of the results. The software was used to generate key summary statistics such as frequencies, percentages, and mean values, which provided an overview of respondents' characteristics and their responses to various survey items. In parallel, the qualitative data collected through semi-structured interviews were carefully transcribed, coded, sorted, and thematically analyzed to capture deeper insights and contextual explanations that complemented the quantitative findings.

The factors influencing the adoption of SLM practices among smallholder farmers in the study area were assessed using binary logistic regression analysis. This model is appropriate when the dependent variable is dichotomous. The main objective of the regression analysis was to estimate the probability of adoption based on a set of perceived barriers reported by the farmers, thereby identifying the most significant constraints and informing policy recommendations. This model estimates the odds of adoption for each factor, allowing the identification of significant barriers and facilitators of SLM adoption among smallholder farmers.

3. Results and discussion

3.1. Farmers' adoption of land management technologies

Figure 3 shows the adoption rates of various land management technologies among respondents, ranked by their usage percentages. Soil and water conservation was the most widely adopted, with 96.88% of respondents using it, followed by home garden agroforestry (92.97%), farmyard manure (88.28%), and compost (85.16%). Technologies aimed at improving soil fertility (79.69%) and forest management (76.56%) also have high adoption

rates, though slightly lower. Irrigation (59.38%) and leaving crop residues (41.41%) have more moderate and low adoption rates, respectively.

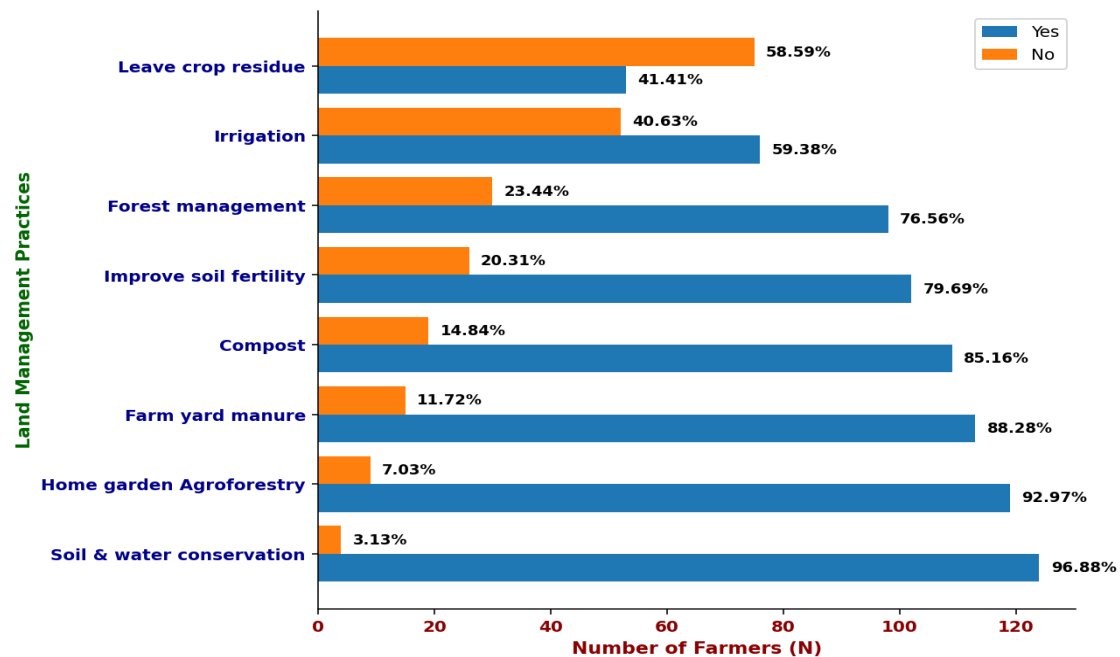


Figure 3. Farmers' adoption of land management technologies

The results indicate a strong preference for soil and water conservation methods, reflecting an awareness of their importance in sustainable land management. The adoption of soil and water conservation practices has significantly improved crop yields and soil health, especially in regions prone to erosion and water scarcity (Teshome *et al.*, 2023). Home garden agroforestry, farmyard manure, and composting are also widely practiced, suggesting that these methods are well integrated into the respondents' land management strategies. These technologies are known for their benefits in improving soil structure, enhancing biodiversity, contributing to household food security and climate change adaptation strategies (Wanget *al.*, 2022; Kareemet *al.*, 2022; Nebere& Afework,2025).

