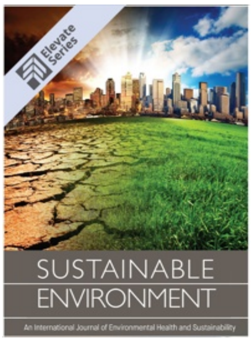

Taylor & Francis
Taylor & Francis Group

Sustainable Environment

An international journal of environmental health and sustainability

ISSN: (Print) (Online) Journal homepage: www.tandfonline.com/journals/oaes21

Does socioeconomic status of farmers determine the adoption of forest landscape restoration practices? Evidence from Central Togo

Hamza Moluh Njoya, Kossi Hounkpati, Kossi Adjonou, Kouami Kokou, Stefan Sieber & Katharina Löhr

To cite this article: Hamza Moluh Njoya, Kossi Hounkpati, Kossi Adjonou, Kouami Kokou, Stefan Sieber & Katharina Löhr (2025) Does socioeconomic status of farmers determine the adoption of forest landscape restoration practices? Evidence from Central Togo, Sustainable Environment, 11:1, 2487294, DOI: 10.1080/27658511.2025.2487294

To link to this article: https://doi.org/10.1080/27658511.2025.2487294

Published online: 03 Apr 2025.

SUSTAINABLE ENVIRONMENT
2025, VOL. 11, NO. 1, 2487294
https://doi.org/10.1080/27658511.2025.2487294

SOCIETY & THE ENVIRONMENTAL | RESEARCH ARTICLE

OPEN ACCESS Check for updates

Does socioeconomic status of farmers determine the adoption of forest landscape restoration practices? Evidence from Central Togo

Hamza Moluh Njoya [a,b,c], Kossi Hounkpati [a,d], Kossi Adjonou [d], Kouami Kokou [d], Stefan Sieber [a,b] and Katharina Löhr [a,e]

[a]Leibniz Centre for Agricultural Landscape Research (ZALF), Sustainable Land Use in Developing Countries, Müncheberg, Germany; [b]Department of Agricultural Economics, Faculty of Life Sciences, Humboldt Universität zu Berlin, Berlin, Germany; [c]Department of Rural Socio-Economics and Agricultural Extension, Faculty of Agronomy and Agricultural Sciences, University of Dschang, Dschang, Cameroon; [d]Forest Research Laboratory, Climate Change Research Centre, University of Lomé, Lome, Togo; [e]Urban Plant Ecophysiology, Humboldt Universität zu Berlin, Berlin, Germany

ABSTRACT

Forest Landscape Restoration (FLR) has gained significant attention as a global initiative to address forest and land degradation. While most studies emphasize the diverse benefits of FLR, very few have investigated the extensive nature of its adoption. This study investigates the drivers that determine the adoption and intensity of FLR practices among smallholder farmers in central Togo. Using multivariate probit (mvprobit) and ordered probit models, we analyze the socioeconomic, ecological, and biophysical determinants of FLR adoption. The data was collected from 313 households in the Tchamba prefecture through a two-stage sampling technique. The FLR practices considered in this study include agroforestry, woodlot plantations, compost application, conservation agriculture, soil and water conservation, and farmer-managed natural regeneration. The mvprobit results indicate that gender, age, marital status, household size, land degradation status, land acquisition mode and perceived plot land values significantly influence FLR adoption. Furthermore, gender, residence status, household size, land degradation status, association membership, and the perceived plot land value are critical drivers of FLR adoption intensity. These findings underscore the importance of enhancing land tenure security, especially for women and marginalized groups, and expanding financial support through credit and subsidies. Strengthening agricultural extension services is also crucial for effective FLR implementation.

ARTICLE HISTORY
Received 26 December 2024
Accepted 24 March 2025

KEYWORDS
Forest landscape restoration; socioeconomic drivers; adoption; smallholder farmers; sustainable land management

1. Introduction

Environmental degradation, including deforestation, forest degradation, soil erosion, land degradation and desertification, poses significant threat to biodiversity and human well-being (Ekka et al., 2023; Eshetu et al., 2024; Jain et al., 2024; Jiang et al., 2020; Prăvălie, 2021). Globally, unsustainable land practices lead to losing 24 billion tons of fertile soil annually, harming agriculture and ecosystem resilience (Abdel Rahman, 2023; Weeraratna, 2022). At the same time, the world has experienced a staggering loss in tree cover, with a dramatic decline from 13.4 million hectares in 2001 to 28.3 million hectares in 2023 (WRI, 2024). In response to this increasing concern, the Bonn Challenge, initiated in 2011, originally aimed to restore 150 million hectares of degraded land by 2020, which was then increased to 350 million hectares by 2030 under the New York Declaration on Forests in 2014 (Djenontin et al., 2021; Stanturf et al., 2019). This global effort aims to rehabilitate degraded landscapes, enhancing ecosystem services and community well-being (Mansourian et al., 2017). Many Sub-Saharan African (SSA) countries have actively joined this effort, committing to restoring over 100 million hectares under the African Forest Landscape Restoration Initiative (AFR100). This initiative aligns with the Sustainable Development Goals (SDGs) by promoting rural development, climate resilience, and poverty reduction (Owusu et al., 2021). Forest landscape restoration (FLR) further supports these goals by enhancing ecosystem services, sustaining livelihoods, and fostering social cohesion through collaborative land management efforts (Ullah, 2024).

Like many other SSA countries, Togo faces severe land degradation and deforestation driven by agricultural expansion, illegal logging, and charcoal production (Hounkpati, Adjonou, et al., 2024). Across the entire country, forest cover declined from 49.9% in 1985 to

CONTACT Hamza Moluh Njoya Hamza.Moluh-Njoya@zalf.de Leibniz Centre for Agricultural Landscape Research (ZALF), Sustainable Land Use in Developing Countries, Eberswalder Straße 84, 15374 Müncheberg, Germany

23.8% in 2020, with a deforestation rate of −2.11% per year, equivalent to 422.15 km^2 annually (Kombate et al., 2022). To address this, Togo pledged to restore 1.4 million hectares of degraded land by 2030 as part of the Bonn Challenge, aiming to reverse land degradation and improve livelihoods (Hounkpati et al., 2022). Restoration efforts prioritize smallholder farmers through sustainable land management in the National Reforestation Programme (PNR), enhancing ecosystem services such as biomass energy, water management, and biodiversity (FAO, 2023). These initiatives are crucial for addressing declining ecosystem services in regions like Tchamba Prefecture (Hounkpati, Adjonou, et al., 2024). Complementing these global restoration pledges, Togo also aims to reforest one billion trees and increase vegetation cover to 25% by 2030 and 30% by 2050, using participatory approaches to empower local stakeholders, especially smallholder farmers, to combat high deforestation rates and land degradation (Hounkpati, Moluh Njoya, et al., 2024).

Successful adoption of new agricultural and environmental practices, including FLR, requires attention to farmers' socioeconomic status. Research has shown that factors such as education level, income, land tenure security, and availability of extension services play a crucial role in shaping farmers' willingness and ability to adopt innovative land management practices (Ali, 2021; Anang et al., 2021; Asante et al., 2024; Belachew et al., 2020; Camara et al., 2023; Drescher et al., 2024; Kifle et al., 2022; Musafiri et al., 2022; Oduniyi, 2022). For instance, educated farmers tend to be more likely to understand the benefits of FLR practices (Hounkpati, Moluh Njoya, et al., 2024; Li et al., 2023), such as agroforestry or reforestation, and thus be more inclined to implement them. Higher-income levels can also provide the financial resources needed to invest in restoration activities, including the purchase of seedlings, acquisition of tools, and hiring labor (Li et al., 2023). Also, secure land tenure encourages farmers to engage in long-term land management practices, as they have greater assurance that they will reap the future benefits of their investments in restoration (Djenontin et al., 2022). Moreover, the availability of extension services and participation in farmer cooperatives or local organizations can facilitate the adoption of FLR practices by offering technical expertise, resources, and peer support (Ullah et al., 2024). Social networks such as farmer associations and community involvement also play a crucial role, as information sharing and collective action can enhance the uptake of restoration practices (Ullah, 2024). However, many FLR initiatives in SSA continue to pay more attention to ecological factors in FLR, often overlooking the socioeconomic drivers, which can lead to less effective implementation (Mansourian et al., 2024; Yuan et al., 2024). Gaining insight into how these factors impact the uptake of FLR practices is essential for developing restoration programs that are both inclusive and effective.

Many studies have examined the FLR and its ecological, social, and economic impacts. For example, FLR has been shown to combat soil erosion in the Lake Abaya catchment in Southern Ethiopia (Eshetu et al., 2024), foster social cohesion and enhance livelihoods in Pakistan (Ullah, 2024), and offer large-scale restoration potential in the Amazon (da Silva et al., 2023). Additionally, cost-benefit analyses of FLR in China (Wang et al., 2023), the evaluation of the sustainability of existing agricultural systems to promote FLR adoption (Moluh Njoya et al., 2024) and the role of social learning in restoration in North Africa (Derak et al., 2024) reflect the diverse benefits of FLR. While these examples underscore the broad advantages of FLR practices, most studies focus on their drivers and benefits rather than quantifying the extent and intensity of their adoption. Few studies assess how farmers adopt multiple FLR practices simultaneously and what factors influence their level of adoption (Djenontin et al., 2022; Etongo et al., 2018; Nigussie et al., 2017; Rotich et al., 2024). In the Tchamba district, research has primarily explored the general drivers of FLR adoption. However, it has not examined how these drivers influence the adoption of specific practices or the extent to which they are adopted (Hounkpati, Moluh Njoya, et al., 2024). Additionally, methodological limitations, such as the reliance on univariate models, often fail to capture the possibility that farmers may adopt multiple technologies simultaneously (Hounkpati, Moluh Njoya, et al., 2024; Owusu et al., 2021). This limitation hinders a nuanced understanding of the combined adoption of multiple practices and their drivers. This research thus focuses on the adoption pattern and intensities of FLR practices in Togo, particularly within smallholder farming systems. Understanding these trends is important for designing sustainable restoration initiatives that align with ecological goals and community socioeconomic realities (Djenontin et al., 2022).

