Water and Soil Management and Modeling

Online ISSN: 2783 - 2546

University of Mohaghegh Ardabili

Socio-economic and biophysical determinants of landscape restoration adoption among smallholder farmers

Desalegne Chanie, Halie [1], Mulugeta Debele Bedhane[2], Wakshum Shiferaw[3] Daniel Azazie Birra[4] Zeleke Dosa Morgamo[5] Gebremedhin Chameno Chalite[6] Zerihun Ayalew Gebre[7]

[1]Assistant Professor, Department of Geography and Environmental Studies, College of Social Science and Humanities, Arba Minch University, Arba Minch, Ethiopia
[2]Associate Professor, Department of Geography and Environmental Studies, College of Social Science and Humanities, Arba Minch University, Arba Minch, Ethiopia
[3]Associate Professor, Department of Natural Resource Management of Agricultural Science, College of Agriculture, Arba Minch University, Arba Minch, Ethiopia
[4] M.Sc, Department of Geography and Environmental Studies, College of Social Science and Humanities, Arba Minch University, Arba Minch, Ethiopia
[5] M.A, Department of Marketing Management, College of Commerce, Arba Minch University, Arba Minch, Ethiopia
[6] M.Sc., Department of Natural Resource Management of Agricultural Science, College of Agriculture, Arba Minch University, Arba Minch, Ethiopia
[7] Ph.D Candidate, Department of Psychology, College of Education and Behavioral Science, Arba Minch University, Arba Minch, Ethiopia

Abstract

Land degradation significantly threatens global food security and ecosystems, necessitating effective landscape restoration measures, particularly among smallholder farmers in vulnerable areas like the Womba watershed. This study investigates the localized socio-economic and physical factors influencing the adoption of landscape restoration practices within the Womba watershed. Utilizing data from 337 randomly selected household heads, along with focus group discussions and key informant interviews, the data were analyzed using descriptive and multivariate probit modeling estimation. The findings reveal that physical restoration practices, biological land management practices, and agronomic measures are prevalent among farmers. Key factors influencing adoption include gender dynamics, with male-headed households favoring physical interventions, while female-headed households prefer agronomic approaches. Age negatively impacts the adoption of physical and biological practices, while education correlates positively with agronomic methods. Family size enhances agronomic adoption, and access to credit significantly increases the likelihood of implementing diverse restoration strategies. Village memberships are positively associated with four landscape restoration practices at a 1% significance level. Notably, while farmers recognize the ecological benefits of these practices, their perceptions of socio-economic advantages remain limited. To promote broader adoption of restoration initiatives, policymakers should enhance educational outreach on the long-term socio-economic benefits and improve access to credit and extension services. Integrating these dimensions into policy frameworks will foster greater participation from both male and female farmers, ultimately supporting sustainable development in the Womba watershed and beyond.

Keywords: Landscape restoration, Smallholder farmers, Factors, Multivariate probit modeling, Womba watershed

Article Type: Research Article

*Corresponding Author, E-mail: dessalegnechanie@gmail.com

Citation: Haile, D. C., Bedhane, M. D, Shiferaw, W., Birra, D. A., Morgamo, Z. D., Chalite, G. C., & Gebre, Z. A. (2025). Socio-economic and biophysical determinants of landscape restoration adoption among smallholder farmers in the Womba watershed, Southern Ethiopia, Water and Soil Management and Modeling, 5(4), 116-142.
doi: 10.22098/mmws.2025.18362.1680
Received: 16 September 2025, Received in revised form: 02 October 2025, Accepted: 29 October 2025, Published online: 07 November 2025
Water and Soil Management and Modeling, Year 2025, Vol. 5, No. 4, pp. 116-142.
Publisher: University of Mohaghegh Ardabili

1. Introduction

Land degradation poses a significant threat to food security and ecosystems globally, impacting over 3.2 billion individuals (UNCCD, 2022). To address this issue, various landscape restoration measures, such as agroforestry and soil bunds, are being promoted to bolster resilience, especially among smallholder farmers in at-risk areas. Recent research highlights the complex socio-ecological factors influencing the adoption of various landscape restoration activities. A global meta-analysis conducted by Crouzeilles et al. (2016) revealed that factors like land tenure security, access to extension services, and immediate economic incentives are key motivators for restoration efforts across 120 cases in Africa, Asia, and Latin America. Additionally, Prakash et al. (2024) demonstrated that participatory governance and inclusive gender programs can increase landscape restoration adoption rates by 40–60% in degraded tropical regions, underscoring the importance of developing locally appropriate institutional frameworks. A cross-continental study conducted by Boardman et al. (2003) found that high initial costs and delayed returns prevent 65% of smallholders from adopting soil and water conservation practices, despite the long-term benefits surpassing the initial investments. Similarly, Chirwa et al. (2024) pointed out the discrepancies between policy-driven goals, such as the Bonn Challenge, and the realities on the ground. They noted that top-down strategies often overlook indigenous knowledge and the critical trade-offs between crops and livestock that are essential for smallholder livelihoods. These insights are consistent with evidence from Southeast Asia, where farmer-led agroforestry systems have proven to be more effective than government-mandated reforestation in promoting ecological recovery and generating income (Huyer et al., 2021).In Africa, the integration of landscape restoration practices by smallholder farmers is influenced by various socio-economic, institutional, and environmental elements. For instance, in East Africa, successful communal agroforestry projects emerge when traditional land ownership aligns with national regulations (Wynants et al., 2019). In Southern Africa, however, challenges like limited access to financing and competing land-use interests hinder the progress of land management activities (Reed et al., 2023). Research conducted across 15 Sub-Saharan countries shows that gender inequalities lead to a 30% lower participation rate of women in restoration initiatives, despite their vital role in agroecological practices (Gebrehiwot et al., 2021; Assefa & Gebrehiwot, 2023). According to , Owen P (2020), highlighted that soil conservation practices in Zimbabwe's communal lands rely significantly on the exchange of knowledge among farmers rather than on formal extension services. In West Africa, a participatory watershed management initiative in Burkina Faso led to a 45% increase in the adoption of land resource management practices, but this improvement was only achieved when it was paired with the use of drought-tolerant seeds and the integration of livestock (Ouédraogo et al., 2022). Sub-Saharan Africa, where 65% of arable land is compromised, faces severe challenges, exemplified by Ethiopia's loss of 1.9 billion tons of soil each year (Tamene et al., 2017). In Ethiopia, efforts to restore landscapes have gained traction through soil and water conservation (SWC) initiatives designed to combat land degradation and improve ecosystem resilience (Teshome et al., 2016; Mengie et al., 2019). Land management practices such as terracing, agroforestry, check dams, and area closures have been widely adopted to reduce soil erosion, enhance water retention, and restore vegetation (Haile et al., 2006; Teklewold et al., 2013; Gidey, 2015; Haile et al., 2024). Recent research emphasizes the benefits of combining indigenous knowledge with modern techniques, which promotes community ownership and sustainability (Seid et al., 2022). For example, Ethiopia's Sustainable Land Management Program (SLMP), in collaboration with international partners, has encouraged large-scale afforestation and watershed management. This initiative has led to increased groundwater recharge and improved crop productivity in regions such as Tigray and Amhara (Mekuria et al., 2017; Mekuria et al., 2020; Girma et al., 2023). However, the effectiveness of these measures relies on adaptive strategies designed for specific local agroecological zones, as uniform approaches frequently overlook differences in soil types, topography, and rainfall patterns. Engaging farmers in decision-making through participatory frameworks has been essential for the long-term adoption of soil and water conservation practices (Adimassu et al., 2017; Bekele et al., 2021; Haile et al., 2024).

Despite advancements, several interconnected factors impede the implementation of landscape restoration activities in Ethiopia (Mekuriaw, 2017; Mekuriaw et al., 2018). Institutional challenges, such as fragmented governance and weak coordination between federal and regional agencies, often delay project execution and resource allocation (Fekadu & Belay, 2024). Socioeconomic barriers, including limited financial incentives for farmers and competing land-use priorities, diminish community motivation to adopt soil and water conservation measures (Teshome et al., 2013; Kirui, 2016; Yirgu, 2022). Furthermore, land tenure insecurity exacerbates this issue, as households are reluctant to invest in long-term conservation without guaranteed land rights (Alemu et al., 2022). Technical constraints, such as inadequate training on the maintenance of structures (Mengistu & Assefa, 2019; Haile et al., 2024) and limited access to drought-resistant seedlings, also undermine effectiveness. Climate change intensifies these challenges, with unpredictable rainfall and prolonged droughts disrupting hydrological cycles, which necessitate adaptable, climate-smart approaches. Recent research highlights the necessity for integrated policies that combine SWC interventions with livelihood diversification, secure land tenure, and decentralized governance to tackle these multidimensional barriers (Dangiso & Wolka, 2023; Tadesse, 2023). Landscape restoration in southern Ethiopia, known for its varied agro-ecological zones from highland areas to arid lowlands, relies significantly on tailored soil and water conservation (SWC) measures to address land degradation and strengthen livelihood resilience (Toma et al., 2017; Wolka et al., 2018). Practices such as hillside terracing, fanya juu, agroforestry integrations, and micro-watershed management have demonstrated effectiveness in reducing erosion and enhancing soil fertility (Haile et al., 2024; Yagaso et al., 2024). Nonetheless, the region faces distinct challenges, including unpredictable rainfall patterns, the spread of invasive species like *Prosopis juliflora*, and population pressures that contribute to unsustainable land use practices (Assefa & Tsegaye, 2023). Socioeconomic factors, including restricted access to credit and markets, prevent smallholder farmers from investing in sustainable soil and water conservation practices. Additionally, cultural traditions and land tenure conflicts, especially in communal grazing areas, complicate the adoption of these practices (Hailu, 2025). Institutional shortcomings, such as ineffective extension services and disjointed project management, impede the scaling of successful pilot initiatives, as observed in the Gamo highlands (Tadesse et al., 2025) and Gofa highlands (Desalegn et al., 2020). Recent research highlights the importance of adaptive, participatory approaches that combine indigenous agroecological knowledge with climate-smart technologies, such as drought-resistant crop varieties and rainwater harvesting systems, to overcome these complex challenges (Bekele et al., 2021; Tadesse et al., 2021; Hailu, 2022). There is also a growing emphasis on strengthening community governance and integrating SWC with livelihood diversification strategies, such as beekeeping and eco-tourism, to achieve sustainable restoration outcomes in the ever-evolving socio-environmental landscape of southern Ethiopia. In the Gofa highlands, particularly the Womba watershed, various landscape restoration activities have been implemented, including terracing, fanya juu, soil and stone bunds, check dams, gabions, agroforestry, and area closures, facilitated through community mobilization, network campaigns, and individual farmers (Saguye, 2017. The main objectives of these measures are to rehabilitate degraded landscapes, improve soil fertility, and enhance livelihood resilience (Desalegn et al, 2020; Haile et al., 2024). Research on land management practices in the area highlights their significance and influencing factors. However, localized socioeconomic aspects such as household income, fragmented landholdings, overgrazing, terrain slope, and socio-cultural barriers have not been thoroughly examined in the smaller micro watersheds of Womba. Moreover, insufficient attention has been given to socio-cultural obstacles, including conflicts between traditional land-use practices and modern soil and water conservation methods, as well as gender inequalities in resource access that impact households' decisions to adopt land management technologies. The long term economic sustainability of landscape restoration efforts also remains underexplored, creating gaps in evidence-based policy development. Additionally, institutional challenges such as irregular extension services and ineffective enforcement of communal land-use regulations have been identified but lack empirical connections to implementation failures in the peer-reviewed literature, particularly using robust methodologies in the target watershed.

Moreover, previous studies by Saguye (2017) and Desalegn et al. (2020) analyzed the factors influencing rural households' management practices using logistic regression models. However, these models did not account for the interdependencies and substitutive relationships among various restoration activities. Additionally, some recommended socioeconomic variables, such as land certificates, land fragmentation, household income, and village membership (Dessalegn et al., 2024), were not considered. To address these methodological and variable gaps, the current study aims to 1) identify factors that influence smallholder farmers to implement landscape restoration practices in the Womba Watershed 2) assess smallholder farmers' level of agreement on the benefits of landscape restoration practices.