However, lower adoption rates for forest management, irrigation, and leaving crop residue suggest barriers such as resource limitations, knowledge gaps, and competing land-use priorities (Paul & Knoke, 2015; Garrett *et al.*, 2021; Rosa, 2022). Addressing these challenges through targeted interventions could encourage broader adoption and enhance sustainable land management practices. The findings align with previous studies emphasizing that agroforestry practices, soil conservation methods, and irrigation techniques play crucial roles in addressing climate variability and promoting sustainable land management. These practices enhance ecosystem resilience, improve soil fertility, and support climate adaptation

in agricultural systems (Asrat & Simane, 2018; Kumar *et al.*, 2023; Abdelhak, 2024; Enahoro-Ofagbe *et al.*, 2025). Additionally, farmers prioritize soil and water conservation strategies, as studied by Gezie (2019), primarily in response to soil degradation and erosion, expressing their desire to rehabilitate their fields.

3.2. Farmers' adoption of crop production technologies

The data in Figure 4 reveals how farmers utilized various crop production practices to cope with the challenges posed by climate variability. Particularly, the use of fertilizers and pest and weed management practices are universally adopted, with 100% of respondents relying on these methods. Improved seed varieties, adopted by 96.09% of farmers, are another key strategy for coping with climate variability. These seeds are often bred for enhanced resistance to drought, pests, and diseases, making them a cornerstone of climate-resilient agriculture.