Therefore, the present study aims to assess the drivers that determine the adoption and intensity of FLR practices among smallholder farmers in central Togo. We assume that the socioeconomic status of farmers and their households may correlate positively with adopting FLR practices. Using the Tchamba prefecture as a case study, we employ a multivariate probit model (mvprobit) to estimate the likelihood of smallholder farmers adopting different FLR practices on farmer-managed land, considering factors such as socioeconomic, biophysical, environmental, cognitive, geographical and institutional. Similar econometric methods have been applied in prior studies, such as Chang and Andersson (2021); Ngaiwi et al. (2023). The findings provide empirical insights into the drivers and constraints affecting FLR adoption, enabling policymakers and practitioners to design restoration programs that address socioeconomic barriers through targeted support, such as training, financial incentives, and secure land tenure. By making restoration efforts more targeted and inclusive, these initiatives can help advance Togo's restoration commitments under the Bonn Challenge while contributing to sustainable rural development, poverty alleviation, and resilience in degraded landscapes.

2. Forest landscape restoration practices

SSA's land use and management strategies, including diverse restoration measures, are highly context-dependent (Djenontin et al., 2018). Restoration practices are important for achieving conservation goals by increasing vegetation cover and restoring agroecological functions. Thus, it is important to understand the various restoration practices that farmers implement on their plot lands. Numerous studies explore forest and agricultural landscape restoration practices and climate change mitigation strategies among farmers in SSA. These include studies on tree planting and agroforestry practices (Amadu et al., 2020; Gupta et al., 2020; Sida et al., 2018) and farmer-managed natural regeneration (FMNR) (Binam et al., 2015; Camara et al., 2023). FMNR is a simpler and less expensive method for restoring vegetation cover on degraded land, compared to reforestation (Camara et al., 2023). SSA extensively supports it as an economical method to rehabilitate degraded land in arid and semi-arid regions, tackling the low survival rates sometimes linked with tree planting (Chomba et al., 2020). Also, agroforestry practices, effectively improve soil fertility, conserve biodiversity, enhance carbon sequestration, and provide climate change mitigation and adaptation (Gupta et al., 2020). While FMNR focuses explicitly on managing existing tree and shrub root systems for natural regeneration, agroforestry encompasses a broader range of practices that integrate trees into agricultural systems.

Efforts to restore forest and land degradation also take into account non-tree-based restoration practices, such as diverse and sustainable land management (SLM) strategies that involve soil and water conservation (SWC) techniques (Muriu-Ng'ang'a et al., 2017; Okeyo et al., 2014) and conservation agriculture (CA) practices (Mandal et al., 2021). SWCs consist of small water retention and soil stabilization technologies and infrastructures, such as rainwater harvesting or soil infiltration methods for cultivated crops (Wolka et al., 2018). These are essential in many rural settings in SSA, such as Tchamba Prefecture, where rainfed agriculture dominates, helping mitigate soil erosion, prevent land degradation, and sustain farming systems. SWC techniques positively impact yield, enhance farming sustainability, prevent degradation, and reduce soil erosion (Darkwah et al., 2019). Similarly, CA practices—such as no or minimum tillage, mulching with cover crops or crop residues, crop rotation, and intercropping—are widely adopted by smallholder farmers in SSA to enhance soil fertility, ensure stable crop yields, and bolster resilience against climate change and variability (Ali, 2021; Masvaya et al., 2017; Ward et al., 2018). In Tchamba, these techniques, alongside agroforestry and FMNR, are integral to restoring degraded lands and ensuring sustainable agriculture. Whilst much research assesses impacts of different practices, this study further evaluates the barriers to their adoption and explores strategies to address these challenges (Baade et al., 2024).

Building on these broader practices, this study focuses on the primary FLR practices promoted in Tchamba Prefecture: agroforestry and woodlot plantations. During fieldwork, farmers reported nine restoration practices: agroforestry, woodlot plantations, compost application, intercropping, crop rotation, mulching, minimum tillage, contour farming, and FMNR. To facilitate analysis and alignment with existing FLR frameworks, these practices were categorized into six groups based on their functional and ecological characteristics. First, agroforestry was classified as a distinct group due to its role in integrating trees into farming systems. Woodlot plantations were also treated separately, reflecting their focus on establishing managed tree plantations. FMNR formed another category, focusing on the management of existing tree and shrub root systems for natural regeneration. The practices of intercropping, crop rotation, mulching, and minimum tillage were grouped under CA because of their shared emphasis on sustainable soil and crop management. Similarly, contour farming was categorized as part of SWC practices focusing on water retention and soil stabilization. Finally, compost application was classified separately due to its specific role in enhancing the fertility of soil through the use of organic materials.

The grouping process was essential for analytical clarity and to ensure consistency with the literature. For example, CA practices—though distinct—are often applied in combination, making their collective analysis more meaningful. Likewise, contour farming aligns well with broader SWC techniques. This study investigates how these six grouped FLR practices contribute to sustainable land use in Tchamba. By linking the practices to local conditions and farmer realities, this research evaluates the barriers to their adoption and explores strategies to address these challenges. It provides a comprehensive understanding of FLR adoption patterns and their implications for restoration programs.

3. Methodology

3.1. Study area

The study focuses on the Tchamba district in central Togo (Figure 1), spanning 3,166 km^2, accounting for 23.5% of the central region and 5.6% of the country's total area. Tchamba has a tropical semi-humid climate of the Sudano-Guinean type characterised by a monomodal rainfall pattern, with a prolonged rainy season from April to October and a dry season from November to March (Hounkpati, Adjonou, et al., 2024). The average annual rainfall is between 1200 and 1300 mm, supporting a mosaic landscape of savanna forests, dry semi-deciduous forests, woodlands, and gallery forests rather than continuous dense forest cover (Bassan et al., 2020). The Forêt Classée d'Abdoulaye, covering over 30,000 hectares, represents a Guineo-Congolian forest remnant, emphasizing the presence of natural forest formations in the region before increasing anthropogenic pressures.The district's land use is dominated by crops and fallow land (52.27%), followed by open forests and wooded savannahs (19.32%), forest and agroforestry plantations (7.09%), and dense forests and gallery forests (13.70%) (Hounkpati, Adjonou, et al., 2024). While tropical savannas hold significant ecological and biological value, historical records indicate that forested ecosystems were integral components of this landscape before degradation due to agricultural expansion, shifting cultivation, and extensive firewood extraction (Moluh Njoya et al., 2024). The restoration efforts in Tchamba, therefore, do not aim to replace naturally open savannas with dense forest cover, but rather to rehabilitate degraded forest ecosystems and restore essential ecosystem services, such as biodiversity conservation, soil protection, and carbon sequestration.

Many restoration efforts in the region incorporate agroforestry as a key strategy, recognizing its conservation benefits and role in improving soil fertility, water retention, and carbon sequestration. While agroforestry is often viewed as a sustainable land-use practice rather than direct ecological restoration, in Tchamba, it serves as a vital mechanism for landscape rehabilitation,

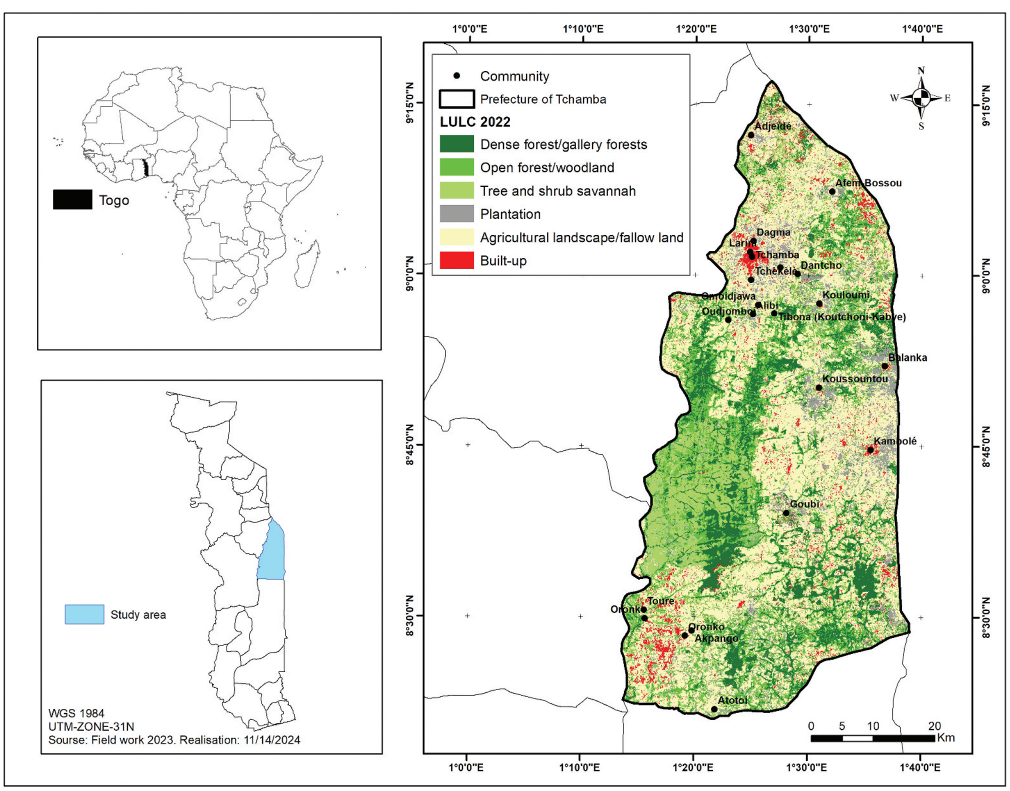

Figure 1. Localization and land use land cover (Hounkpati, Adjonou, et al., 2024) of the study area.

particularly in previously forested areas that have experienced degradation. Given the balance required between conservation and livelihoods, these restoration initiatives align with the principles of FLR, which seek to restore ecological integrity while supporting local socio-economic needs. The region's history of forest degradation and ongoing restoration initiatives make it a valuable case study for understanding adoption patterns and challenges in landscape restoration.

3.2. Sampling and data collection

This study is primarily based on cross-sectional data gathered through a household survey conducted in the Tchamba district of Togo's central region during August and September 2023. The data collection involved face-to-face interviews with heads of farm households, conducted in French, the official language of Togo. Surveyors provided translation assistance for farmers who did not speak or understand French. All surveyors could speak the local language. The interviews typically lasted between 45 to 55 minutes. The data collection process was executed by trained surveyors with experience in farm household surveys, who were hired explicitly for this study. In addition, field observations were made to identify socioeconomic drivers and farming practices. A two-stage sampling technique was used to select the participants for this research. Due to the predominance of agriculture in Tchamba and the widespread distribution of farmers, in the first stage, we divided the population of farmers into 3 clusters (Affem and Alibi in Tchamba1, Bago and Koussountou in Tchamba 2 and Goubi in Tchamba3). In the second stage, we determined the sample size using Cochran's formula (Cochran, 1977). Then we applied the proportional allocation technique to distribute the sample across the three clusters based on their population weight. Specifically, the sample size for each cluster was determined as a proportion of its share in the total farmer population of Tchamba. This resulted in 75 households from Tchamba 1, 158 from Tchamba 2, and 80 from Tchamba 3. Households were then randomly selected within each cluster to ensure representativeness. We collected data during the peak period of agricultural activities using a questionnaire designed in the Kobo Toolbox survey software and administered offline via smartphones (Leisher, 2014; Tate et al., 2021).