Identifying the factors influencing community landscape restoration practices in the Womba watershed is essential for sustainable land management and environmental conservation. This understanding enables the development of tailored interventions that enhance the effectiveness and cultural acceptance of restoration efforts. Recognizing the interplay of social, economic, and environmental factors allows stakeholders to create targeted educational programs and resource strategies, fostering community engagement and ownership. Such knowledge supports local agricultural practices, promotes resilience against climate change, and improves ecosystem health. Additionally, this research aligns with SDG 15 (life on land) by promoting sustainable land management and biodiversity. Assessing farmers' agreement on the benefits of these practices also corresponds with SDG 1 (No poverty) and SDG 2 (zero hunger), as it raises awareness of restoration benefits, ultimately improving food security and livelihoods for smallholder farmers.

2. Materials and Methods

2.1. The biophysical characteristics of the study watershed

The Womba River, from which the watershed derives its name, is a semi-perennial river originating in the hills of the Geze Gofa district and draining into the Zenti River, a tributary of the upper Omo River. The watershed is located between the Geze Gofa and Demba Gofa districts, approximately 155 km northwest of Arba Minch, Ethiopia. Astronomically, it spans latitudes 6°15'00"N to 6°30'00"N and longitudes 36°45'00"E to 37°00'00"E, covering an area of 2,765.74 hectares (ha) (Figure 1). The project site lies within three *kebeles* (the smaller administrative units of Ethiopia), with the majority situated in *Dakisho Kebele* in the upper portion of the watershed. The geology of the watershed area is primarily shaped by the trap series lava flow from tertiary volcanic eruptions. The landscape is characterized by mountains, undulating terrains, plains, and rugged surfaces, which account for 16%, 30%, 49%, and 5% of the total area, respectively (Desalegn et al., 2020). This area is one of the most affected parts of the Ethiopian mountain system in terms of soil erosion, forest degradation, farmland exhaustion, and related disruptions to livelihoods (Desalegn et al., 2020). Dakisho Mountain, the highest peak in the area, separates the *Jawula* highlands from the *Karcho-mella* hills. The diverse geology, relief, climate, land use, and land cover of the watershed have fostered the development of various soil types, including dystric cambisols, orthic acrisols, and dystric nitisols (Figure 2). The climatic conditions of the Womba watershed fall under the categories of dega, weyna-dega, and kola agro-ecological zones (Desalegn et al., 2020). The mean annual temperature ranges from 25 to 35.1 degrees Celsius (°C). The average daily maximum and minimum temperatures are 30.3 °C and 14.8 °C, respectively (ENMSA, 2017). According to Saguye (2017), the area experiences two distinct rainy seasons: the bimodal *Belg* and *meher*. The majority of rainfall occurs during the *meher* season, which lasts from July to September. In the project site, the dominant native vegetation includes *agam* (*Carissa edulis*), *girar* (*Acacia bussie*), *bahirzaf* (*Eucalyptus camaldulensis*), sesbania (*Sesbania sesban*), *wanza* (*Cordia africana*), and *kitkita* (*Dodonaea*), all of which help to reduce environmental degradation.

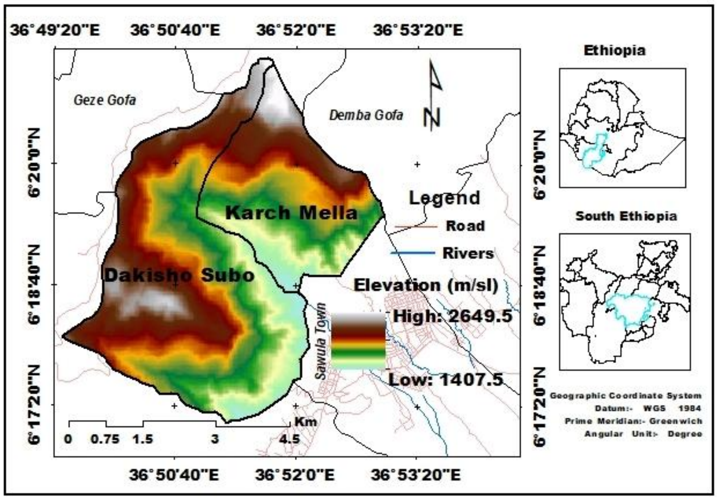

Figure 1. Location map of the Womba watershed

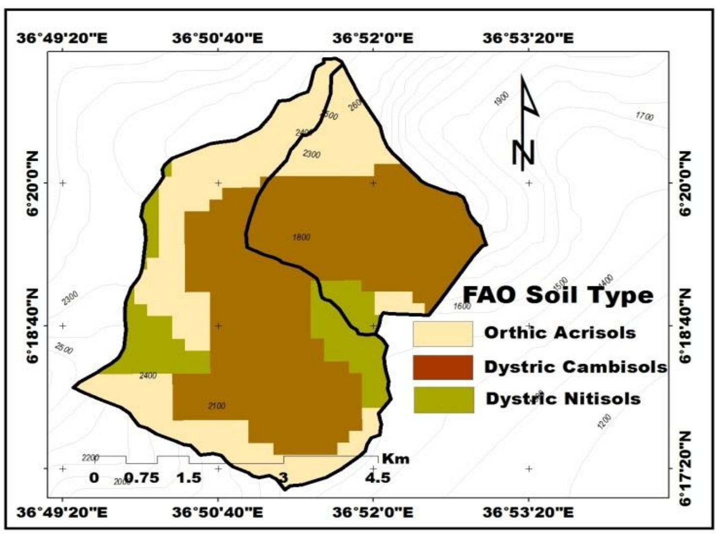

Figure 2. The dominant soil types in the Womba Watershed

2.2. Socio-economic background

The projected total population of the watershed for July 2017 is 7,680 people, distributed across the six *kebeles* within the watershed (CSA, 2013). These inhabitants occupy an estimated area of 2,636.74ha. Agricultural activities are characterized by a small-scale subsistence mixed farming system, with livestock production as an integral component. Crop production includes maize (Zea mays), sorghum (*Sorghum bicolor*), barley (*Hordeum vulgare*), wheat (*Triticum aestivum*), teff (*Eragrostis tef*), sweet potatoes (*Ipomoea batatas*), taro (*Colocasia esculenta*), and yams (*Dioscorea spp*.) cultivated across diverse landscapes. Perennial crops such as enset (*Ensete ventricosum*), stimulant coffee (*Coffea arabica*), and chat (*Catha edulis*), and timber species like eucalyptus trees are also grown in significant quantities. In addition to crop production, livestock rearing is a key occupation, with communities raising cattle, sheep, goats, donkeys, and poultry. Off-farm activities, petty trade, and handicrafts serve as additional income-generating activities.

2.3. Research design and approach

To fulfill the objectives of the study, a pragmatic philosophy was employed, as it incorporates different approaches and methods to address the problems under investigation. Consequently, the study employed a mixed research approach with a concurrent triangulation design (Figure 3). This design was chosen because both quantitative and qualitative data collection and analysis were conducted simultaneously at a specific time. Creswell (2014) suggested that mixed-method survey research has the advantage of utilizing a large amount of data in a descriptive study, allowing for a high degree of interaction with respondents. For this project, concurrent triangulation, involving both quantitative and qualitative approaches, was used to generate and analyze the data (Figure 3). The mixed research approach is preferred for this study because it provides an opportunity for researchers to utilize both quantitative and qualitative data collection methods and analysis techniques to address the issues under investigation (Creswell, 2014). Finally, the study illustrates its conclusions through data interpretation and analysis, explains its limitations, and forwards policy implications (Figure 3).

2.4. Sampling technique and sample size determination

In this research, a multi-stage sampling approach was utilized. Initially, the Womba watershed was intentionally chosen through a non-probability sampling method due to its notable environmental challenges and the disruptions to livelihoods caused mainly by local traditional agricultural practices. In the subsequent stage, specific *kebeles* were selected. Two *kebeles,* dakisho and karcho-mella, located in the middle and upper parts of the watershed, were chosen because of their pronounced environmental and socio-economic difficulties. Finally, participants from these *kebeles* were systematically identified using a proportional allocation method, guided by stratified lists of 2,132 farm household heads maintained by the *kebele* administration. The necessary sample size was determined using a formula developed by Yamane (1967), as detailed below in Eq. (1):

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

Where n is the sample size, N is the total household heads of *dakisho* and *karcho-mella kebeles* (upper and middle streams of Womba watershed), and e is the level of precision (5 %), from which 337 household heads were selected as the sample.

Therefore, in order to determine the size of the sample household heads of each *kebele* (n), the researchers are applying the following formula, Eq. (2), derived from Yamane (1967)

$$n_{k_i} = \frac{N}{\sum N} * S \tag{2}$$

Where, n_{ki} = the number of necessary samples respondents of each *kebele,* N Total household heads of each *kebele,* S Total sample household heads to be treated (337), ΣN= Total household heads of the three sample *kebeles equals* 2132

Therefore, the sample size for Dakisho kebele was determined to be 174 household heads, while the sample size for Karch-Mella kebele was 163 household heads, based on their proportion of the total households.

Table 1: Sample distribution of households in the selected watershed kebeles

Sample *kebeles*	Total number of household heads*	Total sample	Sample in percentage
Dakisho	1098	174	51.6
Karcho-mella	1034	163	48.4
Total	2132	337	100
Source from Demba-Gofa Agricultural Development Office Report (DGARDOR, 2022).			

2.5. Data source and data collection instruments

The study drew from two primary sources of data: primary and secondary. Primary data were gathered through household surveys, field observations, focus group discussions, and interviews with key informants.

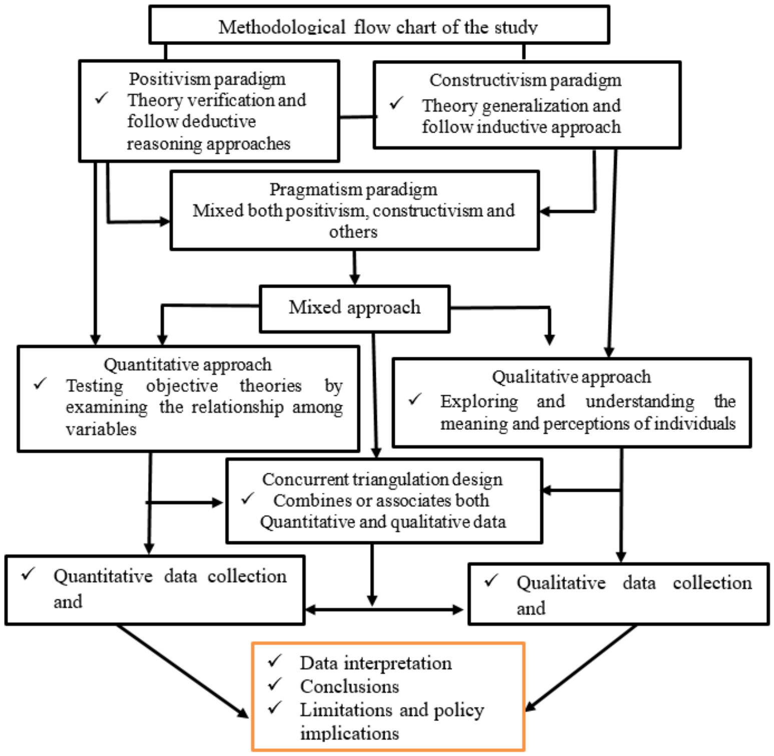

Figure 3: The methodological flowchart of the study, Source: Developed by authors, 2025

The household survey aimed to collect quantitative information. Before execution, the questionnaire was meticulously designed to ensure clarity and relevance, avoiding ambiguous language to foster respondent confidence and preserve data quality. It was also pre-tested in the study area to confirm its content relevance. Secondary data were sourced from a review of project documents, reports, and both published and unpublished research papers. This review helped identify existing factors affecting implementation and soil and water management practices, along with knowledge gaps that necessitate further investigation. Qualitative data were collected through participant observation, interviews with key informants, and focus group discussions, utilizing prepared checklists and selecting individuals purposefully to align with the research objectives.