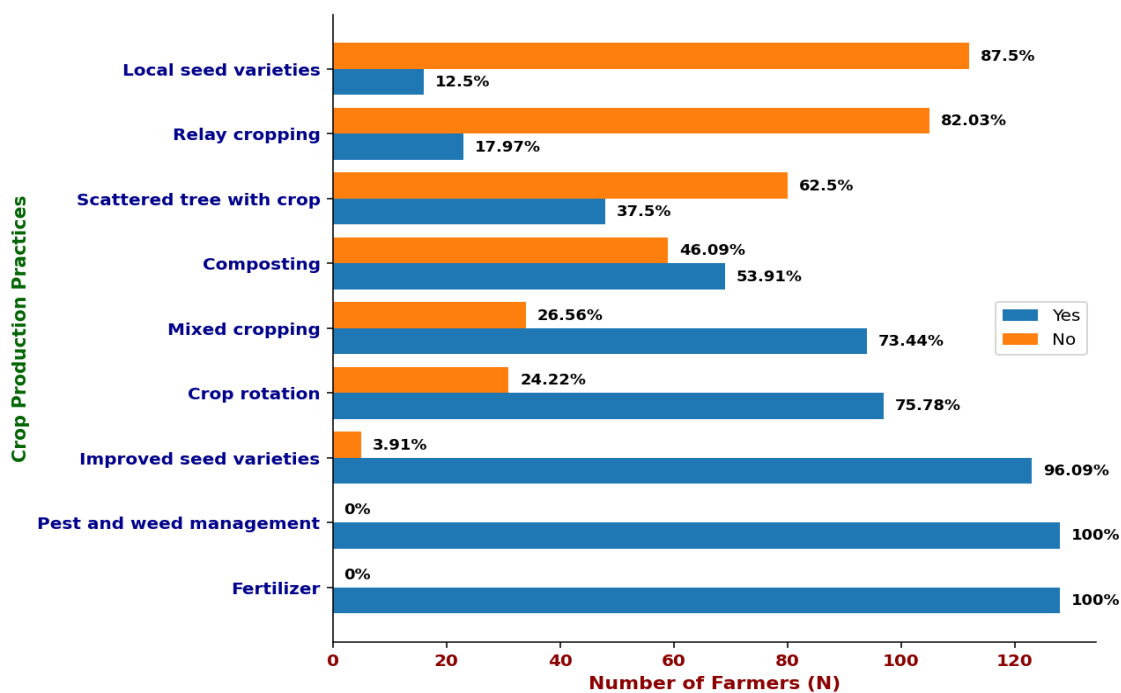


Figure 4. Farmers' adoption of crop production technologies

Crop rotation and mixed cropping are also widely practiced, with adoption rates of 75.78% and 73.44%, respectively. Composting, adopted by 53.91% of farmers, plays a vital role in improving soil organic matter and water retention, which are crucial for crop resilience. However, the adoption rates for practices such as integrating scattered trees with crops (37.5%), relay cropping (17.97%), and using local seed varieties (12.5%) are less commonly applied in land management strategies.

Studies emphasize the importance of fertilizers in replenishing essential nutrients in the soil, which is particularly crucial in areas where nutrient leaching is intensified by erratic rainfall (Vanlauweet *et al.*, 2023; Rashmi *et al.*, 2017). Additionally, integrated pest management strategies and the use of improved seed varieties have been shown to effectively mitigate increased pest pressures and enhance crop productivity under changing climatic conditions, particularly in regions prone to erratic weather patterns (Subedi *et al.*, 2023; Tesfaye *et al.*, 2023). These practices are essential for maintaining soil health and reducing the risk of crop failure due to pests or diseases. Sanzovoet *al.* (2023) demonstrate that crop rotation, especially when legumes are included, can improve soil nitrogen levels, which is vital for sustaining yields under climate stress.

Mixed cropping, as shown by Moussaidet *al.* (2023), enhances biodiversity and creates a more resilient cropping system capable of withstanding climate variability. Younisset *al.* (2022) emphasize that composting not only enhances soil health but also reduces the need for synthetic fertilizers, contributing to more sustainable farming practices. The limited adoption of relay cropping might be due to its complexity and labor requirements, despite its potential to extend the growing season and optimize land-use (Ebbisaet *al.*, 2023). The decline in the use of local seed varieties suggests a shift towards improved seeds (Sperling *et al.*, 2008), though stress the importance of preserving local germplasm for maintaining agricultural biodiversity and resilience (Anju & Kumar, 2022).

3.3. Factors affecting the application of sustainable land management practices

The binary logistic regression analysis revealed critical insights into the perceived barriers influencing farmers' decisions to adopt SLM practices. The inadequacy or absence of extension services was highly significant ($p \leq 0.001$) and emerged as one of the most influential deterrents to SLM adoption (Table 2). Farmers who viewed this as a serious constraint were approximately 73% less likely to implement SLM practices, underscoring the indispensable role of agricultural extension in facilitating knowledge transfer, offering site-specific technical guidance, and providing motivational support for innovation.

Similarly, limited availability of agricultural inputs ($p \leq 0.004$) significantly reduced the likelihood of adoption by 61% (Table 2). This finding highlights the practical barriers faced by farmer seven when they are informed or willing to adopt SLM due to the unaffordability or inaccessibility of necessary materials such as fertilizers, improved seeds, or agricultural inputs. Land scarcity was also a critical barrier, especially in densely populated areas where

small fragmented plots discourage the implementation of land-intensive practices like terracing or bund construction.

Water scarcity ($p \leq 0.001$) had the strongest negative association, with an estimated 77% reduction in the odds of SLM adoption. Given that many land management practices require adequate water availability, this result reflects the vulnerability of rain-fed farming systems and the deterrent effect of unpredictable rainfall or shortage of irrigation infrastructure. In contrast, the remaining four variables access to information ($p \leq 0.303$), knowledge ($p \leq 0.386$), labor availability ($p \leq 0.706$), and market access ($p \leq 0.852$) were statistically insignificant (Table 2), indicating that while important in broader agricultural development discourse, these factors did not have a decisive influence on adoption decisions in this specific context.