We use descriptive statistics and mvprobit econometric model to analyse the data. We used descriptive statistics to outline the socio-demographic characteristics of smallholder farmers and identify the number of practices adopted by the individual households (hereafter referred to as adoption intensity). Given the tendency in SSA farming systems for farmers to adopt multiple technologies simultaneously to restore degraded land (Ali, 2021), multinomial logit and probit models are often applied to estimate the equations separately. However, the negative binomial model presents mathematical limitations, as it fails to ensure that the sum of the predicted values aligns with the sum of the input values (Ngaiwi et al., 2023), leading to inconsistencies. To address this, we use the mvprobit and ordered probit models to correct this bias. These models effectively capture both the adoption process and the intensity of FLR technology adoption. The mvprobit model is an efficient extension of the probit model for simultaneously estimating several correlated binary outcomes (Chanie Haile et al., 2024). Compared to the multivariate logit model (mvlogit), the mvprobit is often considered more accurate, as it does not assume the independence of irrelevant alternatives. Additionally, it accounts for error correlations, making it a more efficient choice than the multivariate logit model (Ngaiwi et al., 2023).

3.3. Specification of the econometric model

3.3.1. Multivariate probit model

We used a mvprobit model to examine the drivers influencing the adoption of various FLR practices among smallholder farmers in Tchamba district. The mvprobit approach is particularly suitable for analyzing farmers' decision-making processes, as it allows for simultaneously modelling the influence of a set of explanatory variables on multiple practices (Teklewold et al., 2019). This approach captures potential correlations between the unobserved factors influencing the adoption of different FLR practices, which can arise due to complementarity or substitutability among the practices. By using the mvprobit model, we can account for the interdependencies in adoption decisions, as farmers may choose more than one practice based on their circumstances. This distinguishes the mvprobit from single-equation models where the adoption of one practice is considered independently of others. For instance, in a single-equation approach, adopting one FLR practice does not affect the likelihood of adopting another. However, the mvprobit model enables a more flexible correlation structure for unobserved factors across different practices, ensuring that the potential relationships between practices are considered.

We follow the random utility framework to model the observed outcome of the adoption of FLR practices. Theoretically, adopting restoration practices depends on farmers' expected utility in responding to forest and land degradation, climate change, and socioeconomic conditions (DiFalco et al., 2011; Khonje et al., 2018). Using a combination of practices can enable resource-constrained farmers—lacking access to capital—to enhance their productivity and income without relying on costly inputs while preserving the resources they depend on. In line with this idea, the study operates on the assumption that R_j is a nonempty and finite set of potential restoration practices where j represents the adoption of Agroforestry (A), woodlot olantations (W), compost (M), Conservation agriculture (C) soil and water conservation (R) and FMNR (I). By maximizing expected utility, a risk-averse farmer i will choose to adopt a restoration practice j if the expected utility from that practice, $E(U(R_1))$, exceeds the utility they would obtain without implementing any restoration measures, $E(U(R_0))$. This is a comparative behaviour analysis based on the following equation.

$$E(U(R_1)) > E(U(R_0)) \tag{1}$$

Where $E(U(R_1))$ is the expected utility derived from adopting the restoration practice $R_{1,}$ while $E(U(R_0))$ the expected utility that a farm household would gain in the absence of any restoration measures, R_0. The utility associated with adopting a particular restoration practice j is not directly observable; instead, it is a latent variable that reflects the likelihood of adoption for practice j. This can be expressed as follows:

$$U_{ij}^* = \beta_j Z_i + \varepsilon_i \tag{2}$$

Where β is a vector of parameters to be estimated, and Z_i represents a vector of exogenous variables that may influence the farm household's decision to adopt a restoration practice, the term ε denotes the error term. The binary observed dependent variable is whether or not to adopt j^{th} restoration practice by the i^{th} farmer (U_{ij}). where $U_{ij} = 1$ for adoption of restoration practice and $U_{ij} = 0$ for non-adoption of restoration practice, is related to U_{ij}^* as follows:

$$U_{ij} = \begin{cases} 1\, if\, U_{ij}^* > 0 \\ 0\, otherwise. \end{cases} Where j = A, W, M, C, R, I, \tag{3}$$

Assuming j restoration practices, Equation (2) can be rewritten as follows:

$$U_{iA}^* = \beta_A Z_{iA} + \varepsilon_{iA}$$

$$U_{iT}^* = \beta_T Z_{iT} + \varepsilon_{iT}$$

$$\ldots$$

$$U_{ij}^* = \beta_j Z_{ij} + \varepsilon_{ij}$$

Where U_{iA}^*, U_{iT}^*, U_{ij}^* are the probabilities that farmer i adopts restoration practices 1, 2, or j, respectively.

$$\Omega = \begin{bmatrix} 1 & \rho AW & \rho AM & \rho AC & \rho AR & \rho AI \\ \rho WA & 1 & \rho WM & \rho WC & \rho WR & \rho WI \\ \rho MA & \rho MW & 1 & \rho MC & \rho MR & \rho MI \\ \rho CA & \rho CW & \rho CM & 1 & \rho CR & \rho CI \\ \rho RA & \rho RW & \rho RM & \rho RC & 1 & \rho RI \\ \rho IA & \rho IW & \rho IM & \rho IC & \rho IR & 1 \end{bmatrix} \tag{4}$$

Where rho (ρ) is a pairwise correlation between any two FLR practices, the sign of ρ between any two practices shows the relationship. As mentioned previously, a positive sign signifies complementary relationships, while a negative sign denotes substitutive ones.

The off-diagonal elements in the covariance matrix are particularly important as they capture the unobserved correlations between the stochastic components of different FLR practices. This assumption implies that Equation 3 forms a mvprobit model, which simultaneously models the adoption decisions for various FLR practices. By incorporating non-zero off-diagonal elements, this specification allows for cross-correlation between the error terms. These error terms represent unobserved factors influencing the choice of different FLR practices. When analyzing adoption determinants, we account for the potential impact of unobservable household characteristics on these decisions. For example, there might be a correlation between plot-specific factors, such as managerial ability, and the choice to adopt a particular FLR practice.

3.3.2. Ordered probit model

In our analysis, the mvprobit model conceptualizes that a farm household evaluates the net benefits of adopting one or more FLR practices relative to the benefits of non-adoption before making a decision. The utility derived from prior adoption influences the likelihood of adopting additional FLR practices. However, while the mvprobit model effectively estimates the determinants of FLR adoption and accounts for interdependencies between practices, it is limited in assessing the intensity of adoption (Musafiri et al., 2022; Ngaiwi et al., 2023). To evaluate the extent of adoption, we used the ordered probit model, which allows us to analyze the number of FLR practices implemented at the farm household level as an ordinal outcome. This approach is suitable because it captures the sequential nature of adoption decisions, where the likelihood of adopting additional practices may vary based on the experience and perceived benefits from earlier adoptions. Unlike Poisson regression, which assumes the same probability for all adoption events, the ordered probit model accommodates variations in adoption intensity due to factors such as labor requirements, practical knowledge, initial investments, and expected benefits (short-term or long-term) (Musafiri et al., 2022). Therefore, the adoption intensity—measured as the number of FLR practices adopted by a household—is treated as an ordinal variable, representing categories of adoption levels (e.g. adopting one, two, or more practices). The ordered outcomes are modeled as a latent variable U*, where U* is an underlying unobserved measure of households' adoption intensity, with the sequential nature of adoption decisions reflecting different levels of commitment to FLR practices as described in Equation 5.

$$U_j^* = X_j^{'}\beta + u_j \quad (5)$$

For a j^{th} farm household, where normalisation presumes that the regressors x exclude an intercept, the adoption intensity of FLR practices adoption escalates with an increase in the latent variable U*. For lower values of U*, the adoption of FLR is low. For $U^* > 1$, the number of FLR increases, for $U^* > 2$, adoption increases further, and the number of adopted FLR practices continues to increase incrementally. In a typical ordered probability model, the equation below represents the likelihood of observing a particular adoption outcome, denoted as j.

$$\Pr(outcome\ i = j) = \Pr\left(n_{j-1} < X_j^{'}\beta + u_j \leq \alpha_j\right) \quad (6)$$

The coefficients $\beta_1, \beta_2, \ldots, \beta_{j-1}$ are estimated together with the cut points $\alpha_1, \alpha_2, \ldots, \alpha j$, where j represents the number of possible outcomes. It is assumed that the error term u_j follows a normal distribution with a standard normal cumulative distribution function. This research used a pooled ordered probit model, supposing that unobserved heterogeneity is not correlated with the independent variables. In contrast, previous research has often utilized plot-level analyses, using fixed or pseudo-fixed effect models to account for unobserved heterogeneity (Kpadonou et al., 2017), this approach is not applicable here due to the nature of the data we have. Table 1 details the variables of the model.