Household survey

To investigate the factors that affect smallholder farmers' adoption of landscape restoration practices and their views on the benefits of these practices, both open-ended and closed-format questions were formulated. Initially prepared in English, these questions were later translated into Amharic to ensure clear communication with the participants. The household survey was carried out with the help of development agents working in rural kebeles. As a result, data on household demographics, socio-economic status, institutional involvement, and social asset characteristics, as well as perceptions of land management technologies, were gathered through face-to-face interviews conducted from February to July 2024.

Focus group discussion

Focus group discussions (FGDs) play a crucial role in collecting qualitative insights and validating data gathered from household surveys. Engaging participants in dialogue about their perceptions often leads to a greater likelihood of them expressing their genuine feelings. Therefore, FGDs were organized with carefully chosen participants. As noted by Angehrn (2017), an ideal FGD group consists of about 6 to 12 individuals for effective participatory research. Groups exceeding 12 can be difficult to manage, while those with fewer than 6 might not accurately reflect the community. Consequently, 24 elder participants were selected, comprising 16 males and 8 females, with 12 males and 4 females from each *kebele*. The selection was purposeful, taking into account their prior knowledge of the benefits of landscape restoration practices, as well as their understanding of institutional, cultural, and socio-economic barriers to implementing these practices, along with their familiarity with land certification and related issues in the study areas. Each *kebele* in the watershed hosted one FGD..

Interview and observation

Creswell (2014) highlights that one of the primary benefits of the observation method is its ability to remove subjective bias associated with data collected through surveys, provided that the observations are conducted properly. In the field, two transect walks were conducted in the study area, guided by the *kebele* administrator, along with four volunteer farmers and the researchers, visiting each sample *kebele*. The researchers prepared specific observation notes in advance and took several photographs. This approach allowed for the collection of information from various community members, facilitating interaction with a diverse range of individuals.

2.6. Empirical model estimation

Choosing and implementing the right econometric model is crucial for precisely estimating the overall effect of independent variables on dependent outcomes. In this study, a multivariate probit (MVP) model was utilized to assess the factors affecting smallholder farmers' adoption of landscape restoration practices in the Womba Watershed. This model examined a range of hypothesized variables, including socio-economic and institutional factors, land characteristics, household perceptions of restoration practices, policy influences, and cultural aspects. The MVP approach is particularly well-suited for analyzing treatment variables with multiple binary categories (Teklewold et al., 2013; Haile et al., 2024), In the study area, smallholder households participate in a variety of restoration activities, such as physical land management techniques (including terraces, stone bunds, soil bunds, fanya-juu, gabions, and cut-off drains), biological practices (tree planting, agroforestry, and reforestation), as well as agronomic methods (crop rotation, mulching, fallowing, and strip cropping) and area closure management. The MVP model also sheds light on the interconnections and synergies among these practices (Ewunetu et al., 2021; Haile et al., 2024). Featuring four binary categorical dependent variables, the model's predictions were generated using the methodologies specified by Kassie et al. (2013), Teklewold et al. (2013), as shown Eq. (3 & 4).

$$Y^{*}_{im} = \beta_m X_{im} + \mathcal{E}_{im\,;} \quad (= 1,2,3) \tag{3}$$

$$Y_{im} = 1 \text{ if } > 0 \text{ and } 0 \text{ otherwise} \tag{4}$$

Due to the assumption that rational ith households possess a latent variable Y*im, which reflects unobserved preferences linked to their participation in landscape restoration activities (m = 1, 2, 3, and 4) within the study watershed, the following is proposed: X_{im} represents a vector of independent variables expected to predict each of the restoration activities. The parameter β_m denotes the number of variables that illustrate the effects of changes in the independent variable vector, while $\mathcal{E}_{im}$ signifies error terms that adhere to a multivariate normal distribution, each with a mean of zero and a variance-covariance matrix characterized by 1 on the diagonal and non-zero correlations in the off-diagonal elements (Ewunetu et al., 2021). The off-diagonal elements indicate the relationships between various landscape restoration activities.

$$\text{Cov. matrix } (\mathcal{E}_i\ , \mathcal{E}_{ii..}\ \mathcal{E}_n\ ) \begin{vmatrix} 1 & p_{12} & p_{13} \\ p_{21} & 1 & p_{23} \\ p_{31} & p_{31} & 1 \end{vmatrix} \tag{5}$$

In the MVP model, $\mathcal{E}_i$, $\mathcal{E}_{ii}$... $\mathcal{E}_n$ refer to the disturbance associations, and p denotes the parameter representing the relationships among the determinants of landscape restoration activities. A positive sign indicates complementary relationships, whereas a negative sign suggests a substitution effect between the practices (Teklewold et al., 2013).

2.7. Description of variables in the MVP model

This research explores the involvement of households in activities aimed at landscape restoration, such as land management practices, biological measures, agroforestry practices, and area closure strategies, using a binary dependent variable (1 = participation, 0 = non-participation). The analysis includes 14 independent variables, which are outlined in Table 2. The selection of these variables is based on pertinent literature and established theoretical models. Table 2 provides a summary of the independent variables, including their descriptions, expected effects, and measurement methods.

2.8. Ethical consideration

Ethics are the moral principles that direct the actions of an individual or a group of people. To commence the research activities, the authors have received participants' verbal consent approval letter from Arba Minch University Sawla campus ethical approval consent committee (with identification Ref CSH/178/08 and protocol CSSHRO/033**.** The authors of this research prioritized integrity and ethical standards throughout the study. They carefully considered conflicts of interest, plagiarism, and proper authorship while ensuring participants were fully informed and their consent was voluntary. All individuals were treated equitably, with no unnecessary risks involved, and they received adequate information to make informed decisions. The authors believe that these ethical practices safeguarded the rights and welfare of all participants.

Table 2: Independent variables, along with their descriptions, expected effects, and measurement methods

Independent variable	variable description	variable measurement	expected sign	mean	STDEV
Sex of HHs	sex of household heads	1= male, 0=otherwise	±	0.887	0.291
Age of HHs	age households	age in years	±	0.464	0.341
Marital status	marital status of household heads	1= single, 2= married, 3= divorced, 4= widowed	±	0.021 0.961 0.011 0.007	0.391
Education of HHs	educational status of household heads	1= not read and write, 2= read and write 3= primary school 4=high school	−	0.620 0.310 0.060 0.010	0.431 0.219 0.082 0.002
Family size of HHs	households family size	family size in number	+	0.610	0.132
TLU	number of livestock owned	livestock owned in TLU	+	0.401	0.161
Farm size	households landholding size	households' farm size in hectares	−	2.01	0.184
Land fragmentation	The characteristics of land in the local areas	1= fragmented ; otherwise 0	−	0.671	0.301
Farm distance	households farm distance	farm distance in kilometers	±	0.051	0.101
Land certification	households possess official certificates of land ownership.	1= have official certificate, otherwise 0	+	0.825	0.137
Slope of household-owned land.	the topographical features of the land	1= gentle; otherwise 0	±	0.382	1.18
HHs income*	households' annual income in ETB	households' annual income in ETB	±	45,231ETB	-
HHs perception of the BLSRA	Households' perceptions of the BLRA activities.	1= households pensive the BLSRA; otherwise 0	±	0.496	0.341
Extension services	households' access to extension services	1= households' access to extension services; otherwise 0	+	0.525	0.217
Access to credit services	households' access to credit services	1= households' access to credit services; otherwise 0	±	0.561	0.174
Village membership	Households involvement in village membership	1= households involving village membership; otherwise 0	±	0.374	0.473
HHs perception of SE	households' perception of soil erosion	1=households pensive SE severities; otherwise 0	−	0.402	0.281
Dependent variable					
Landscape restoration activities in the Womba watershed	PLMP, BLMP, AGRNOP, and area closure	1= physical land management practices; 2 biological measures; 3 agronomic practices; 4 area closure management	+	0.873 0.774 0.839 0.381	-

HH, household heads; BLSRA, benefits of landscape restoration activities; BLMS, biological land management practices; PLMP, physical land management practice; AGRONP, agronomic practices; SE, soil erosion; TLU, tropical livestock unit; ETB, Ethiopian birr. *Households' annual income is the crop harvesting season 2024/2025

3. Result and Discussion

3.1. Socio-economic profile of sample households

The survey reveals a notable gender disparity, with 88.7% of household heads being male and only 12.3% female (Table 2). This discrepancy likely reflects cultural, social, or institutional norms in the region, where men are traditionally viewed as the leaders of households. Such a gender imbalance may affect landscape restoration efforts, as women often play unique roles in managing resources, such as agriculture and water collection. Their limited representation as household heads could hinder the inclusion of gender-specific viewpoints in restoration initiatives. Of the total respondents, 96.1% are married, while 2.1% are single, 1.1% are divorced, and 0.7% are widowed (Table 2). This significant majority of married individuals implies that they likely have more stable financial and social structures, which enable greater investment in landscape restoration activities. Their predominant presence suggests that restoration programs should emphasize family-oriented approaches, as married individuals may be more inclined to prioritize long-term environmental sustainability for their families. Furthermore, married individuals often possess stronger community ties, which can facilitate collective efforts in restoration initiatives. Engaging this demographic could not only enhance the effectiveness of community-based projects but also foster a sense of ownership and responsibility towards the local environment, ultimately leading to more successful and sustainable restoration outcomes. By fostering a sense of ownership over local resources, engaging this demographic can enhance the effectiveness of restoration programs and promote more sustainable outcomes for the community. Educational attainment among respondents was alarmingly low. A significant portion 62% indicated they couldn’t read and write, while 31% reported having basic literacy skills. Only 6% had completed primary education, and just 1% achieved secondary education, highlighting a substantial literacy gap within the surveyed group (Table 2). Participants were also asked about the characteristics of their land in the study watersheds. A majority, 67.1% described their land as fragmented, while 32.9% reported owning consolidated plots (Table 2). Overall, the survey indicated that over half of the households sampled consider land fragmentation to be a significant concern in the watersheds.

The sampled households were located an average of 5.1 kilometers from their farm plots, with distances varying from 1 km to 9 km within the study area (Table 2). About 49.6% of participants recognized the advantages of effective landscape restoration, while 50.4% remained doubtful about the success of current restoration efforts. This difference may stem from diverse experiences with implementation or varying observed results. A majority, 56.1%, had access to credit services, mainly through Omo Microfinance Institutions (OMI). Each household managed an average farmland size of 2.01 hectares, with sizes ranging from 0.25 to 7 hectares (Table 2). Furthermore, 82.5% of households held official land tenure certificates, which confirm their ownership rights. More than half of the respondents, 52.5% accessed agricultural extension services, while 47.5% did not receive any guidance on land management practices. The survey revealed that 34.7% of respondents were involved in village organizations, leaving 65.3% without participation in local community groups (Table 2). This indicates limited involvement in collective decision-making and fewer opportunities for sharing knowledge on sustainable practices. Approximately 40.2% of respondents acknowledged the detrimental effects of soil erosion and land degradation in the study watershed. In contrast, a majority, 59.8% did not recognize the seriousness of the issue, possibly due to a lack of awareness regarding the consequences of erosion. As indicated in Table 2, the average annual household income during the survey period was 45,231ETB (Ethiopian birr). This economic context is critical because limited income may restrict investments in sustainable land management practices.

3.2. Types of land restoration practices in the Womba watershed

A variety of landscape restoration strategies have been implemented in the Womba watershed to address soil erosion, restore degraded ecosystems, improve soil fertility, and enhance rural livelihoods. These strategies encompass both physical and biological practices, as well as agronomic measures and area closure management.