Table 2. Binary logistic models of factor influencing SLM practice adoption

Factors	Exp(B)	S.E.	Wald	Sig. (P ≤)	
Extension service	-1.298	0.273	0.319	16.562	0.001
Information	-0.358	0.699	0.348	1.060	0.303
Inputs	-0.938	0.391	0.326	8.264	0.004
Knowledge	-0.304	0.738	0.350	0.753	0.386
Labor	0.143	1.154	0.379	0.143	0.706
Land scarcity	-1.124	0.325	0.322	12.181	0.001
Market	0.070	1.072	0.373	0.035	0.852
Water scarcity	-1.464	0.231	0.317	21.352	0.001

This finding emphasizes the critical role that extension services play in disseminating knowledge and technologies that help farmers adapt to sustainable land management practices. Effective extension services are vital for equipping farmers with the skills and information needed to implement adaptive practices, particularly in regions vulnerable to climate change and variability (Makamane, 2023, Nebere *et al.*, 2024; Nebere *et al.*, 2025). The lack of available land limits the ability to implement certain adaptation strategies, such as crop rotation and irrigation practices (van Asseldonk *et al.*, 2023; Zerssa, 2022), which require more space and access to irrigation water. Water is essential for crop production, and its scarcity severely limits farmers' ability to cope with climate variability. Water shortage, driven by erratic rainfall and increased competition for water resources, are a growing concern in many agricultural regions, necessitating the adoption of water-efficient practices and technologies (Suna *et al.*, 2023).

This barrier highlights the need for better education and training programs that can equip farmers with the necessary understanding and skills to implement effective adaptation measures. According to Ricart *et al.* (2022), knowledge dissemination is key to improving the adaptive capacity of smallholder farmers, especially in developing countries where access to formal education and training is often limited. Limited access to these inputs can prevent farmers from adopting improved agricultural practices that are necessary for sustainable land management practices (Adimassu *et al.*, 2016).

Reliable and timely information about weather patterns, market conditions, and best agricultural practices is crucial for effective decision-making. Kalimba & Culas (2019) underline that improving information dissemination through modern communication technologies can significantly enhance farmers' ability to adapt to climate variability. Labor shortages can limit the ability to implement labor-intensive practices such as mixed cropping or agroforestry (Yaebiyo *et al.*, 2024), while market access affects farmers' ability to sell their produce and obtain fair prices, which is crucial for sustaining livelihoods under changing climatic conditions (Melketo *et al.*, 2020). Credit is essential for farmers to invest in new technologies and practices that enhance their resilience to climate variability (Batunget *et al.*, 2023).

4. Conclusions

This study examined the extent and determinants of sustainable land management adoption among smallholder farmers in Sedie District. The analysis revealed that while practices such as soil and water conservation, agroforestry, and composting are widely adopted, others like irrigation and crop residue retention remain underutilized. The most significant constraints to SLM adoption were identified as the absence of extension services, limited availability of agricultural inputs, land scarcity, and water scarcity. Factors such as market access, labor, and information were found to be non-significant in this study, although they may still play indirect roles. The findings underscore that without addressing these tangible barriers, policy efforts focusing solely on awareness and education are unlikely to result in meaningful improvements in SLM adoption. Therefore, a comprehensive approach that tackles both knowledge gaps and structural constraints is critical for achieving sustainable land management practices.

Conflict of interest

The authors declare that there is no conflict of interest regarding the publication of this paper

Authors contributions

Selomon Afework Yenesew: Conceptualization, data curation, formal analysis, software, writing original draft and writing review & editing.

Mamaru Shitaw: Data curation, formal analysis, and writing review & editing.

Yetwale Alemayehu: Formal analysis, software, and writing review & editing.

Abere Mulusew: Data curation, formal analysis, software, and writing review & editing.

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