Table 1. Definition and description of the variables

Variables	Description	Nature	Expected sign
Outcome variable			
Agroforestry	Adoption of agroforestry (1 = yes, 0 = no)	Dummy	+
Woodlot plantations	Adoption of woodlot (1 = yes, 0 = no)	Dummy	+
Compost application	Adoption of compost (1 = yes, 0 = no)	Dummy	+
Conservation Agriculture (CA)	Adoption of CA (1 = yes, 0 = no)	Dummy	+
Soil and Water Conservation (SWC)	Adoption of SWC (1 = yes, 0 = no)	Dummy	+
Farmer-managed natural regeneration (FMNR)	Adoption of FMNR (1 = yes, 0 = no)	Dummy	+
Explanatory variables			
Gender	Gender of the Head of Household (1 = Male, 0 = Female)	Dummy	±
Age	Age of the head of household (years)	Count	±
Residence status	Residence status of the head of household in the locality (1 = native 0 = non-native)	Dummy	±
Marital status	1 = married 0 = non married	Dummy	±
Education status	1 = Educated, 0 = Not Educated	Dummy	±
Household size	The number of people in the household	Count	+
Active members	Count of Household Members Currently Engaged in farm activities.	Count	+
Plot land is degraded	Plot land is perceived as degraded (1 = yes, 0 = no)	Dummy	±
Credit access	The head of the household has access to credit (1 = yes, 0 = no)	Dummy	±
Access to extension services	Contact with extension agent (1 = yes, 0 = no)	Dummy	±
Membership in Association Engaging in Ecological Activities	The head of household is a member of the Association engaging in Ecological Activities (1 = yes, 0 = no)	Dummy	±
Membership in Association Engaging in Economic Activities	The head of household is a member of the Association engaging in Economic Activities (1 = yes, 0 = no)	Dummy	±
Farm size	Farm size of the household (Hectares)	Count	+
Livestock owned	The number of animals the household has	Count	+
Distance from home to farm	Distance between farm household and farmland (Km)	Count	-
Farm experience	Number of year of experience of household head (years)	Count	+
Land Acquisition mode : Purchased land	The head of household acquired the land through purchase (1 = yes, 0 = no).	Dummy	±
Land Acquisition mode: Inherited land	The head of household acquired the land through inheritance (1 = yes, 0 = no)	Dummy	±
Land Acquisition mode: Donation	The head of household acquired the land through donation (1 = yes, 0 = no).	Dummy	±
Land Acquisition mode: Rented land	The head of household acquired the land through rental (1 = yes, 0 = no).	Dummy	±
Land Acquisition mode: Finance arrangement	The head of household acquired the land through Finance arrangement (1 = yes, 0 = no)	Dummy	±
Harvest of non timber forest producs (NTFPs)	Additional Harvest of NTFPs	Dummy	±
Fuelwood harvest	Fuelwood as additional harvest (1 = yes, 0 = no)	Dummy	±
Plot is crucial for Food security	Plot land is seen as crucial for Food security(1 = yes, 0 = no)	Dummy	±
Plot land is crucial for Energy	Plot land is seen as crucial for Energy	Dummy	±
Plot land is crucial for climate change	Plot land is seen as crucial for climate change	Dummy	±

3.4. Data analysis

Farmers reported nine distinct land management practices for restoring farmland. Based on our literature review, we categorized the strategies into six groups. We ran our mvprobit model in Stata 16 using the conditional mixed process estimator ('cmp' command). Aligning with Roodman (2011), we used this package estimator because of its ability to handle the extensive computing requirements for optimizing the log-likelihood function and attaining convergence. We inform cmp about the natures of the dependent variables and which equations apply to which observations by including the 'indicators ()' option after the comma in the cmp command line, as Roodman (2011) suggests. The cmp command first fits each equation individually to provide an optimal entry point for the overall model fitting process.

4. Results

4.1. Descriptive statistic of the socioeconomic status of smallholder farming households

Most households of this study are male-headed, with the average age of the household head around 43 years, indicating a predominantly middle-aged demographic. Most of these household heads are married (81%), and 59% have received a formal education. Households are relatively large, average composed of approximately 7 members, with an average of 4 individuals contributing to household labor. 65% of respondents report having access to credit, and 66% benefit from extension services. Additionally, 65% of respondents participate in associations focused on ecological initiatives, while 47% are involved in economic associations.

Farm assets reveal significant potential for the adoption of FLR, characterized by an average farm size of 5 hectares, albeit with considerable variability in land holdings. The average ownership of livestock and poultry—6.32 and 8.71, respectively—indicates a diversified livelihood approach, which may both facilitate and pose challenges to FLR initiatives. With an average of about 15 years of experience, farmers bring valuable insights into traditional land management practices. However, the average distance of almost 5 km from home to farm may impede implementing practices requiring frequent visits.

The land acquisition modes indicate that most land is inherited, purchased, or donated, which may influence tenure security and investment in FLR. Moreover, plot lands are perceived as key for household well-being, with a substantial majority considering them crucial for food security (85%), energy (77%), and climate resilience (79%). These functions translate into a strong intrinsic motivation for sustainable land use. Table 2 shows that factors such as education, access to resources, social networks, and the value placed on land are pivotal in understanding FLR practice adoption trends. These factors highlight specific opportunities and challenges unique to Tchamba's agroecological

Table 2. Socioeconomic variables description

Variables	Mean	Std.Dev	Min	Max
Gender	0.66	0.47	0	1
Age	42.77	13.76	20	82
Residence status	0.69	0.46	0	1
Marital status	0.81	0.39	0	1
Education status	0.59	0.49	0	1
Household size	6.61	3.22	1	25
Household labor	3.41	2.37	0	17
Perception of plot land degradation	0.53	0.49	0	1
Credit access	0.65	0.48	0	1
Access to Extension services	0.66	0.47	0	1
Association Engaging in Ecological Activities	0.65	0.48	0	1
Association Engaging in Economic Activities	0.47	0.50	0	1
Household total farm size	5.05	3.77	0.25	40
Livestock owned	6.32	8.27	0	70
Poultry	8.71	11.75	0	80
Experience in Farming	15.88	10.02	0	51
Distance household to farm	4.9	3.77	0.4	23
Land Acquisition mode: Purchased land	0.69	0.46	0	1
Land Acquisition mode: Inherited land	0.68	0.47	0	1
Land Acquisition mode: Donation	0.67	0.47	0	1
Land Acquisition mode: Rented land	0.37	0.48	0	1
Land Acquisition mode: Finance arrangement	0.33	0.47	0	1
Additional Harvest of NTFPs	0.78	0.42	0	1
Fuelwood as additional harvest	0.78	0.42	0	1
Plot land is seen as crucial for Food security	0.85	0.35	0	1
Plot land is seen as crucial for Energy	0.77	0.42	0	1
Plot land is seen as crucial for climate change	0.79	0.40	0	1

context, providing a foundation for analyzing the dynamics of restoration efforts in the region.

4.2. Factors determining adoption of FLR practices

In the Tchamba District, smallholder farmers show significant commitment to various FLR practices, highlighting their dedication to sustainable land management. According to Figure 2, agroforestry is the most widely adopted practice, embraced by 80.19% of farmers. This widespread adoption is likely due to the economic benefits of integrated tree-crop systems, which provide both food and marketable produce. FMNR and SWC practices are utilized by 72.2% and 70.61% of farmers, respectively. Woodlot plantations are practiced by 67.09% of farmers, indicating an awareness of the ecological advantages of increased tree cover. CA practices, including reduced tillage and crop rotation, are implemented by 65.5% of farmers, reflecting efforts to maintain soil structure and resilience. Even though compost application is more labour-intensive, it remains a practice adopted by 53.99% of households, emphasizing the importance of improving soil fertility through organic methods. Overall, adopting these different practices demonstrates a strategic integration of FLR practices aimed at optimizing productivity while managing environmental challenges in the region.

Table 3 displays the coefficient estimates from the mvprobit model, illustrating the interdependence among the six FLR practices adopted by smallholder farmers in the Tchamba District. The notable log-likelihood ratio (LR) of −916.42, along with a Wald chi-squared value of 430.70 ($p < 0.01$), suggests that the model fits well. This significance indicates that the decision-making process for adopting various FLR strategies is interconnected and likely influenced by shared, unobserved household factors that simultaneously affect multiple adoption choices. These findings reinforce that common underlying socioeconomic or environmental factors can drive the concurrent adoption of restoration practices, as noted in similar studies (Oyetunde Usman et al., 2021).

The results of the mvprobit analysis indicate that demographic, socioeconomic, and land-related factors influence the adoption of different FLR practices in the agricultural landscapes of Tchamba Prefecture. Gender plays a significant role, with male-headed households demonstrating a higher likelihood of adopting agroforestry, woodlots, and FMNR practices. This trend may reflect traditional gender roles in land management and labor allocation within the study area. Women often face structural barriers, including limited access to land, tenure insecurity, and restricted rights to natural resources, which hinder their ability to invest in long-term restoration practices. Additionally, cultural norms and labor constraints may further restrict their engagement in FLR adoption. Age also has a nuanced impact on FLR practices. While older farmers are less likely to adopt agroforestry, they tend to favor soil-enriching methods such as compost application and FMNR. This pattern suggests that older farmers, who may possess greater farming experience, prioritize practices that provide immediate enhancements to soil fertility and yield stability, thus balancing long-term sustainability with immediate agricultural needs.

Household dynamics—including size, labor availability, and marital status—play a critical role in the adoption of FLR practices. Larger households with more available labor tend to engage in labor-intensive activities such as compost applications and SWC, suggesting that household capacity directly influences these practices. Additionally, marital status is associated with a higher likelihood of adopting agroforestry, SWC, and FMNR, indicating that family responsibilities may motivate sustainable land use and intergenerational resource conservation. Socioeconomic factors, including access

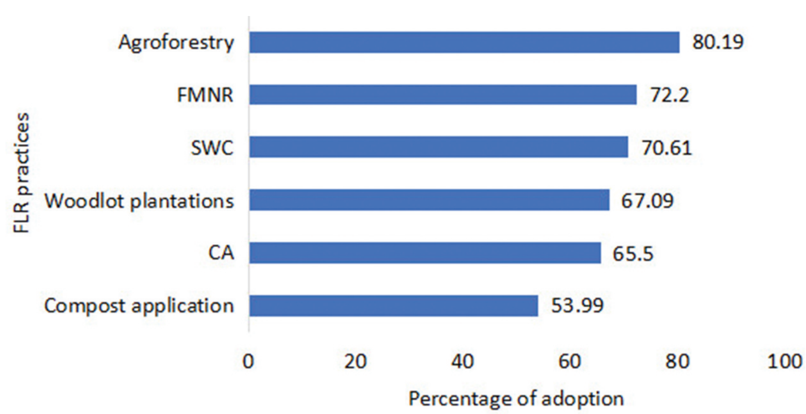

Figure 2. FLR practices of smallholder farming households.