Physical land management practices (PLMP) employed in communal and smallholder farms include hillside terracing, stone and soil bunds, *fanya-juu* practices, cut-off drains, gabions, and trenches (Giz, 2015; Adimassu et al., 2017; Etsay et al., 2019; Yirgu, 2022; Haile et al., 2024). Biological land management practices (BLMP) focus on the use of multipurpose grass species (such as fodder species), agroforestry trees, and fruit-bearing plants to stabilize soils and diversify income sources (Hishe et al., 2017; Umer et al., 2019; Haile et al., 2024). Agronomic practices (AGRNOP) include sustainable farming techniques like crop rotation, mulching, organic manure application, and strategic fallowing (Giz, 2015). The area closure strategy involves the temporary or permanent exclusion of degraded areas from human and livestock activities to facilitate natural regeneration (Abeje et al., 2016; Mekuria et al., 2020; Workie & Teku, 2025).

As shown in Figure 4, 87.3% of the surveyed households have embraced at least one PLMP on their farms, while 77.4% utilize biological practices such as agroforestry and grass species.

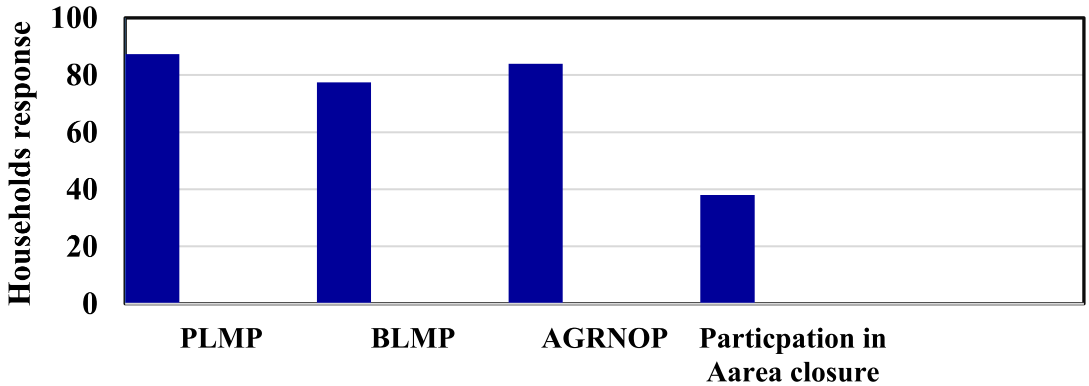

Figure 4. Types of landscape restoration practices

Furthermore, 83.9% incor
porate agronomic strategies, including crop rotation and mulching. Additionally, 38.1% have implemented partial area closure techniques to reduce soil erosion and ensure fodder availability for livestock, highlighting its dual function in both land conservation and livelihood enhancement (Figure 4).

3.3. Factors that influence smallholder farmers to implement landscape restoration activities: MVP model prediction

An econometric assessment was conducted to examine the factors influencing smallholder farmers in their engagement with landscape restoration activities, utilizing the MVP function with robust standard errors. Before applying the MVP model, multicollinearity among the independent variables was assessed using the variance inflation factor (VIF) and tolerance (Table 3). The results show that all independent variables have a VIF of less than 10 and a tolerance level exceeding 0.1, indicating that these variables are not correlated and that the estimated coefficients meet the model's minimum requirements (Table 3). Additionally, the log-likelihood value is -821.361, with a probability greater than chi-squared of 0.0000 (Table 4). The likelihood ratio test for the hypothesis that $\rho21 = \rho31 = \rho41 = \rho32 = \rho42 = \rho43 = 0$ produced a chi-squared statistic of 88.780 with 16 degrees of freedom and a significant probability greater than chi-squared of 0.000, demonstrating significance at p = 0.01 (Table 4). This outcome leads to the rejection of the null hypothesis, which posits that decisions regarding involvement in each of the four landscape restoration activities are independent.

Table 3. Results of multicollinearity among independent variables

Independent variables	Tolerance	VIF
Sex of HHs	.801	1.248
Age of HHs	.762	1.312
Marital status	.562	1.779
Education of HHs	.809	1.236
Family size of HHs	.771	1.297
TLU	.678	1.474
Farm size	.976	1.024
Land fragmentation	.807	1.239
Farm distance	.597	1.675
Land certification	.921	1.085
Slope of household-owned land.	.861	1.639
HHs income	.799	1.251
HHs perception of the BLSRA	.712	1.404
Extension services	..600	1.666
Access to credit services	.591	1.692
Village membership	.884	1.131
HHs perception of SE	.581	1.721
Mean VIF	1.403	

HHs, household heds, VIF, variance inflation factor, TLU; tropical livestock unit; SE; soil erosion, BLSRA; benefits of landscape restoration activities

Sex: The analysis of the MVP model reveals a significant positive correlation between the sex of household heads and the adoption of erosion control practices (PLMP) with a p-value of less than 0.01, as well as area closure management practices ($p < 0.05$). In contrast, the sex of household heads demonstrated a significant negative relationship with the adoption of AGRNOP practices ($p < 0.05$). Specifically, male-headed households were 70.1% more likely to implement PLMP compared to their female counterparts, while they were 17.7% less likely to adopt AGRNOP practices. (Table 4).

Furthermore, the results of the likelihood ratio test highlight the model's strong goodness of fit. The use of multivariate probit (MVP) modeling is advantageous because it captures the interdependencies among multiple treatment variables that influence the outcome variables. This approach allows for a more nuanced understanding of how these variables interact, providing insights that are not accessible through simpler models. By accounting for these relationships, the MVP model enhances the accuracy of predictions and better reflects the complexity of the factors affecting landscape restoration activities (Lokshin & Sajaia, 2004; Kassie et al., 2009; Teklewold et al., 2013). Additionally, the MVP model is capable of capturing unobserved heterogeneity that concurrently affects smallholder farmers' engagement in landscape restoration activities. It also enhances the efficiency of parameter estimation by utilizing the information embedded in the covariance among the error terms across the various equations (Lokshin & Sajaia, 2004).

The results from the MVP model revealed that among the 16 independent variables, several factors were linked to the adoption of landscape restoration practices by smallholder farmers. Key influences included the sex of household heads, marital status, age, educational level, family size, land fragmentation, perceptions of soil erosion, slope, land certification, and households' views on the BLSRA. These factors demonstrated both positive and negative relationships with adoption rates (Table 4). In contrast, village membership, access to credit, household income, and Tropical Livestock Units (TLU) displayed positive correlations, while the size of landholdings was negatively associated with participation in landscape restoration activities (Table 4).

Sex: The analysis of the MVP model revealed a significant positive correlation between the sex of household heads and the adoption of erosion

control practices (PLMP) with a p-value of less than 0.01, as well as area closure management practices ($p < 0.05$). In contrast, the sex of household heads demonstrated a significant negative relationship with the adoption of AGRNOP practices ($p < 0.05$). Specifically, male-headed households were 70.1% more likely to implement PLMP compared to their female counterparts, while they were 17.7% less likely to adopt AGRNOP practices. (Table 4). This suggests that the dynamics of gender play a crucial role in determining the landscape restoration strategies chosen by smallholder farmers. Specifically, male-headed households tend to prefer structural interventions, which may include physical changes to the landscape, such as building terraces or installing drainage systems. On the other hand, female-headed households are more likely to focus on agronomic approaches, emphasizing practices like crop rotation, cover cropping, or soil management techniques that enhance agricultural productivity while restoring the landscape. This distinction highlights how gender influences decision-making in agricultural practices and landscape management. Our results align with (Ayele et al., 2024), who found that 73.78% of male-headed households in North Wollo, Ethiopia, adopted at least one adaptation strategy, whereas only 58.91% of female-headed households did. Additionally, (Asfaw et al. (2019), Mihiretu et al. (2020), and Haile et al. (2024) noted that female-headed households primarily depend on collecting and selling fuelwood for energy to support their livelihoods. Similarly, Friman (2020) in Burkina Faso observed that women are more involved in the trade of forest products like fuelwood rather than engaging in physical practices, compared to men.

Also, the qualitative data obtained from the majority of focus group discussions (FGD) participants noted that gender has a significant impact on erosion control practices, with male-headed households preferring structural measures like terraces and female-headed households favoring agronomic practices such as crop rotation. Moreover, key informants (KIs) confirmed that these disparities stem from traditional roles, which reduce the effectiveness of landscape management and emphasize the need for gender-sensitive policies that incorporate the diverse strategies of both male and female farmers.

Marital status of the household head: The results indicate that marital status positively influences physical landscape restoration practices (PLMP), like stone and soil bunds, but negatively affects biological practices, such as planting grasses (Table 4). There is no significant impact on agronomic practices or area closure. This implies that, as the reference point, married household heads tend to adopt labor-intensive practices, likely due to increased family labor availability and stability. Recent research shows that married farmers are more inclined to adopt soil and water conservation measures due to increased labor and stability (Wordofa et al., 2020; Munthali et al., 2025). However, the negative impact on biological and agronomic practices is linked to their higher financial and domestic responsibilities, which limit investments in long-term practices (Bekele et al., 2024). Some studies even suggest that single farmers, particularly women, may adopt biological or agronomic innovations more actively due to decision-making autonomy (Kanjanja et al., 2022).

However, some studies contradict this pattern, showing that marriage can also encourage the adoption of agronomic practices, such as fertilizer use or agroecological methods, especially when access to credit, inputs, or extension services is improved (Gashu et al., 2025). These mixed findings suggest that the role of marital status is context-dependent, particularly regarding labor availability, resource access, land tenure security, and household decision-making dynamics (Kanjanja et al., 2022). Overall, while marriage seems to promote visible, labor-intensive restoration methods, its impact on other practices is less consistent and influenced by social and economic factors (Gashu et al., 2025).

Owing to more than half of the FGD and KIs noted that marital status significantly impacts the adoption of physical landscape restoration practices (PLMP), with married household heads more likely to engage in labor-intensive methods like stone and soil bund construction due to greater family labor availability. However, they confirmed that a negative effect on biological practices, such as grass planting, is attributed to the increased financial and domestic responsibilities of married individuals. Participants emphasized that while marriage can promote visible restoration techniques, its effects on other practices, like agronomic methods, vary based on factors such as resource availability and decision-making dynamics.

Age: the analysis indicates a significant negative relationship between the age of household heads and the adoption of both PLMP ($p < 0.01$) and BLMP ($p < 0.01$). Specifically, each year decrease in the age of household heads is associated with a 51% lower likelihood of engaging in physical landscape restoration activities and a 34.1% lower likelihood for biological measures (Table 4). In contrast, older household heads demonstrate a positive correlation with the implementation of area closure management practices. This implies that younger household heads may experience greater labor constraints, hindering their ability to participate in labor-intensive practices such as erosion control and biological measures, while older heads may favor area closure, which aligns better with long-term land management and may have fewer immediate physical demands. Moreover, older household heads often have more experience and knowledge about sustainable practices and land management. This experience may lead them to prioritize long-term strategies, such as area closure, over immediate physical restoration efforts. These results are consistent with recent research on the dynamics of sustainable land management (SLM) adoption. For example, a study conducted in Nigeria found that socio-economic factors, particularly age, play a crucial role in SLM adoption, as younger farmers often face constraints related to limited resources and labor availability (Oduniyi & Tekana, 2021).

Additionally, a study in Ethiopian highlands indicated that older farmers, benefiting from greater experience, were more inclined to adopt low-labor strategies such as area closure. In contrast, younger households encountered challenges related to the initial labor and financial investments necessary for implementing physical and biological measures (Tesfaye, 2019). Younger households, typically juggling off-farm jobs and smaller landholdings, may focus on short-term gains rather than long-term restoration. In contrast, older households draw on their experience and stability to implement practices such as area closure. These practices demand less immediate labor but provide lasting benefits over time (Xie et al., 2024)

Education: The MVP model shows a negative correlation between household educational attainment and the adoption of biological landscape restoration activities (like agroforestry and reforestation), while revealing a positive correlation with agronomic practices (such as crop rotation) at a significance level of $p < 0.05$ (Table 4). This difference may stem from agronomic practices being more aligned with traditional farming methods that require less technical training, making them accessible to less educated households. In contrast, biological restoration activities demand specialized knowledge and resources, which may be less available to these households. This is supported by Tesfaye (2019), who reported that households with limited formal education favored agronomic practices for their familiarity and quick yields, while biological measures like agroforestry were less adopted due to their perceived complexity and delayed returns. Research in Togo indicated that farmers with lower education levels were more likely to use crop rotation and fallow systems rather than physical structures (Hounkpati et al., 2024; Moluh Njoya et al., 2024)

The results show a negative relationship between education and biological practices, but a positive effect on agronomic practices. This seems counterintuitive.

Family size: This variable was a statistically significant predictor of AGRNOP ($p < 0.05$), with each additional household member increasing the likelihood of adopting agronomic practices by 17.9%, assuming other factors remain constant (Table 4). This supports recent studies indicating that larger families boost labor availability for labor-intensive agricultural activities, especially in rural economies where household labor is essential (Haile et al., 2024). For instance, research in low-income settings indicates that families with more members can allocate human resources to tasks such as crop diversification or soil fertilization, which require sustained effort (Abeneh et al., 2024; Haile et al., 2024). Zeb et al. (2019) found that in Pakistan, households with more family members were more likely to engage in landscape restoration and soil fertility practices due to increased labor availability. Conversely, family size negatively correlated with the adoption of physical land management practices, with a decrease of one household member reducing the likelihood of implementing structural strategies like terracing or irrigation by 41.8% (Table 4). This suggests that fewer household members lead to greater labor constraints for such projects (Wang et al., 2023)

The majority of participants reported that education has a significant impact on the adoption of landscape management practices. Many of them observed a negative relationship between educational attainment and the implementation of biological restoration activities like agroforestry and reforestation. Instead, they found a positive correlation with agronomic practices, which are more closely related to traditional farming methods. They propose that households with lower educational levels may prefer familiar and less complex agronomic practices, as they yield faster results and require less specialized knowledge. Participants in both groups emphasized the importance of family size in the adoption of agronomic practices. Participants stated that larger families have more available labor, which facilitates participation in intensive agricultural activities. This increased labor availability enables families to better allocate resources to tasks like crop diversification and soil fertilization. In contrast, discussions revealed that smaller families frequently encounter difficulties in implementing physical land management practices. Participants noted that having fewer household members may limit the ability to implement labor-intensive strategies such as terracing or irrigation. Overall, these findings highlight the complex interplay between family size, labour availability, and the adoption of various agricultural practices.

Access to extension services was positively associated with the implementation of both the PLMP and the AGRNOP ($p < 0.001$), increasing the likelihood of implementation by 67.1%, 41%, and 46.3%, respectively (Table 4). Additionally, access to institutions significantly enhanced the probability of households adopting both PLMP and AGRNOP at the 1% significance level (Table 4). This supports findings by (Ullah et al., 2023; Haile et al., 2024), which indicate that access to extension services enhances farmers' ability to invest in essential inputs and engage in knowledge-sharing networks. Additionally, institutional support, such as agricultural extension services, boosts AGRNOP adoption by helping farmers leverage peer experiences to navigate risks associated with new techniques (Tabe Ojong et al., 2023). However, access to extension services shows a statistically significant negative correlation with the implementation of BLMP ($p < 0.05$), reducing the likelihood of household activities by 19.8% (Table 4). This suggests that rural households lack adequate information about BLMP through extension networks, leading to inconsistent or incomplete adoption of these practices. The findings align with broader critiques of extension systems in low-resource settings, where advice often prioritizes conventional agronomic inputs (e.g., seeds, fertilizers) over physical ecological restoration techniques (Friman, 2020; Xie et al., 2024). Studies in Nigeria and Malawi reveal that while extension services improve crop productivity, they frequently neglect biodiversity-focused practices like BLMP due to institutional biases toward short-term yield gains (Sahu et al., 2024)

Village memberships: Village memberships (e.g., Debo and Idir) were positively associated with four landscape restoration practices at a 1% significance level (Table 4). Active involvement in local organizations increased smallholder households' likelihood of implementing practices by 75.8% for PLMP, 66.2% for BLMP, 29.9% for AGRNOP, and 87.1% for area closure, while controlling for other variables (Table 4). This finding aligns with (Wondie & Mekuria, 2018; Girma et al., 2023), who noted that active participation in local organizations significantly enhances community engagement in sustainable practices, fostering a collaborative approach to landscape restoration that yields more effective and lasting outcomes. Additionally, a recent study by Alemu et al. (2022) emphasized the crucial role of local village memberships in promoting environmental awareness and collective action among farmers. Their findings indicated that households engaged in local membership groups were 65% more likely to adopt agroforestry practices, benefiting soil conservation and biodiversity. Additionally, Bekele et al. (2024) noted that robust local networks not only boost participation in restoration activities but also improve access to resources and training, thereby increasing the effectiveness of landscape restoration efforts in rural Ethiopia.

Household's income, possession of a land certificate, and land fragmentation: The study found that a household's annual income, possession of a land certificate, and land fragmentation are positively and significantly associated with the likelihood of rural households engaging in various landscape restoration activities at both the 1% and 0.05% significance levels (Table 4). The result indicated that households utilize their agricultural earnings to meet domestic expenditures, which exerts a substantial positive influence on the adoption of BLMP at the significance level of $p < 0.01$. Furthermore, the adoption of PLMP also shows significance at $p < 0.05$ (Table 4). This indicates that as farm income rises, households exhibit a greater propensity to embrace diverse agricultural technologies. Similarly, the advantageous correlation between increased income and a greater willingness to adopt various land management practices has been reported by Arunrat et al. (2017) and Gudina & Alemu (2024). Specifically, the results indicate that households with higher annual incomes, land certificates, and fragmented land are more likely to implement erosion control measures, soil management techniques, and area closure practices. Land tenure security demonstrated a significant positive correlation with PLMP and AGRNOP at $p < 0.05$, as well as with BLMP and area closures at $p < 0.01$. This suggests that secure land tenure motivates and incentivizes investments in effective land management practices. These findings support earlier studies in Ethiopia that highlight the critical role of tenure security in the adoption of such practices (Belay & Bewket, 2013; Miheretu & Yimer, 2017; Belachew et al., 2020). Moreover, Tessema (2024) emphasizes the importance of secure land tenure and financial resources in promoting sustainable agricultural practices. The study underscored that when farmers have clear ownership of their land, they are more motivated to invest in long-term improvements, such as tree planting or terrace construction, which enhance soil health and mitigate erosion. Similarly, Melaku et al.(2024) suggest that households with stable income sources are more likely to engage in practices that protect and restore the environment, as they can afford the initial costs associated with these efforts. Additionally, a study by Etsay et al. (2023) found that fragmented land holdings often drive innovative farming practices, as farmers strive to maximize productivity on smaller plots. Enhancing economic conditions and land rights can significantly boost participation in landscape restoration initiatives (Miheretu & Yimer, 2017). According to focus group discussions and key informant interviews, access to extension services is critical for implementing both physical landscape management (PLMP) and agronomic practices (AGRNOP). Over 90% of participants agreed that these services improve their ability to implement practices by providing critical information and resources. However, some participants expressed concern that access may impede the adoption of biological landscape management practices (BLMP) due to insufficient information, echoing broader criticisms of extension systems in low-resource settings. Participants emphasized the importance of village memberships in promoting landscape restoration activities. Many people noted that active participation in local organizations increases their chances of engaging in sustainable practices, improving community collaboration, and raising environmental awareness. Furthermore, discussions revealed that household income, land certificates, and land fragmentation have a positive influence on the adoption of restoration activities. Secure land tenure encourages investment in land management, while higher incomes assist households in covering the initial costs of sustainable practices, emphasizing the importance of community engagement, economic conditions, and resource access in promoting effective landscape restoration efforts.

Household views on the benefits of soil erosion control and agronomic practices: this shows a significant but negative association ($p < 0.01$), while they are positively linked to area closure management strategies ($p < 0.01$) (Table 4). The negative coefficient of physical land management practices (PLMP) may indicate that households perceive structures such as terraces and stone bunds as requiring more land, complicating oxen plowing, and attracting rats and termites that damage crops. These challenges discourage the adoption of physical structures by smallholder farmers. Furthermore, farmers believe that practices like crop rotation and mulching are ineffective in reducing runoff or improving soil fertility. These findings align with the conclusions of Belay and Bewket (2013), Adimassu et al. (2017), and Haile et al. (2024), who noted that households often perceive physical land management practices as burdensome due to their land requirements and the challenges they present to traditional farming methods. This perception contributes to a reluctance to adopt such measures. In contrast, households view area closure favorably as a landscape restoration strategy, acknowledging its potential to restore degraded landscapes, improve soil properties, and support fodder species through cut-and-carry systems (Adimassu et al., 2017).

Slope of farmland, distance of farmland, and TLU: the slope of the land exhibited a significant positive correlation with the adoption of agronomic practices (AGRNOP) and implementation of PLMP at $p < 0.05$ (Table 4). This indicates that farmers are more inclined to implement erosion control practices such as stone bunds combined with different agronomic measures on steep slopes, which are prone to quicker surface runoff. This observation aligns with the results of earlier research studies, which conclude that steeper slopes in Ethiopia are often linked to soil erosion and reduced agricultural productivity, and encourage farmers to adopt soil conservation measures (Miheretu & Yimer, 2017). Amsalu and de Graaff (2007) and Etsay et al. (2019) found that farmers tend to invest in plots where they anticipate greater benefits from conservation. Therefore, conservation initiatives should focus on landscapes with higher expected advantages, such as steep slopes, to promote adoption. This suggests that farmers are more inclined to implement conservation measures on their plots situated on steeper terrain. Conversely, Haile et al. (2024) reported that gentler slopes promote better soil organic carbon and nutrient retention, facilitating practices such as crop rotation and manure application.

The total livestock units (TLU) demonstrated a significant positive correlation with the implementation of both BLMP and AGRNOP ($p < 0.01$), as well as with the adoption of area closures ($p < 0.05$) (Table 4). Households with higher TLUs were more inclined to adopt BLMP strategies, such as growing multipurpose grass species for livestock feeding. Moreover, the likelihood of these households establishing area closures around adjacent farmland increased by 45.9% when controlling for other factors (Table 4). Larger livestock herds, indicative of higher TLUs, are associated with a greater tendency to invest in sustainable practices like tree planting and grass cultivation to ensure a steady fodder supply (Mesfin et al., 2018; Sinore et al., 2018; Umer et al., 2019; Haile et al., 2024). Additionally, a study by Mekuria et al. (2018) indicated that area closures enhanced soil quality and increased vegetation diversity, leading livestock owners to prioritize these practices for securing feed resources.

The distance from a household's farm shows a significant negative correlation with the adoption of AGROP at $p < 0.01$ (Table 4). Specifically, for each additional minute of walking distance, the likelihood of adopting AGROP decreases by 60.6% in the Womba watershed. Farmers whose fields are closer are more inclined to implement AGROP compared to those with greater distances. Notably, there is a variation in the distances affecting the application of AGROP techniques, such as manure and compost preparation. This finding aligns with the research of Beyene et al. (2019), Wordofa et al. (2020), Alemu et al. (2022), and Bekele et al. (2024), who established that greater distances between farmland and homesteads negatively impact the adoption of agricultural technologies such as manure and compost preparation.