Table 3. Multivariate probit estimates of the adoption of FLR practices in agricultural landscapes of the study area

Variables	Agroforestry	Woodlot	Compost applications	CA	SWC	FMNR
Gender	1.003***	0.655***	0.163	0.237	0.202	0.386**
	(0.360)	(0.172)	(0.169)	(0.174)	(0.174)	(0.181)
Age	−0.033***	0.004	0.015**	0.005	0.001	0.018**
	(0.013)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)
Residence status	0.957**	−0.023	0.196	0.290	−0.006	0.421**
	(0.380)	(0.191)	(0.186)	(0.189)	(0.194)	(0.199)
Marital status	0.685**	−0.049	0.280	−0.210	0.491**	0.436*
	(0.341)	(0.220)	(0.219)	(0.228)	(0.224)	(0.224)
Education status	0.207	−0.002	0.064	0.323*	−0.142	−0.005
	(0.386)	(0.177)	(0.176)	(0.178)	(0.184)	(0.187)
Household size	0.093	−0.011	0.073**	−0.043	0.078**	−0.009
	(0.070)	(0.032)	(0.034)	(0.031)	(0.034)	(0.034)
Household labor	0.200**	0.022	0.020	0.010	−0.008	−0.027
	(0.094)	(0.042)	(0.043)	(0.041)	(0.043)	(0.045)
Degradation status	0.350	−0.103	0.619***	−0.152	0.025	0.208
	(0.343)	(0.157)	(0.153)	(0.155)	(0.160)	(0.165)
Credit access	0.627*	0.091	0.169	0.050	0.173	0.039
	(0.352)	(0.170)	(0.167)	(0.168)	(0.171)	(0.179)
Access to Extension services	0.373	0.185	0.304*	−0.057	0.224	−0.193
	(0.382)	(0.186)	(0.183)	(0.186)	(0.184)	(0.194)
Association Engaging in Ecological Activities	0.632*	−0.093	0.137	−0.020	−0.029	−0.142
	(0.368)	(0.182)	(0.181)	(0.184)	(0.189)	(0.195)
Association Engaging in Economic Activities	−0.198	0.077	−0.071	0.209	0.292*	0.457**
	(0.376)	(0.169)	(0.165)	(0.168)	(0.175)	(0.181)
Household farm size	−0.064	0.007	0.057**	−0.011	0.037	0.003
	(0.041)	(0.022)	(0.027)	(0.022)	(0.026)	(0.022)
Livestock owned	−0.004	−0.019*	0.011	0.004	−0.005	−0.006
	(0.027)	(0.011)	(0.011)	(0.010)	(0.011)	(0.010)
Poultry	0.036*	0.007	−0.000	−0.002	0.012	0.010
	(0.022)	(0.008)	(0.007)	(0.007)	(0.008)	(0.008)
Experience in Farming	0.034*	0.004	0.000	0.021**	−0.005	−0.010
	(0.021)	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)
Distance household to farm	−0.082*	0.004	−0.029	−0.021	−0.019	−0.020
	(0.048)	(0.022)	(0.021)	(0.021)	(0.021)	(0.021)
Land Acquisition mode: Purchased land	0.144	−0.141	−0.030	0.154	0.179	−0.129
	(0.381)	(0.193)	(0.185)	(0.185)	(0.186)	(0.199)
Land Acquisition mode: Inherited land	−0.403	−0.086	0.391**	0.157	−0.162	0.449**
	(0.428)	(0.189)	(0.190)	(0.190)	(0.196)	(0.210)
Land Acquisition mode: Donation	0.069	0.425**	0.289	−0.302	−0.298	0.153
	(0.373)	(0.182)	(0.184)	(0.188)	(0.195)	(0.194)
Land Acquisition mode: Rented land	0.193	−0.033	−0.185	0.307*	0.023	−0.229
	(0.443)	(0.176)	(0.177)	(0.183)	(0.184)	(0.183)
Land Acquisition mode: Finance arrangement	−0.886**	−0.130	0.049	0.209	0.233	−0.035
	(0.368)	(0.180)	(0.173)	(0.180)	(0.189)	(0.189)
Additional Harvest of NTFPs	−0.254	0.098	−0.213	−0.170	0.290	−0.145
	(0.423)	(0.229)	(0.226)	(0.235)	(0.228)	(0.243)
Fuelwood as additional harvest	1.184***	−0.143	−0.279	−0.108	0.119	−0.276
	(0.416)	(0.246)	(0.245)	(0.251)	(0.249)	(0.260)
Plot land is perceived as crucial for Food security	0.502	0.100	0.198	0.638**	0.048	0.669***
	(0.456)	(0.245)	(0.253)	(0.253)	(0.252)	(0.259)
Plot land is perceived as crucial for Energy	0.783**	0.160	0.169	0.058	−0.364	0.344
	(0.390)	(0.238)	(0.236)	(0.247)	(0.253)	(0.249)
Plot land is perceived as crucial for climate change	1.130***	0.118	0.246	−0.166	0.109	−0.007
	(0.405)	(0.221)	(0.219)	(0.229)	(0.233)	(0.237)
Constant	−2.686**	−0.598	−1.499***	−0.537	0.134	−0.923*
	(1.116)	(0.512)	(0.509)	(0.509)	(0.520)	(0.529)

Likelihood-ratio test for all null correlations (rho_12 = rho_13 = rho_14 = rho_15 = rho_16= rho_23 = rho_24 = rho_25 = rho_26 = rho_34 = rho_35 = rho_36 = rho_45 = rho_46 = rho_54 = 0).
LR chi2(162) = 430.70.
Prob > chi2 = 0.0000.
Log likelihood = −916.41702
Observations = 313.
Standard errors in parentheses. Level of significance: ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

to credit and association membership, also emerge as crucial drivers of FLR adoption. Households with access to financial resources are more inclined to pursue agroforestry, underscoring the importance of economic support for tree-based initiatives. Moreover, participation in ecological and economic associations is positively correlated with the adoption of practices such as agroforestry, SWC, and FMNR, highlighting the significance of social networks and community engagement in promoting sustainable practices.

The findings indicate that the mode of land acquisition significantly influences the adoption of FLR practices. Households that inherit land are more inclined to use compost and FMNR, likely due to their long-term perspective and commitment to preserving and enhancing the soil quality of their family land for future generations. In contrast, households that acquire land through financing arrangements tend to be less engaged in agroforestry, which may be attributed to financial constraints or an emphasis on short-term returns needed to repay debts, making it difficult to invest in practices that provide benefits over the long run. Households that obtain land as donations are more likely to adopt tree-planting initiatives, possibly because they feel a heightened sense of responsibility to maintain and improve the land's ecological value as part of their stewardship. Additionally, the trend for rented land shows a higher adoption rate of conservation agriculture, suggesting that renters may prefer practices that enhance soil quality without making long-term investments in tree-based strategies, as they may not benefit from such efforts if they ultimately leave the land.

These variations highlight the impact of land acquisition methods on households' perceptions of investment security and long-term planning, which influences their choices regarding the adoption of FLR practices. Customized strategies considering these distinct circumstances could enhance adoption rates by aligning interventions with land tenure realities and fostering increased investment confidence among farmers. Moreover, the significance of land for meeting household needs—such as food security, climate resilience, and energy provision—plays a critical role in shaping FLR adoption decisions. Households that regard their land as vital for food security or climate adaptation are more likely to embrace conservation agriculture and FMNR, integrating their agricultural activities with broader livelihood objectives. Similarly, households that focus on fuelwood harvesting tend to prefer agroforestry, reflecting a strategic land management approach that addresses both ecological and practical requirements.

These findings highlight the complex interactions among household characteristics, access to resources, and perceptions of land utility. To effectively promote FLR practices, it is essential to consider these various factors. Tailoring interventions to address specific household dynamics and how land value is perceived could improve the adoption of sustainable practices, ultimately supporting broader environmental and livelihood goals in the region.

4.3. Extend of FLR adoption

Smallholder farmers must intensify their adoption of FLR practices to improve agricultural yields, increase income, and mitigate the impacts of climate change. Our findings indicate that the model employed is statistically significant, as demonstrated by the Wald chi^2 (27) = 145.15 and Prob > chi^2 = 0.0000. This high significance level underscores the reliability of the ordered probit model in evaluating the factors influencing the intensity of FLR adoption. With a pseudo-R^2 of 0.139 and a log pseudolikelihood of −428.04, the model effectively captures the variability in adoption intensity, emphasizing the crucial role of socioeconomic and land-related factors in shaping smallholder adoption behaviors.

The robustness of these results was further corroborated using an ordered probit model as an additional validation measure, which confirmed the consistency of key variables. In both the primary model and the robustness check, these variables maintained their significance and direction, reinforcing the stability of our findings. For instance, the perception of plot land as essential for food security, participation in economic associations, and land acquisition through inheritance remained significant predictors of higher adoption intensity. This consistency across models highlights the reliability and robustness of these socioeconomic and land tenure factors in influencing FLR adoption (Table 4).

The ordered probit model presented in Table 4 identifies several key socioeconomic and land-related factors that influence the intensity of adoption of FLR practices. Notably, gender is a significant factor, with male household heads demonstrating a higher propensity for adopting FLR practices. Age also shows a positive correlation with adoption, indicating that older individuals, possibly due to their accumulated experience or a longer-term perspective on land management, are somewhat more inclined to engage in restoration activities. Furthermore, both residence status and marital status are linked to greater adoption intensity. Permanent residents and married individuals may possess a stronger sense of responsibility or permanence, which motivates them to invest in sustainable land management practices.

Household characteristics, such as size and access to labor, play a significant role in the adoption of FLR practices. Larger households tend to engage in these practices more intensively, which may be attributed to their increased labor capacity, shared responsibilities, or greater resource demands. Additionally, awareness of land degradation and access to credit are positively correlated with FLR adoption, suggesting that households confronted with urgent land

Table 4. Factors that influence the intensity of FLR adoption (number of practices adopted)

Variables	Coefficient.	Robust Std.Err.	P-value
Gender	0.664***	0.133	0.000
Age	0.012**	0.005	0.026
Residence status	0.419***	0.151	0.005
Marital status	0.468**	0.207	0.024
Education status	0.133	0.132	0.311
Household size	0.065**	0.026	0.012
Household labor	0.003	0.032	0.917
Degradation status	0.269**	0.121	0.026
Credit access	0.282**	0.127	0.026
Access to Extension services	0.123	0.144	0.392
Association Engaging in Ecological Activities	0.026	0.149	0.861
Association Engaging in Economic Activities	0.279**	0.128	0.030
Household farm size	0.024	0.024	0.313
Livestock owned	−0.005	0.008	0.575
Poultry	0.011**	0.005	0.048
Experience in Farming	0.004	0.006	0.499
Distance household to farm	−0.030*	0.017	0.088
Land Acquisition mode: Purchased land	0.014	0.153	0.926
Land Acquisition mode: Inherited land	0.299**	0.159	0.060
Land Acquisition mode: Donation	0.116	0.149	0.438
Land Acquisition mode: Rented land	−0.101	0.139	0.469
Land Acquisition mode: Finance arrangement	−0.068	0.134	0.609
Additional Harvest of NTFPs	−0.069	0.197	0.727
Fuelwood as additional harvest	−0.095	0.199	0.633
Plot land is seen as crucial for Food Security	0.636***	0.208	0.002
Plot land is seen as crucial for Energy	0.278	0.196	0.157
Plot land is seen as crucial for climate change	0.236	0.153	0.124

Observations = 313.
Wald chi2 (27) = 145.15.
Prob > chi2 = 0.0000.
Pseudo R2 = 0.139.
Log pseudolikelihood = −428.04331
Level of significance: ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

degradation issues or those with financial resources are more likely to prioritize restoration efforts. Furthermore, membership in economic associations enhances adoption rates, likely by providing resources and collective incentives that help mitigate individual entry barriers.