Table 4: Factors influencing landscape restoration activities with the MVP model approach

Independent Variables	Landscape restoration practices (dependent variables)							
	PLMP (1)		BLMP (2)		AGRNOP (3)		Area closure (4)	
	Coef.	z	Coef.	z	Coef.	P>z	Coef.	P>z
Sex HHs	0.701(.152)***	4.611	0.008 (.066)	0.121	-0.177 (.082)**	2.158	0.133(.066)**	2.015
Marital status of HHs	0.643 (.201)***	3.199	-0.258 (.110)**	2.345	-0.036(.235)	0.153	0.281(.458)	0.613
Age HHs	-0.510(.101)***	5.049	- 0.341(.107)***	3.187	0.054(.218)	0.247	0.432(.118)***	3.661
Education HHs	-0.061(.097)	0.628	-0.266(.103)**	2.582	0.368 (.161)**	2286	-0.417(.236)	0.024
Family members	-0.418(.203)**	2.059	0.085(.062)	1.371	0.179(.033)***	5.424	0.060(.040)	0.137
TLU	0.035(.428)	0.082	0.632(.204***)	3.098	0.478(.136)***	3.514	.316(0.6)**	1.992
Landholding size	-0.667(.209)***	3.19	0.087(.441)	0.107	-0.287(.122)**	2.352	- 0.712(.209)***	3.406
Land fragment	0.491(.110)***	4.463	0.524(.131)***	4.001	0.520(.105)***	4.952	-0.322(.119)**	2.705
Farm distance	0.097(.219)	0.447	-0.06(0.217)	0.77	- 0.606(.200)***	3.030	0.459(.107)	4.289
Slope	0.703(.241)**	2.917	0.055(.712)	0.772	0.441(.220)**	2.001	-0.055(.090)	0.611
HH income	0.730(.277)**	2.635	0.891(.236)***	3.775	0.265(.108)**	2.453	0.191(.077)**	2.480
HH perceptions on BLSRA	- 0.578.(.188)***	3.074	0.009(.322)	0.027	- 0.382(.123)***	3.105	0.618(.188)***	3.286
Land certificate	0.499(.181)**	2.75	0.501(.137)***	3.656	0.607(.245)**	2.477	- 0.763(.237)***	3.219
Extension service	0.671(.197)***	3.406	- 0.198(.101)**	1.960	0.463(.109)***	4.247	0.182(.371)	0.490
Access to credit	0.418 (.121)***	3.452	0.277(.122)	2.270	0.700(.168)***	4.166	0.072(.089)	0.808
Village membership	0.758(.145)***	5.226	0.662(.202)***	3.277	0.299(.115) ***	2.600	0.871(.036)***	3.690

Number of obs. = 336, Wald chi2 (173) = 289.11; Log likelihood = -821.361; Prob > chi2 = 0.000; Likelihood ratio test of rho21 = rho31 = rho41 = rho32 = rho42 = rho43 = 0: chi2 (16) = 88.780; Prob > chi2 = 0.000 ** and *** are significant at 5% and 1% level of significance, in parenthesis are standard error

Access to credit: Access to credit services is represented as a binary variable, with a value of 1 for households that have access and 0 for those that do not. This variable was posited to significantly influence the adoption of various landscape restoration practices in the Womba watershed. Survey results revealed a positive and significant correlation between access to credit services and both PLMP ($p < 0.01$) and AGRNOP ($p < 0.01$), while controlling for other factors. As households gained access to credit, their likelihood of adopting PLMP and AGRNOP increased by 41.8% and 70%, respectively (Table). This study aligns with findings from Belachew et al. (2020), Gudina and Alemu (2024), and Haile et al. (2024), which indicate that access to credit encourages smallholder farmers to implement diverse land management practices in their respective regions.

Finally, the FGD and KI participants concluded that older farmers have valuable local knowledge and social networks that help with landscape restoration efforts, whereas larger families and households with more resources are more likely to adopt a variety of practices. They emphasized the importance of proximity to farmland for effective manure application, as well as the benefits of credit access for successful farmers implementing restoration projects. Participation in village associations also promotes collaboration in addressing common challenges. Despite acknowledging progress in restoration activities over the past two decades, participants expressed concern about the uncertain long-term benefits, which may be hampered by socioeconomic challenges and differing household perspectives on restoration benefits.

3.4 Smallholder farmers' level of agreement on the benefits of landscape restoration practices in the study watershed

Notably, the statement: reduces soil erosion and protects land from degradation received the highest mean score of 4.99 (SD = 0.234) (Table 5). Following enhances biodiversity, which supports ecological balance (mean = 4.89) and improves soil fertility, leading to better crop yields (mean = 4.72). These findings indicate a clear acknowledgment of the tangible ecological benefits stemming from restoration initiatives. This observation is consistent with various studies conducted in northern Ethiopia, where similar interventions led to reductions in sediment yield by up to 77% and marked enhancements in soil structure and fertility (Tamene et al., 2017). Techniques such as enclosures and physical soil and water conservation measures have been effective in minimizing erosion and boosting vegetative cover, thereby fostering biodiversity and soil regeneration (Chanie et al., 2025). Respondents expressed a moderate recognition of the benefits associated with enhanced water resources and skill development. The statement: improves farmers' knowledge and skills in sustainable practices, achieved a mean score of 4.74, reflecting an acknowledgment of capacity-building effects. In contrast, contributions to improved water quality and availability in the watershed received a score of 3.67, while increasing access to government support and funding scored 3.55. These results indicate a reasonable understanding of the indirect advantages of restoration initiatives. Similar trends have been observed in other regions of Ethiopia, including Amhara and Tigray, where integrated watershed management has successfully improved farmer training, bolstered local institutions, and enhanced water retention and governance (Wolka et al., 2023). Statements regarding economic and social advantages received the lowest levels of agreement from participants. The item: provide economic benefits through increased agricultural productivity recorded the lowest mean score of 2.95, followed by increasing farmers' resilience to climate change impacts at 2.77, and enhancing community well-being by promoting social cohesion with a score of 2.68. These findings indicate that many respondents may not yet perceive or believe in the long-term socio-economic benefits of restoration initiatives. Nevertheless, various studies indicate that these advantages do emerge over time. For example, initiatives such as Ethio-Trees and ORDA in northern Ethiopia have demonstrated that restoration can yield substantial income through mechanisms like carbon credits, beekeeping, and improved fodder availability. Additionally, restoration efforts have been associated with enhanced resilience to climate variability and the development of stronger community ties (WRI, 2023).The benefit related to attracting more wildlife, which can benefit agricultural ecosystems, received a mean score of 2.50, reflecting a limited but emerging awareness of this aspect. While not yet widely recognized, there is increasing evidence that restored landscapes support wildlife diversity, which can contribute to pest control, pollination, and ecosystem stability. Studies from enclosures in Tigray have documented the return of species such as jackals and guinea fowl, highlighting the potential of landscape restoration to enhance ecological networks (WRI, 2023). This aspect of restoration may require more visible demonstration and education to build local recognition and support. The focus group and key informant participants reached a strong consensus on the ecological benefits of landscape restoration, particularly in reducing soil erosion and enhancing biodiversity. They recognized improvements in soil fertility and crop yields, demonstrating awareness of these advantages. However, there was only moderate recognition of indirect benefits like improved water resources and farmer knowledge. Participants expressed skepticism regarding the long-term economic and social impacts of restoration, indicating a need for further education on benefits such as income from carbon credits and resilience to climate change. While awareness of wildlife attraction is still emerging, evidence suggests significant ecological advantages, highlighting the need for continued outreach to build local support for restoration efforts.

Table 5 Household levels of agreement on the benefits of landscape restoration practices

Items	measurement (N= 337)			
	level of agreement (1,2,3,4,5)			
	mean	std. dev.	min	max
Various landscape restoration practices**:**				
Improves soil fertility, leading to better crop yields.	4.72	0.77	1	5
Enhance biodiversity, which supports ecological balance	4.89	0.44	1	5
Reduces soil erosion and protects land from degradation.	4,99	0.24	1	5
Contribute to improved water quality and availability in the watershed.	3.67	1.66	1	5
Increases farmers' resilience to climate change impacts.	2.77	1.93	1	5
Provide economic benefits through increased agricultural productivity.	2.95	1.08	1	5
Enhance community well-being by promoting social cohesion	2.68	1.91	1	5
Attract more wildlife, which can benefit agricultural ecosystems	2.50	1.76	1	5
Improves farmers' knowledge and skills in sustainable practices."	4.74	0.98	1	5
Can increase access to government support and funding.	3.55	1.66	1	5

Level of respondent's agreement, 1= strongly disagree, 2 = disagree, 3 = no decision/neutral, 4 = agree, and 5 = strongly agree; std. dev, standard deviation; min, minimum; max, maximum; *N* = total respondents.

4. Conclusions

The implementation of various landscape restoration strategies in the Womba watershed has received considerable backing from smallholder farmers, who appreciate their ecological advantages, especially in combating soil erosion and promoting biodiversity. The strong consensus on the benefits related to soil fertility and crop yields illustrates the direct effects these practices have on agricultural productivity. However, perceptions of indirect benefits, such as improved water supply and socio-economic advantages, tend to be moderate to low, suggesting that many farmers may not fully grasp or trust the long-term gains of these initiatives. This gap in understanding may pose a challenge to the wider implementation of landscape restoration practices. The research also indicates that socio-economic elements, such as household income, access to financial resources, and education levels, play a significant role in farmers' participation in restoration activities. Thus, while the ecological benefits are widely recognized, there is a need to highlight the economic and social advantages more effectively.

4.1. Limitations and policy implications of this study

One limitation of this study is its reliance on data from the Womba watershed, which may restrict the applicability of the findings to other regions with different socioeconomic and environmental contexts. The focus on specific socioeconomic factors, like gender dynamics and credit availability, might overlook other important variables, such as cultural beliefs and market conditions. Additionally, the use of self-reported data could introduce bias, as farmers' perceptions of socioeconomic benefits may be shaped by their experiences and expectations.

Based on our findings, we propose the following actionable policies to address the gaps identified in our study:

- **Targeted educational programs:** implement programs to educate farmers about the socioeconomic benefits of restoration, such as income from carbon credits and climate resilience.

Tradeoff: requires resources and time, with benefits that are not immediately apparent.

- **Creating tailored credit packages**: Develop credit packages for farmers, particularly those with larger families or livestock, to encourage the use of biological land management practices. **Tradeoff**: accessible credit may increase debt risks if not properly managed.

- **Implementing gender sensitive approaches**: Create gender-sensitive strategies for policy frameworks to ensure that both male and female farmers can participate in restoration efforts. **Tradeoff**: may encounter resistance in traditional settings, but increases community engagement.

- **Improving access to extension services**: Increase the quality and availability of extension services to include both traditional and biodiversity-focused practices.

Tradeoff: may initially strain resources, but can ultimately yield long-term agricultural benefits.

- **Integrating socioeconomic factors into restoration initiatives**: create initiatives that promote sustainable development while taking into account both environmental and socioeconomic factors.

Tradeoff: Balancing these factors may complicate project implementation, but leads to more effective results.

Acknowledgments

The authors would like to thank Arba Minch University for its financial support during the course of this research. They would also like to express their appreciation to the natural resource management experts and farmers of the Womba watershed.

Authors' contributions

All authors of this project contributed to the writing of the original draft, study design, review and editing, creation of data collection instruments, verification and coding of the data, formal analysis, data curation, and conceptualization. Additionally, they provided valuable feedback and supervision on the manuscript.

Competing interests

The authors of this article declared that no potential conflict of interest exists regarding the authorship or publication of this article.

Availability data

All data generated or analyzed during this study are included in this published article.