Land tenure types and perceptions regarding the importance of land significantly influence the adoption of FLR. Households that inherit land tend to be more committed to restoration efforts, likely due to a mindset focused on generational investment. The belief that land is essential for food security also strongly motivates adopting FLR, emphasizing how subsistence needs can drive sustainable practices. Conversely, households with farms farther from their residences are less likely to adopt FLR strategies intensively, potentially due to logistical challenges or diminished monitoring capabilities. Additionally, ownership of small livestock, such as poultry, positively correlates with FLR adoption, suggesting that diversified agricultural livelihoods may promote sustainable land use. These insights highlight the critical role of socioeconomic factors, land tenure, and perceptions of land's purpose in shaping the intensity of FLR adoption.

5. Discussions

This study investigates the drivers influencing the adoption and intensity of FLR practices among smallholder farmers, revealing a complex interplay of variables that shape both the likelihood and extent of adoption. Key drivers include gender, age, land tenure, household size, and access to resources like credit and extension services.

One of the most notable findings of this study is the significant influence of gender on both the adoption and intensity of FLR practices. Households headed by men were more likely to adopt FLR practices and engage more actively in restoration efforts. This observation is consistent with several studies highlighting the gendered nature of land management, where men typically have greater access to land, resources, and decision-making authority (Celine et al., 2023; Chazdon & Guariguata, 2016; Hounkpati, Moluh Njoya, et al., 2024; Malapit et al., 2019; Pettinotti & Raga, 2023). For instance, Meinzen-Dick et al. (2019) emphasize how gender-differentiated access to land and agricultural inputs perpetuates inequalities in land-use decisions. Similarly, Midamba and Ouko (2024) demonstrate that male-headed households often have better access to extension services, which enhances their ability to adopt FLR practices. Conversely, women in rural areas often face challenges such as restricted access to capital, education, and land ownership (Djenontin et al., 2022), which can impede their ability to invest in long-term restoration initiatives. This gender disparity in the intensity of adoption underscores the necessity for gender-sensitive policies and approaches that empower women by enhancing their access to resources and decision-making opportunities.

Household size also emerged as a key factor influencing the intensity of FLR adoption. Larger households, typically associated with a greater labor force, were more likely to adopt FLR practices more intensively. This finding resonates with Ahmad et al. (2023); Ngaiwi et al. (2023), who suggest that larger households are better equipped to engage in labor-intensive agricultural practices, including land restoration efforts. The availability of labor is crucial in the context of FLR, as it often requires significant manual effort, especially in the early stages of restoration, such as tree planting and land preparation. Additionally, larger households may have greater access to resources and social capital, further facilitating the adoption of FLR practices. Moreover, larger households often benefit from a more diverse array of income sources, which can provide the financial stability necessary for investing in long-term restoration activities. Their broader networks of family members and social connections may also improve access to information, capital, and support from local agricultural extension services, thereby enhancing the success of restoration efforts. Consequently, understanding household dynamics is very important for designing effective FLR programs that capitalize on the strengths of larger households while also addressing the potential challenges smaller households may encounter in adopting similar practices.

Access to credit and extension services have been identified as critical drivers of FLR adoption. Farmers with access to capital are more inclined to implement FLR practices, highlighting the necessity of financial resources for investing in sustainable land management techniques. This observation aligns with research by Bayisa et al. (2024); Hounkpati, Moluh Njoya, et al. (2024); Kolapo et al. (2022), which indicates that access to financial services significantly facilitates the adoption of environmentally sustainable practices by lowering the financial barriers to implementation. Extension services are vital in equipping farmers with the necessary knowledge and technical support to adopt new agricultural methods. The lack of significance of other variables, such as education and membership in ecological associations, suggests that while education may have long-term benefits, its immediate impact on the intensity of FLR adoption is constrained by more direct factors, including labor availability, access to financial resources, and secure land tenure.

The study reaffirms the significant role of land tenure in the adoption of FLR practices. Notably, land acquired through inheritance was positively linked to both the adoption and intensity of these practices, highlighting how secure land tenure fosters long-term investment in land management. This finding aligns with previous research that emphasizes the importance of land tenure security in promoting sustainable land use practices (Gedefaw, 2023; Olumba et al., 2024). Farmers who own land or have secure access to it through inheritance are more likely to invest in practices that enhance soil fertility, restore degraded land, and mitigate the effects of climate change. Conversely, those with insecure tenure—such as renters or individuals involved in informal financial arrangements—may be less inclined to adopt practices that necessitate long-term investments.

The perceived value of restored plot land significantly influences farmers' engagement in restoration activities, shaping their decisions to invest in these practices. Farmers who recognize the benefits of land restoration —such as enhanced food security, increased fuelwood availability, and improved resilience to climate change —are more inclined to adopt restoration techniques. The belief that restoring their land will boost productivity and ensure long-term sustainability is a compelling incentive. However, while restoration efforts can enhance resource availability, the immediate advantages for food security may not always be evident, presenting a challenge for farmers under short-term livelihood pressures (Muluneh & Sime, 2024). This highlights the importance of presenting the benefits of land restoration in ways that resonate with farmers' immediate needs and priorities. Understanding the trade-offs between long-term ecological advantages and short-term food security concerns is essential for developing restoration initiatives that are both attractive and sustainable.

The findings of this research highlight that interventions aimed at promoting the adoption of FLR practices must consider a complex array of barriers. Implementing gender-sensitive policies that ensure equal access to land, capital, and extension services is crucial for enabling both men and women to participate fully in FLR initiatives. Strengthening land tenure security can positively influence adoption. Additionally, improving access to credit and extension services can help overcome financial and knowledge-related obstacles, empowering farmers to engage in restoration efforts actively. Subsequent studies should examine the role of social networks and collective action, as these factors may significantly influence farmers' willingness to embrace new practices. Moreover, exploring the interactions between socioeconomic factors and environmental conditions —such as soil degradation and climate change—could provide a more nuanced understanding of adoption decisions.

6. Conclusion

We investigate the socioeconomic factors influencing the adoption and intensity of FLR practices among smallholder farmers in central Togo. By integrating mvprobit and ordered probit models, we have illustrated how various drivers interact to shape the likelihood and extent of FLR adoption. The results indicate that male-headed households, larger households, and those with secure land tenure are more likely to adopt FLR practices, including also more multiple practices in parallel. Furthermore, access to capital and extension services emerges as a crucial enabler of FLR adoption, whereas the distance from the household to the farm negatively affects the intensity of adoption. These findings underscore the need for policies that enhance land tenure security, particularly for women and marginalized groups, to ensure equitable access to FLR opportunities. Additionally, Policymakers should focus on expanding financial support mechanisms such as credit programs and subsidies to help farmers invest in restoration practices. Strengthening agricultural extension services is also essential to provide farmers with the technical knowledge and training needed for effective FLR implementation. Future research should explore the dynamic relationship between socioeconomic drivers, environmental conditions, and collective action in the adoption of FLR practices. Such insights will contribute to developing more effective policies to promote FLR and achieve long-term environmental sustainability.

Acknowledgements

We thank the Leibniz Centre for Agricultural Landscape Research (ZALF) and the University of Lomé (UL) for logistical support in conducting the research. We express our sincere thanks and appreciation to the experts and farmers who agreed to participate in this study.

Disclosure statement

The authors declare that they have no conflict of interest.

Funding

The project received financial support from the German Federal Ministry for Economic Cooperation and Development (BMZ), commissioned and administered through the global project on forest landscape restoration and good governance in the forest sector (Forests4Future) of the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) [ref no: 81277142/19.0125.5- 101.00]. The contents of this publication are the sole responsibility of the author of this publication and can under no circumstances be regarded as reflecting the position of GIZ/F4F or the Federal Ministry for Economic Cooperation and Development (BMZ).

ORCID

Hamza Moluh Njoya http://orcid.org/0000-0002-5067-2871
Kossi Hounkpati http://orcid.org/0000-0003-0212-7331
Kossi Adjonou http://orcid.org/0000-0001-8491-8107
Kouami Kokou http://orcid.org/0000-0002-2400-0852
Stefan Sieber http://orcid.org/0000-0002-4849-7277
Katharina Löhr http://orcid.org/0000-0003-2691-9712

Author contributions

Hamza Moluh Njoya: Conceptualization, Methodology, Investigation, Formal analysis, Visualization, Writing—Original Draft. **Kossi Hounkpati**: Investigation, Writing—Review & Editing. **Kossi Adjonou**: Writing—Review & Editing. **Kouami Kokou**: Supervision, Writing—Review & Editing, **Stefan Sieber**: Funding acquisition, Supervision, Writing—Review & Editing. **Katharina Löhr**: Funding acquisition, conceptualization, supervision, Writing—Review & Editing. All authors read and approved the final manuscript.

Consent for publication

A verbal consent for publishing was obtained, and no identifying details of the participants is published

Data availability statement

The datasets generated during and/or analysed during the current study are available from the corresponding author upon reasonable request.

Ethics statement and written informed consent

The research followed the ethical standards as laid down in the Declaration of Helsinki, and the protocol was approved by the National Institute of Scientific and Technical Research of Togo. Informed consent was obtained from all participants, with a written consent form provided within the Kobo Collect survey. The consent form was read aloud to participants, and their voluntary agreement to participate was documented before data collection commenced.

References

Abdel Rahman, M. A. E. (2023). An overview of land degradation, desertification and sustainable land management using GIS and remote sensing applications. *Rendiconti Lincei Scienze Fisiche e Naturali*, *34*(3), 767–808. https://doi.org/10.1007/s12210-023-01155-3

Ahmad, S., Xu, H., & Ekanayake, E. M. B. P. (2023). Socioeconomic determinants and perceptions of smallholder farmers towards agroforestry adoption in northern irrigated plain, Pakistan. *The Land*, *12*(4), 813.

Ali, E. (2021). Farm households' adoption of climate-smart practices in subsistence agriculture: Evidence from Northern Togo. *Environmental Management*, *67*(5), 949–962. https://doi.org/10.1007/s00267-021-01436-3

Amadu, F. O., Miller, D. C., & McNamara, P. E. (2020). Agroforestry as a pathway to agricultural yield impacts in climate-smart agriculture investments: Evidence from southern Malawi. *Ecological Economics*, *167*, 106443. https://doi.org/10.1016/j.ecolecon.2019.106443

Anang, B. T., Amesimeku, J., & Fearon, J. (2021). Drivers of adoption of crop protection and soil fertility management practices among smallholder soybean farmers in Tolon district of Ghana. *Heliyon*, *7*(5), e06900. https://doi.org/10.1016/j.heliyon.2021.e06900

Asante, B. O., Ma, W., Prah, S., & Temoso, O. (2024). Promoting the adoption of climate-smart agricultural technologies among maize farmers in Ghana: Using digital advisory services. *Mitigation and Adaptation Strategies for Global Change*, *29*(3), 19. https://doi.org/10.1007/s11027-024-10116-6

Baade, J., Aucamp, I., Collett, A., Eckardt, F., Funk, R., Glotzbach, C., von Holdt, J., Kestel, F., Knot, J., Lombard, A., Morgenthal, T., Msipa, A., & Roux, J. J. L. (2024). Soil erosion research and soil conservation policy in South Africa. In G. P. von Maltitz, G. F. Midgley, J. Veitch, C. Brümmer, R. P. Rötter, F. A. Viehberg, & M. Veste (Eds.), *Sustainability of Southern African ecosystems under global change: Science for management and policy interventions* (pp. 335–368). Springer International Publishing. https://doi.org/10.1007/978-3-031-10948-5_13

Bassan, K. A., Sills, E. O., & Kokou, K. (2020). Linear panel data and farming cash flow analyses to assess the causes of deforestation in the Upper Guinean Forest: Data and evidence from the prefectures of the Central Region in Togo. *Natural Resources*, *11*(3), 71–95. https://doi.org/10.4236/nr.2020.113005

Bayisa, H., Kebede, B., & Benti, F. (2024). Factors influencing the implementation and adoption of sustainable land management practices on Wacaca Mountain in Central Highlands of Ethiopia. *Environmental Modeling & Assessment*, *30*(1), 53–70. https://doi.org/10.1007/s10666-024-09993-7

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

Binam, J. N., Place, F., Kalinganire, A., Hamade, S., Boureima, M., Tougiani, A., Dakouo, J., Mounkoro, B., Diaminatou, S., Badji, M., Diop, M., Babou, A. B., & Haglund, E. (2015). Effects of farmer managed natural regeneration on livelihoods in semi-arid West Africa. *Environmental Economics and Policy Studies*, *17*(4), 543–575. https://doi.org/10.1007/s10018-015-0107-4

Camara, B. A., Sanogo, D., Ndiaye, O., Diahate, P. B., Sall, M., Ba, H. S., Diop, M., & Badji, M. (2023). Farmers' perception on the benefits and constraints of Farmer managed natural regeneration and determinants of its adoption in the southern groundnut basin of Senegal. *Agroforestry Systems*, *97*(7), 1275–1288. https://doi.org/10.1007/s10457-021-00690-y

Celine, S.-L., Ayushi, T., & Keegan, G. (2023). Enabling women as key actors in nature-based solutions. *Working paper issue*. W. R. Institute.

Chang, K., & Andersson, K. P. (2021). Contextual factors that enable forest users to engage in tree-planting for forest restoration. *Land Use Policy*, *104*, 104017. https://doi.org/10.1016/j.landusepol.2019.05.036

Chanie Haile, D., Kebede Bizuneh, Y., Debele Bedhane, M., & Gelaw Mekonnen, A. (2024). Determinants of land management technology adoptions by rural households in the goyrie watershed of southern Ethiopia: Multivariate probit modeling estimation. *Heliyon*, *10*(11), e31894. https://doi.org/10.1016/j.heliyon.2024.e31894

Chazdon, R. L., & Guariguata, M. R. (2016). Natural regeneration as a tool for large-scale forest restoration in the tropics: Prospects and challenges. *Biotropica*, *48*(6), 716–730. https://doi.org/10.1111/btp.12381

Chomba, S., Sinclair, F., Savadogo, P., Bourne, M., & Lohbeck, M. (2020). Opportunities and constraints for using Farmer managed natural regeneration for land restoration in Sub-Saharan Africa [review]. *Frontiers in Forests and Global Change*, *3*, 3. https://doi.org/10.3389/ffgc.2020.571679

Cochran, W. G. (1977). *Sampling techniques*. John Wiley & Sons.

da Silva, C. M., Elias, F., Nascimento, R. O., & Ferreira, D. (2023). The potential for forest landscape restoration in the Amazon: State of the art of restoration strategies. *Restoration Ecology*, *31*(5), e13955. https://doi.org/10.1111/rec.13955

Darkwah, K. A., Kwawu, J. D., Agyire-Tettey, F., & Sarpong, D. B. (2019). Assessment of the determinants that influence the adoption of sustainable soil and water conservation practices in Techiman Municipality of Ghana. *International Soil & Water Conservation Research*, *7*(3), 248–257. https://doi.org/10.1016/j.iswcr.2019.04.003

Derak, M., Taiqui, L., Fiedler, S., & Cortina-Segarra, J. (2024). Social learning to promote forest restoration in a semi-arid landscape in North Africa. *Environmental Development*, *49*, 100972. https://doi.org/10.1016/j.envdev.2024.100972

DiFalco, S., Veronesi, M., & Yesuf, M. (2011). Does adaptation to climate change provide food security? A micro-perspective from Ethiopia. *American Journal of Agricultural Economics*, *93*(3), 829–846. https://doi.org/10.1093/ajae/aar006

Djenontin, I. N. S., Foli, S., & Zulu, L. C. (2018). Revisiting the factors shaping outcomes for forest and landscape restoration in Sub-Saharan Africa: A way forward for policy, practice and research. *Sustainability*, *10*(4), 906.

Djenontin, I. N. S., Zulu, L. C., & Etongo, D. (2021). Ultimately, what is forest landscape restoration in practice? Embodiments in Sub-Saharan Africa and implications for future design. *Environmental Management*, *68*(5), 619–641. https://doi.org/10.1007/s00267-020-01360-y

Djenontin, I. N. S., Zulu, L. C., & Richardson, R. B. (2022). Smallholder farmers and forest landscape restoration in sub-saharan Africa: Evidence from Central Malawi. *Land Use Policy*, *122*, 106345. https://doi.org/10.1016/j.landusepol.2022.106345

Drescher, M., Hannay, J., Feick, R. D., & Caldwell, W. (2024). Social psychological factors drive farmers' adoption of environmental best management practices. *Journal of Environmental Management*, *350*, 119491. https://doi.org/10.1016/j.jenvman.2023.119491

Ekka, P., Patra, S., Upreti, M., Kumar, G., Kumar, A., & Saikia, P. (2023). Land degradation and its impacts on biodiversity and ecosystem services. *Land and Environmental Management Through Forestry*, 77–101. https://doi.org/10.1002/9781119910527.ch4

Eshetu, S. B., Kipkulei, H. K., Koepke, J., Kächele, H., Sieber, S., & Löhr, K. (2024). Impact of forest landscape restoration in combating soil erosion in the Lake Abaya catchment, Southern Ethiopia. *Environmental Monitoring and Assessment*, *196*(3), 228. https://doi.org/10.1007/s10661-024-12378-8

Etongo, D., Epule, T. E., Djenontin, I. N. S., & Kanninen, M. (2018). *Land management in rural Burkina Faso: The role of socio-cultural and institutional factors*. Natural Resources Forum.

FAO. (2023). *Programme National de Reboisement du Togo 2017–2030*. Retrieved October 18, 2024, from https://www.fao.org/faolex/results/details/fr/c/LEX-FAOC198334/

Gedefaw, A. A. (2023). Analysis of the contribution of land registration to sustainable land management in East Gojjam Zone, Ethiopia. *The Land*, *12*(6), 1157. https://doi.org/10.3390/land12061157

Gupta, S. R., Dagar, J. C., & Teketay, D. (2020). Agroforestry for rehabilitation of degraded landscapes: Achieving livelihood and environmental security. In J. C. Dagar, S. R. Gupta, & D. Teketay (Eds.), *Agroforestry for degraded landscapes: Recent advances and emerging challenges* (pp. 23–68). Springer Singapore. https://doi.org/10.1007/978-981-15-4136-0_2

Hounkpati, K., Adjonou, K., & Kokou, K. (2022). Distribution and cultural identity of sacred groves in Togo. *International Forestry Review*, *24*(2), 163–174. https://doi.org/10.1505/146554822835629550

Hounkpati, K., Adjonou, K., Moluh Njoya, H., Hlovor, A. K. D., Kipkulei, H. K., Sieber, S., Löhr, K., & Kokou, K. (2024). Strengthening forest landscape restoration through understanding land use dynamics: Case study of Tchamba Prefecture (Togo). *The Journal of the Indian Society of Remote Sensing*. https://doi.org/10.1007/s12524-024-01862-w

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 [original research]. *Frontiers in Sustainable Food Systems*, 8. https://doi.org/10.3389/fsufs.2024.1425797

Jain, S., Srivastava, A., Khadke, L., Chatterjee, U., & Elbeltagi, A. (2024). Global-scale water security and desertification management amidst climate change. *Environmental Science and Pollution Research*, *31*(49), 58720–58744. https://doi.org/10.1007/s11356-024-34916-0

Jiang, C., Zhang, H., Zhao, L., Yang, Z., Wang, X., Yang, L., Wen, M., Geng, S., Zeng, Q., & Wang, J. (2020). Unfolding the effectiveness of ecological restoration programs in combating land degradation: Achievements, causes, and implications. *Science of the Total Environment*, *748*, 141552. https://doi.org/10.1016/j.scitotenv.2020.141552

Khonje, M. G., Manda, J., Mkandawire, P., Tufa, A. H., & Alene, A. D. (2018). Adoption and welfare impacts of multiple agricultural technologies: Evidence from eastern Zambia. *Agricultural Economics*, *49*(5), 599–609. https://doi.org/10.1111/agec.12445

Kifle, T., Ayal, D. Y., & Mulugeta, M. (2022). Factors influencing farmers adoption of climate smart agriculture to respond climate variability in Siyadebrina Wayu District, central highland of Ethiopia. *Climate Services*, *26*, 100290. https://doi.org/10.1016/j.cliser.2022.100290

Kolapo, A., Didunyemi, A. J., Aniyi, O. J., & Obembe, O. E. (2022). Adoption of multiple sustainable land management practices and its effects on productivity of smallholder maize farmers in Nigeria. *Resources, Environment and Sustainability*, *10*, 100084. https://doi.org/10.1016/j.resenv.2022.100084

Kombate, A., Folega, F., Atakpama, W., Dourma, M., Wala, K., & Goïta, K. (2022). Characterization of land-cover changes and Forest-cover dynamics in Togo between 1985 and 2020 from Landsat images using google earth engine. *The Land*, *11*(11), 1889. https://doi.org/10.3390/land11111889

Kpadonou, R. A. B., Owiyo, T., Barbier, B., Denton, F., Rutabingwa, F., & Kiema, A. (2017). Advancing climate-smart-agriculture in developing drylands: Joint analysis of the adoption of multiple on-farm soil and water conservation technologies in west African sahel. *Land Use Policy*, *61*, 196–207. https://doi.org/10.1016/j.landusepol.2016.10.050

Leisher, C. (2014). A comparison of tablet-based and paper-based survey data collection in conservation projects. *Social Sciences*, *3*(2), 264–271.