References

Assefa, E., & Gebrehiwot, G. (2023). Gender dimensions of climate change adaptation in Tigray, Ethiopia. *Global Environmental Change*, *82*, 102737 doi: 10.1016/j.gloenvcha.2023.102737

Abeneh, A., Getahun, W. T., Agmassie, G. A., Gelaw, S. S., & Kassie, T. (2024). The magnitude of preconception care utilization and associated factors among women in Ethiopia: Systematic review and Meta-analysis, 2024. doi: 10.21203/rs.3.rs-4347404/v1

Adimassu, Z., Langan, S., Johnston, R., Mekuria, W., & Amede, T. (2017). Impacts of Soil and Water Conservation Practices on Crop Yield, Run-off, Soil Loss and Nutrient Loss in Ethiopia: Review and Synthesis. Environmental Management, 59(1), 87–101. doi: 10.1007/s00267-016-0776-1

Alemu, T., Tolossa, D., Senbeta, F., & Zeleke, T. (2022). Factors Influencing Smallholder Farmers' Decision to Abandon Introduced Sustainable Land Management Technologies in Central Ethiopia. Caraka Tani: Journal of Sustainable Agriculture, 37(2), 385–405. doi: 10.20961/carakatani.v37i2.60720

Amsalu, A., & de Graaff, J. (2007). Determinants of adoption and continued use of stone terraces for soil and water conservation in an Ethiopian highland watershed. In Ecological Economics (Vol. 61, Issues 2–3). doi: 10.1016/j.ecolecon.2006.01.014

Angehrn, Z. (2017). How to conduct a focus group discussion (FGD): Methodological manual. Zurich Open Repository and Archive, April, 1–16. doi: 10.5167/uzh-150640

Arunrat, N., Wang, C., Pumijumnong, N., Sereenonchai, S., & Cai, W. (2017). Farmers' intention and decision to adapt to climate change: A case study in the Yom and Nan basins, Phichit province of Thailand. Journal of Cleaner Production, 143, 672–685. doi: 10.1016/j.jclepro.2016.12.058

Asfaw, A., Simane, B., Bantider, A., & Hassen, A. (2019). Determinants in the adoption of climate change adaptation strategies: evidence from rainfed-dependent smallholder farmers in north-central Ethiopia (Woleka sub-basin). Environment, Development and Sustainability, 21(5), 2535–2565. doi: 10.1007/s10668-018-0150-y

Ayele, E., Temesgen, D., Lemma, T., & Wordofa, M. G. (2024). Gender Dimensions of Determinants of Adaptation Strategies to Climate Change among Smallholder Farmers in Northeast Ethiopia. Global Social Welfare, 0123456789. doi: 10.1007/s40609-024-00364-4

Bekele, E., Abera, G., & Temesgen, H. (2024). Adoption and intensity influencing factors of agroforestry systems for mitigating land degradation (MLD) in Gilgel Gibe I catchment, southwestern Ethiopia. Cogent Food and Agriculture, 10(1). doi: 10.1080/23311932.2024.2380782

Bekele, R. D., Mirzabaev, A., & Mekonnen, D. (2021). Adoption of multiple sustainable land management practices among irrigator rural farm households of Ethiopia. February, 5052–5068. doi: 10.1002/ldr.4091

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

Belay, M., & Bewket, W. (2013). Farmers' livelihood assets and adoption of sustainable land management practices in north-western highlands of Ethiopia. International Journal of Environmental Studies, 70(2), 284–301. doi: 10.1080/00207233.2013.774773

Beyene, A. D., Mekonnen, A., Randall, B., & Deribe, R. (2019). Household Level Determinants of Agroforestry Practices Adoption in Rural Ethiopia. Forests Trees and Livelihoods, 28(3), 194–213. doi: 10.1080/14728028.2019.1620137

Boardman, J., Poesen, J., & Evans, R. (2003). Socio-economic factors in soil erosion and conservation. Environmental Science and Policy, 6(1), 1–6. doi: 10.1016/S1462-9011(02)00120-X

Chanie, D., Yechale, H., & Bizuneh, K. (2025). Effects of land management technology adoptions on land use land cover dynamics using GIS and remote sensing : the case of Goyrie watershed , southern Ethiopia. In Environmental Monitoring and Assessment. Springer International Publishing. doi: 10.1007/s10661-024-13518-w

Chanie Haile, D., Bizuneh, Y. K., Bedhane, M. D., & Mekonnen, A. G. (2024). Impact of integrated land management technology adoption on rural livelihoods in the Goyrie watershed, Southern Ethiopia: Endogenous switching regression modeling estimation. Cogent Social Sciences, 10(1). doi: 10.1080/23311886.2024.2391532

Chanie Haile, D., Bizuneh, Y. K., Bedhane, M. D., Mekonnen, A. G., & Chalite, G. C. (2024). Effects of integrated land management technology adoptions on soil properties, evidence from the Goyrie watershed, Southern Ethiopia. Cogent Food and Agriculture, 10(1). doi: 10.1080/23311932.2024.2353664

Creswell, J. W. (2014). Creswell, John W. Research design : qualitative, quantitative, and mixed methods approaches / John W. Creswell. — 4th ed.

Crouzeilles, R., Curran, M., Ferreira, M. S., Lindenmayer, D. B., Grelle, C. E. V., & Rey Benayas, J. M. (2016). A global meta-Analysis on the ecological drivers of forest restoration success. Nature Communications, 7(May), 1–8. doi: 10.1038/ncomms11666

Dangiso, Y., & Wolka, K. (2023). Assessing sustainable management practices of expert-introduced physical soil and water conservation measures. Environmental Challenges, 13(August), 100780. doi: 10.1016/j.envc.2023.100780

Desalegn Chanie, Daniel Azaze, Teshome Yirgu, & A. Z. (2020). Soil Loss and Its Impact on Crop Productivity Under Varying Land Uses in Demba-Gofa District, Southern Ethiopia. Ethiopian Journal of Business and Social Scienc, 3(1), 57–89. doi: doi: 10.59122/23502lk

Etsay, H., Kelelew, A., Kinfu, S., & Berhe, M. (2023). Do livelihood strategies affect the willingness to participate in land conservation? The case of landless people in rural Tigray. Sustainable Environment, 9(1). doi: 10.1080/27658511.2023.2277559

Etsay, H., Negash, T., & Aregay, M. (2019). Factors that influence the implementation of sustainable land management practices by rural households in Tigrai region, Ethiopia. Ecological Processes, 8(1), 1–16. doi: 10.1186/s13717-019-0166-8

Ewunetu, A., Simane, B., Teferi, E., & Zaitchik, B. F. (2021). Relationships and the determinants of sustainable land management technologies in north gojjam sub-basin, upper blue nile, Ethiopia. Sustainability (Switzerland), 13(11). doi: 10.3390/su13116365

Friman, J. (2020). Gendered woodcutting practices and institutional bricolage processes – The case of woodcutting permits in Burkina Faso. Forest Policy and Economics, 111(March 2019), 102045. doi: 10.1016/j.forpol.2019.102045

Gashu, M. Y., Mesfin, D., & Dessie, T. A. (2025). Farmer perceptions toward the adoption of agroforestry practices: a case study of northwestern Ethiopia. Frontiers in Sustainable Food Systems, 9(January), 1–12. doi: 10.3389/fsufs.2025.1512761

Gebrehiwot, S. G., Bewket, W., Mengistu, T., Nuredin, H., Ferrari, C. A., & Bishop, K. (2021). Monitoring and assessment of environmental resources in the changing landscape of Ethiopia: a focus on forests and water. Environmental Monitoring and Assessment, 193(10), 1–13. doi: 10.1007/s10661-021-09421-3

Gidey, A. (2015). The Contribution of Soil and Water Conservation Practices towards Sustainable Rural Livelihoods in Tigray Region , Northern Ethiopia.

Girma, G., Melka, Y., Haileslassie, A., & Mekuria, W. (2023). Participatory forest management for improving livelihood assets and mitigating forest degradation: Lesson drawn from the Central Rift Valley, Ethiopia. Current Research in Environmental Sustainability, 5(December 2022), 100205. doi: 10.1016/j.crsust.2022.100205

Giz. (2015). Lessons and Experiences in Sustainable Land Management. 1–235.

Gudina, M. H., & Alemu, E. A. (2024). Factors influencing small holder farmers adoption of climate SMART agriculture practices in Welmera Woreda, Central Ethiopia. Frontiers in Climate, 6(May). doi: 10.3389/fclim.2024.1322550

Haile, D. C., Bizuneh, Y. K., & Bedhane, M. D. (2024). Determinants of land management technology adoptions by rural households in the Goyrie watershed of southern Ethiopia : Multivariate probit modeling estimation. Heliyon, 10(11), 1–18. doi: 10.1016/j.heliyon.2024.e31894

Haile, M., Herweg, K., & Stillhardt, B. (2006). Sustainable land management: a new approach to soil and water conservation in Ethiopia. Centre for Development and Environment (CDE) and NCCR North-South, University of Bern, Switzerland.

Hailu, L. (2025). Indigenous Agroforestry Practices for Climate Change Mitigation and Adaptation in Ethiopia : A Review. 47(3), 327–338.

Hailu, M. (2022). Work Motivation of Development Agents in Agricultural Extension Services Provision in Minjar Shenkora and Ada'a woredas, Central Ethiopia. Food Science and Quality Management, October. doi: 10.7176/fsqm/112-03

Hishe, S., Lyimo, J., & Bewket, W. (2017). Soil and water conservation effects on soil properties in the Middle Silluh Valley, northern Ethiopia. International Soil and Water Conservation Research, 5(3), 231–240. doi: 10.1016/j.iswcr.2017.06.005

Hounkpati, K., Moluh Njoya, H., Adjonou, K., Kokou, K., Sieber, S., & Löhr, K. (2024). Drivers affecting adoption of forest landscape restoration among smallholder farmers in Central Togo. Frontiers in Sustainable Food Systems, 8(November). doi: 10.3389/fsufs.2024.1425797

Huyer, S., Simelton, E., Chanana, N., Mulema, A. A., & Marty, E. (2021). Expanding Opportunities: A Framework for Gender and Socially-Inclusive Climate Resilient Agriculture. Frontiers in Climate, 3(December), 1–18. doi: 10.3389/fclim.2021.718240

Kanjanja, S. M., Mosha, D. B., & Haule, S. C. (2022). Determinants of the Implementation of Agroecological Practices among Smallholder Farmers in Singida District, Tanzania. European Journal of Agriculture and Food Sciences, 4(5), 152–159. doi: 10.24018/ejfood.2022.4.5.571

Kassie, M., Jaleta, M., Shiferaw, B., Mmbando, F., & Mekuria, M. (2013). Adoption of interrelated sustainable agricultural practices in smallholder systems: Evidence from rural Tanzania. Technological Forecasting and Social Change, 80(3), 525–540. doi:

10.1016/j.techfore.2012.08.007
Kassie, M., Zikhali, P., Manjur, K., & Edwards, S. (2009). Adoption of sustainable agriculture practices: Evidence from a semi-arid region of Ethiopia. Natural Resources Forum, 33(3), 189–198. doi: 10.1111/j.1477-8947.2009.01224.x
Kirui, O. K. (2016). Drivers of Sustainable Land Management in Eastern Africa. 2016 World Bank Conference on “Land and Poverty” The World Bank - Washington Dc, March 14-18, 2016, May, 1–18. doi: 10.20944/preprints201705.0007.v1
Lokshin, M., & Sajaia, Z. (2004). Maximum Likelihood Estimation of Endogenous Switching Regression Models. The Stata Journal: Promoting Communications on Statistics and Stata, 4(3), 282–289. doi: 10.1177/1536867x0400400306
Mekuria, W., Barron, J., Dessalegn, M., Adimassu, Z., Amare, T., & Wondie, M. (2017). Exclosures for ecosystem restoration and economic benefits in Ethiopia: a catalogue of management options. In Exclosures for ecosystem restoration and economic benefits in Ethiopia: a catalogue of management options. (Issue May). doi: 10.5337/2017.204
Mekuria, Wolde, Gebregziabher, G., & Lefore, N. (2020). Exclosures for landscape restoration in ethiopia: Business model scenarios and suitability. In IWMI Research Report (Vol. 175). doi: 10.5337/2020.201
Mekuria, Wolde, Wondie, M., Amare, T., Wubet, A., Feyisa, T., & Yitaferu, B. (2018). Restoration of degraded landscapes for ecosystem services in North-Western Ethiopia. Heliyon, 4(8). doi: 10.1016/j.heliyon.2018.e00764
Mekuriaw, A. (2017). Assessing the effectiveness of land resource management practices on erosion and vegetative cover using GIS and remote sensing techniques in Melaka watershed, Ethiopia. Environmental Systems Research, 6(1). doi: 10.1186/s40068-017-0093-6
Mekuriaw, A., Heinimann, A., Zeleke, G., & Hurni, H. (2018). International Soil and Water Conservation Research Factors in fl uencing the adoption of physical soil and water conservation practices in the Ethiopian highlands. International Soil and Water Conservation Research, 6(1), 23–30. doi: 10.1016/j.iswcr.2017.12.006
Melaku, E., Alemayehu, A., & Chanie, K. (2024). Investigating the Direct and Indirect Drivers of Land Use and Land Cover Change from Agriculture to Acacia Plantations in Banja District, Awi Zone, Ethiopia. East African Journal of Agriculture and Biotechnology, 7(1), 269–283. doi: 10.37284/eajab.7.1.1973
Mengie, B., Teshome, Y., & Dereje, T. (2019). Effects of soil and water conservation practices on soil physicochemical properties in Gumara watershed , Upper. Ecological Processes, 1–14. doi: 10.1186/s13717-019-0188-2
Mengistu, F., & Assefa, E. (2019). Farmers’ decision to adopt watershed management practices in Gibe basin, southwest Ethiopia. International Soil and Water Conservation Research, 7(4), 376–387. doi: 10.1016/j.iswcr.2019.08.006
Mesfin, S., Taye, G., & Hailemariam, M. (2018). Effects of integrated soil and water conservation measures on soil aggregate stability, soil organic matter and soil organic carbon stock of smallholder farmlands in semi-arid Northern Ethiopia. Carbon Management, 9(2), 155–164. doi: 10.1080/17583004.2018.1443641
Miheretu, B. A., & Yimer, A. A. (2017). Determinants of farmers’ adoption of land management practices in Gelana sub-watershed of Northern highlands of Ethiopia. Ecological Processes, 6(1), 1–11. doi: 10.1186/s13717-017-0085-5
Mihiretu, A., Okoyo, E. N., & Lemma, T. (2020). Small holder farmers’ perception and response mechanisms to climate change: Lesson from Tekeze lowland goat and sorghum livelihood zone, Ethiopia. Cogent Food and Agriculture, 6(1). doi: 10.1080/23311932.2020.1763647
Moluh Njoya, H., Hounkpati, K., Adjonou, K., Kokou, K., Sieber, S., & Löhr, K. (2024). Socioeconomic analysis of deforestation and economically sustainable farming systems to foster forest landscape restoration in central Togo. Frontiers in Sustainable Food Systems, 8(December), 1–16. doi: 10.3389/fsufs.2024.1466008

Munthali, G. N. C., Puming, H., Banda, L. O. L., Ngulube, P. S. D., Daru, G. R., Mzumara, T., Chitete, M. M. N., & Jere, Z. M. (2025). The effect of conservation agriculture technologies adoption on food production and security in Northern Malawi: evidence from Mzimba district. Frontiers in Nutrition, 12(July), 1–16. doi: 10.3389/fnut.2025.1615990

Oduniyi, O. S., & Tekana, S. S. (2021). The impact of sustainable land management practices on household welfare and determinants among smallholder maize farmers in South Africa. Land, 10(5), 1–16. doi: 10.3390/land10050508

Ouédraogo, H., Diallo, Y., Hien, E., Yaméogo, L. P., & Udo, N. (2022). Socio-economic indigenous drivers of soils and water conservation practices use to cope with climate change in the region of Plateau Central in Burkina Faso. International Journal of Biological and Chemical Sciences, 16(6), 2841–2856. doi: 10.4314/ijbcs.v16i6.29

Owen prince Gono. (2020). Sustainable Land Management and Smallholder Farmers in Zimbabwe . Walden University.

Prakash, A., Ley, D., & Thamari, M. (2024). How Gender-Sensitive Are Environmental Institutions , Climate Adaptation , and Mitigation Actions ? A Narrative from the Global South. 449–474.

Reed, M. G., Robson, J. P., Campos Rivera, M., Chapela, F., Davidson-Hunt, I., Friedrichsen, P., Haine, E., Johnston, A. B. D., Lichtenstein, G., Lynes, L. S., Oloko, M., Sánchez Luja, M., Shackleton, S., Soriano, M., Sosa Peréz, F., & Vasseur, L. (2023). Guiding principles for transdisciplinary sustainability research and practice. People and Nature, 5(4), 1094–1109. doi: 10.1002/pan3.10496

Saguye, T. S. (2017). An Empirical Analysis of Land Degradation Risk from Local Community Knowledge Perspective: the Case of Geze Gofa District, Southern Ethiopia. Global Journal of Science Frontier Research: H Environment & Earth Science, 17(2), 59–75. https://core.ac.uk/download/pdf/234691250.pdf

Sahu, S., Bishnoi, S., Sharma, P. R., Satyapriya, Mahra, G. S., Burman, R. R., Barua, S., Misha Madhavan, M., Sangeetha, V., Sinha, S. K., Singh, R., Wason, M., Joshi, P., & Sharma, S. (2024). Exploring popular information sources and determinants of farmers' access to agricultural extension services in the Indo-Gangetic plains. Frontiers in Sustainable Food Systems, 8(March), 1–14. doi: 10.3389/fsufs.2024.1339243

Seid, M., Simane, B., Teferi, E., & Azmeraw, A. (2022). Determinants of farmers' multiple-choice and sustainable use of indigenous land management practices in the Southern Rift Valley of Ethiopia. Current Research in Environmental Sustainability, 4(April), 1–14. doi: 10.1016/j.crsust.2022.100158

Sinore, T., Kissi, E., & Aticho, A. (2018). The effects of biological soil conservation practices and community perception toward these practices in the Lemo District of Southern Ethiopia. International Soil and Water Conservation Research, 6(2), 123–130. doi: 10.1016/j.iswcr.2018.01.004

Tabe-Ojong, M. P., Nyam, Y. S., Lokossou, J. C., & Gebrekidan, B. H. (2023). Farmer advisory systems and pesticide use in legume-based systems in West Africa. Science of the Total Environment, 867(December 2022), 161282. doi: 10.1016/j.scitotenv.2022.161282

Tadesse, L., Uncha, A., & Toma, T. (2025). Effects of landslide hazards on the livelihood strategies of rural households in Gamo Highlands, Southern Ethiopia. Geoenvironmental Disasters, 12(1). doi: 10.1186/s40677-025-00312-0

Tadesse, M., Simane, B., Abera, W., Tamene, L., Ambaw, G., Recha, J. W., Mekonnen, K., Demeke, G., Nigussie, A., & Solomon, D. (2021). The Effect of Climate-Smart Agriculture on Soil Fertility , Crop Yield , and Soil Carbon in Southern Ethiopia. 1–11.

Tadesse, T. (2023). Returns of sustainable land management interventions: Evidence from Southern Ethiopia. Sustainable Environment, 9(1). doi: 10.1080/27658511.2023.2280315

Tamene, L., Adimassu, Z., Aynekulu, E., & Yaekob, T. (2017). Estimating landscape susceptibility to soil erosion using a GIS-based approach in Northern Ethiopia. International Soil and Water Conservation Research, 5(3), 221–230. doi:

10.1016/j.iswcr.2017.05.002

Teklewold, H., Kassie, M., & Shiferaw, B. (2013). Adoption of multiple sustainable agricultural practices in rural Ethiopia. Journal of Agricultural Economics, 64(3), 597–623. doi: 10.1111/1477-9552.12011

Tesfaye, G. (2019). Evaluating Technical Standards of Implemented Soil and Water Conservation Technologies in Jimma Zone, South-Western Ethiopia. Agricultural Research & Technology: Open Access Journal, 19(4). doi: 10.19080/artoaj.2019.19.556100

Teshome, A., de Graaff, J., & Kassie, M. (2016). Household-Level Determinants of Soil and Water Conservation Adoption Phases: Evidence from North-Western Ethiopian Highlands. Environmental Management, 57(3), 620–636. doi: 10.1007/s00267-015-0635-5

Teshome, A., Rolker, D., & de Graaff, J. (2013). Financial viability of soil and water conservation technologies in northwestern Ethiopian highlands. Applied Geography, 37(1), 139–149. doi: 10.1016/j.apgeog.2012.11.007

Tessema, B. T. (2024). Assessing the uptake of sustainable land management programs towards improved land management, tenure security, food security, and agricultural production: evidence from South Wello, Ethiopia.

Toma, S., Leza, T., & Rajan, S. (2017). Factors Influencing the Adoption of Sustainable Land Management Practices Among Smallholder Farmers: the Case of Boloso Sore District in Wolaita Zone , Snnpr , Ethiopia. International Journal of Current Research, 9(7), 54236–54244. http://www.journalcra.com

Ullah, S., Wu, Y., & Khan, A. I. (2023). Evaluating the Socioeconomic Factors on Deforestation in Northern Pakistan: A Study on Existing Economic Incentive Tools for Reducing Deforestation. Sustainability (Switzerland), 15(7), 1–22. doi: 10.3390/su15075894

Umer, S., Aticho, A., & Kiss, E. (2019). J OURNAL OF D EGRADED AND M INING L ANDS M ANAGEMENT Effects of integrated use of grass strip and soil bund on soil properties , Southern Ethiopia. 6(2), 1569–1578. doi: 10.15243/jdmlm.2019.062.1569

Wang, C., Wang, Y., Zhao, Y., Shuai, J., Shuai, C., & Cheng, X. (2023). Cognition process and influencing factors of rural residents' adoption willingness for solar PV poverty alleviation projects: Evidence from a mixed methodology in rural China. In Energy (Vol. 271). doi: 10.1016/j.energy.2023.127078

Wolka, K., Biazin, B., Getachew, F., Girma, F., & Desta, G. (2023). Towards sustainable watershed-based landscape restoration in degraded drylands: Perceived benefits and innovative pathways learnt from project-based interventions in Ethiopia. Journal of Environmental Management, 335(February), 117499. doi: 10.1016/j.jenvman.2023.117499

Wolka, K., Sterk, G., Biazin, B., & Negash, M. (2018). Benefits, limitations and sustainability of soil and water conservation structures in Omo-Gibe basin, Southwest Ethiopia. Land Use Policy, 73(December 2016), 1–10. doi: 10.1016/j.landusepol.2018.01.025

Wondie, M., & Mekuria, W. (2018). Planting of acacia decurrens and dynamics of land cover change in fagita lekoma district in the Northwestern Highlands of Ethiopia. Mountain Research and Development, 38(3), 230–239. doi: 10.1659/MRD-JOURNAL-D-16-00082.1

Wordofa, M. G., Okoyo, E. N., & Erkalo, E. (2020). Factors influencing adoption of improved structural soil and water conservation measures in Eastern Ethiopia. Environmental Systems Research, 9(1), 1–11. doi: 10.1186/s40068-020-00175-4

Workie, M. D., & Teku, D. (2025). Assessing soil erosion hotspots and land degradation extent in Beshilo Watershed, Northeastern Ethiopia: integrating geospatial and field survey techniques, for sustainable land management. Frontiers in Environmental Science, 13(March), 1–17. doi: 10.3389/fenvs.2025.1548881

World Resources Institute. (2023). Restoring a degraded Ethiopian watershed for water and livelihood security. World Resources Institute. https://www.wri.org/update/restoring-degraded-ethiopian-watershed-water-livelihood-securit

Wynants, M., Kelly, C., Mtei, K., Munishi, L., Patrick, A., Rabinovich, A., Nasseri, M., Gilvear, D., Roberts, N., Boeckx, P., Wilson, G., Blake, W. H., & Ndakidemi, P. (2019). Drivers of increased soil erosion in East Africa's agro-pastoral systems: changing interactions between the social, economic and natural domains. Regional Environmental Change, 19(7), 1909–1921. doi: 10.1007/s10113-019-01520-9

Xie, J., Yang, G., Wang, G., & He, S. (2024). How does social capital affect farmers' environment-friendly technology adoption behavior? A case study in Hubei Province, China. Environment, Development and Sustainability, 26(7), 18361–18384. doi: 10.1007/s10668-023-03392-w

Yagaso, Z. S., Bayu, T. Y., & Bedane, M. D. (2024). Estimating soil erosion in response to land use/cover change around Ghibe III hydroelectric dam, Southern Ethiopia. Discover Sustainability, 5(1). doi: 10.1007/s43621-024-00608-5

Yirgu, T. (2022). Assessment of soil erosion hazard and factors affecting farmers' adoption of soil and water management measure: A case study from Upper Domba Watershed, Southern Ethiopia. Heliyon, 8(6), 1–12. doi: 10.1016/j.heliyon.2022.e09536

Zeb, A., Armstrong, G. W., & Hamann, A. (2019). Forest conversion by the indigenous Kalasha of Pakistan: A household level analysis of socioeconomic drivers. Global Environmental Change, 59(January), 102004. doi: 10.1016/j.gloenvcha.2019.102004