Li, J., Ma, W., & Zhu, H. (2023). A systematic literature review of factors influencing the adoption of climate-smart agricultural practices. *Mitigation and Adaptation Strategies for Global Change*, *29*(1), 2. https://doi.org/10.1007/s11027-023-10098-x

Malapit, H., Quisumbing, A., Meinzen-Dick, R., Seymour, G., Martinez, E. M., Heckert, J., Rubin, D., Vaz, A., & Yount, K. M. (2019). Development of the project-level Women's empowerment in agriculture index (pro-weai). *World Development*, *122*, 675–692. https://doi.org/10.1016/j.worlddev.2019.06.018

Mandal, A., Dhaliwal, S. S., Mani, P. K., & Toor, A. S. (2021). Chapter 2 - conservation agricultural practices under organic farming. In V. S. Meena, S. K. Meena, A. Rakshit, J. Stanley, & C. Srinivasarao (Eds.), *Advances in organic farming* (pp. 17–37). Woodhead Publishing. https://doi.org/10.1016/B978-0-12-822358-1.00014-6

Mansourian, S., Derkyi, M., Djenontin, I., Elias, M., Oldekop, J., Pacheco, P., Burns, J., Diederichsen, A., Kleine, M., Vallauri, D., & Walder, B. (2024). *Human dimensions of forest landscape restoration (N 978-3-903345-28-7)*. IUFRO. https://hdl.handle.net/10568/141866

Mansourian, S., Stanturf, J. A., Derkyi, M. A. A., & Engel, V. L. (2017). Forest landscape restoration: Increasing the positive

impacts of forest restoration or simply the area under tree cover? *Restoration Ecology*, *25*(2), 178–183. https://doi.org/10.1111/rec.12489
Masvaya, E. N., Nyamangara, J., Descheemaeker, K., & Giller, K. E. (2017). Tillage, mulch and fertiliser impacts on soil nitrogen availability and maize production in semi-arid Zimbabwe. *Soil and Tillage Research*, *168*, 125–132. https://doi.org/10.1016/j.still.2016.12.007
Meinzen-Dick, R., Quisumbing, A., Doss, C., & Theis, S. (2019). Women's land rights as a pathway to poverty reduction: Framework and review of available evidence. *Agricultural Systems*, *172*, 72–82. https://doi.org/10.1016/j.agsy.2017.10.009
Midamba, D. C., & Ouko, K. O. (2024). Gender disparities in agricultural extension among smallholders in Western Uganda. *Cogent Economics and Finance*, *12*(1), 2391938. https://doi.org/10.1080/23322039.2024.2391938
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 [original research]. *Frontiers in Sustainable Food Systems*, 8. https://doi.org/10.3389/fsufs.2024.1466008
Muluneh, A., & Sime, G. (2024). Participatory forest management for sustainable rural livelihoods and forest ecosystem services: The case of deneba forest managing cooperative in Ethiopia. *Journal for Nature Conservation*, *78*, 126580. https://doi.org/10.1016/j.jnc.2024.126580
Muriu-Ng'ang'a, F. W., Mucheru-Muna, M., Waswa, F., & Mairura, F. S. (2017). Socio-economic factors influencing utilisation of rain water harvesting and saving technologies in Tharaka South, Eastern Kenya. *Agricultural Water Management*, *194*, 150–159. https://doi.org/10.1016/j.agwat.2017.09.005
Musafiri, C. M., Kiboi, M., Macharia, J., Ng'etich, O. K., Kosgei, D. K., Mulianga, B., Okoti, M., & Ngetich, F. K. (2022). Adoption of climate-smart agricultural practices among smallholder farmers in Western Kenya: Do socio-economic, institutional, and biophysical factors matter? *Heliyon*, *8*(1), e08677. https://doi.org/10.1016/j.heliyon.2021.e08677
Ngaiwi, M. E., Molua, E. L., Sonwa, D. J., Meliko, M. O., Bomdzele, E. J., Ayuk, J. E., Castro-Nunez, A., & Latala, M. M. (2023). Do farmers' socioeconomic status determine the adoption of conservation agriculture? An empirical evidence from Eastern and southern regions of Cameroon. *Scientific African*, *19*, e01498. https://doi.org/10.1016/j.sciaf.2022.e01498
Nigussie, Z., Tsunekawa, A., Haregeweyn, N., Adgo, E., Nohmi, M., Tsubo, M., Aklog, D., Meshesha, D. T., & Abele, S. (2017). Factors influencing small-scale farmers' adoption of sustainable land management technologies in north-western Ethiopia. *Land Use Policy*, *67*, 57–64. https://doi.org/10.1016/j.landusepol.2017.05.024
Oduniyi, O. S. (2022). Factors driving the adoption and use extent of sustainable land management practices in South Africa. *Circular Economy and Sustainability*, *2*(2), 589–608. https://doi.org/10.1007/s43615-021-00119-9
Okeyo, A. I., Mucheru-Muna, M., Mugwe, J., Ngetich, K. F., Mugendi, D. N., Diels, J., & Shisanya, C. A. (2014). Effects of selected soil and water conservation technologies on nutrient losses and maize yields in the central highlands of Kenya. *Agricultural Water Management*, *137*, 52–58. https://doi.org/10.1016/j.agwat.2014.01.014
Olumba, C. N., Garrod, G., & Areal, F. J. (2024). Time preferences, land tenure security, and the adoption of sustainable land management practices in Southeast Nigeria. *Sustainability*, *16*(5), 1747.
Owusu, R., Kimengsi, J. N., & Moyo, F. (2021). Community-based Forest landscape Restoration (FLR): Determinants and policy implications in Tanzania. *Land Use Policy*, *109*, 105664. https://doi.org/10.1016/j.landusepol.2021.105664
Oyetunde Usman, Z., Olagunju, K. O., & Ogunpaimo, O. R. (2021). Determinants of adoption of multiple sustainable agricultural practices among smallholder farmers in Nigeria. *International Soil & Water Conservation Research*, *9*(2), 241–248. https://doi.org/10.1016/j.iswcr.2020.10.007
Pettinotti, L., & Raga, S. (2023). Gender equality in Togo.
Prăvălie, R. (2021). Exploring the multiple land degradation pathways across the planet. *Earth-Science Reviews*, *220*, 103689. https://doi.org/10.1016/j.earscirev.2021.103689
Roodman, D. (2011). Fitting fully observed recursive mixed-process models with cmp. *The Stata Journal*, *11*(2), 159–206. https://doi.org/10.1177/1536867X1101100202
Rotich, B., Maket, I., Kipkulei, H., Ocansey, C. M., Justine, P. N., MohammedZein, M. A., Csorba, Á., & Michéli, E. (2024). Determinants of soil and water conservation practices adoption by smallholder farmers in the central highlands of Kenya. *Farming System*, *2*(2), 100081. https://doi.org/10.1016/j.farsys.2024.100081
Sida, T. S., Baudron, F., Kim, H., & Giller, K. E. (2018). Climate-smart agroforestry: Faidherbia albida trees buffer wheat against climatic extremes in the Central Rift Valley of Ethiopia. *Agricultural and Forest Meteorology*, *248*, 339–347. https://doi.org/10.1016/j.agrformet.2017.10.013
Stanturf, J. A., Kleine, M., Mansourian, S., Parrotta, J., Madsen, P., Kant, P., Burns, J., & Bolte, A. (2019). Implementing forest landscape restoration under the Bonn challenge: A systematic approach. *Annals of Forest Science*, *76*(2), 50. https://doi.org/10.1007/s13595-019-0833-z
Tate, A., Smallwood, C., & Moutopoulos, D. K. (2021). Comparing the efficiency of paper-based and electronic data capture during face-to-face interviews. *PLOS ONE*, *16*(3), e0247570. https://doi.org/10.1371/journal.pone.0247570
Teklewold, H., Gebrehiwot, T., & Bezabih, M. (2019). Climate smart agricultural practices and gender differentiated nutrition outcome: An empirical evidence from Ethiopia. *World Development*, *122*, 38–53. https://doi.org/10.1016/j.worlddev.2019.05.010
Ullah, A. (2024). Forest landscape restoration and Its Impact on social cohesion, ecosystems, and rural livelihoods: Lessons learned from Pakistan. *Regional Environmental Change*, *24*(1), 26. https://doi.org/10.1007/s10113-024-02198-4
Ullah, A., Zeb, A., Shah, A. A., & Bavorova, M. (2024). From education to rehabilitation: Empowering farming communities through extension services for landscape restoration. *Environment, Development, and Sustainability*, *26*(5), 11681–11701. https://doi.org/10.1007/s10668-023-03452-1
Wang, H., Tian, F., Wu, J., & Nie, X. (2023). Is China forest landscape restoration (FLR) worth it? A cost-benefit

analysis and non-equilibrium ecological view. *World Development*, *161*, 106126. https://doi.org/10.1016/j.worlddev.2022.106126

Ward, P. S., Bell, A. R., Droppelmann, K., & Benton, T. G. (2018). Early adoption of conservation agriculture practices: Understanding partial compliance in programs with multiple adoption decisions. *Land Use Policy*, *70*, 27–37. https://doi.org/10.1016/j.landusepol.2017.10.001

Weeraratna, S. (2022). Control of land degradation. In S. Weeraratna (Ed.), *Understanding Land Degradation: An Overview* (pp. 39–51). Springer International Publishing. https://doi.org/10.1007/978-3-031-12138-8_4

Wolka, K., Mulder, J., & Biazin, B. (2018). Effects of soil and water conservation techniques on crop yield, runoff and soil loss in Sub-Saharan Africa: A review. *Agricultural Water Management*, *207*, 67–79. https://doi.org/10.1016/j.agwat.2018.05.016

WRI. (2024). *Forest loss indicator*. *Global forest review*. Retrieved November 19, 2024, from https://research.wri.org/gfr/forest-extent-indicators/forest-loss

Yuan, E., Zhou, Q., Yan, W., Peng, D., Wang, Y., Yang, X., & Li, P. (2024). The impact of socioeconomic factors on vegetation restoration in karst regions: A perspective beyond climate and ecological engineering. *Ecological Engineering*, *206*, 107332. https://doi.org/10.1016/j.ecoleng.2024.107332