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Drivers affecting adoption of forest landscape restoration among smallholder farmers in Central Togo

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One possible solution for regaining ecological functionality and enhancing human well-being in deforested and degraded landscapes is Forest Landscape Restoration (FLR). Togo has set a goal to restore 1.4 million hectares of lands by 2030. Despite the national commitment to FLR, no significant progress has been made and drivers that impact FLR adoption remain poorly understood. Thus, it is crucial to enhance knowledge on drivers influencing the adoption of FLR to facilitate its implementation while also providing recommendations for policy and practice. Surveying 494 Togolese smallholder farmers, this study focuses on socio-economic, biophysical, geographical, and institutional aspects of FLR as well as farmers' perceptions. Descriptive statistics and logistic regression are employed to provide a model of the drivers affecting FLR in Togo. The results reveal that 43.62% of smallholder farmers adopt FLR practices in the study areas. FLR practices linked to agricultural land restoration, such as improved fallow and crop rotation system (33.40%) and agroforestry (32.19%), are the most widely adopted, followed by reforestation (13.36%), community forest creation (8.7%), commercial forest plantation (7.29%), and sacred forest enrichment (2.83%). Results also indicate that smallholder farmers in cooperatives and involved in restoration activities have a higher awareness of the importance of restoration and willingness to adopt practices. Similar observations are made for farmers living in a zone with high exposure to FLR activities. Secure property rights also support adopting FLR practices. Further, the services of local technicians or facilitators create favorable conditions that encourage smallholders to implement FLR practices. Perception of restoration practices and need, motivation for maintaining restoration practices, and relevance for food security greatly impact smallholder farmer adoption. These results suggest that FLR practices can be increased through training and access to seedlings, supporting reforestation and community forest creation by incentivizing smallholder participation through subsidies or technical assistance, clarifying and strengthening smallholders' land rights, and deploying more local technicians.

KEYWORDS

adoption, practices, agroforestry, reforestation, perceptions, food security, landscape, restoration

1 Introduction

Forest and land degradation is a complex and dynamic issue that is context-specific. The ongoing forest and land degradation hinder global efforts to end poverty and hunger, reverse biodiversity loss, and empower local communities to tackle climate change (Sabogal et al., 2015). Moreover, land degradation affects one-third of the world's population, with one billion people living in degraded areas, representing 15% of the world's population (Hossain et al., 2020; Sabogal et al., 2015). Facing this situation, the Bonn Challenge sought to extend forest landscape restoration (FLR) by 150 million hectares; subsequently the New York Declaration on Forests (NYDF) extended this goal to 350 million hectares.

A total of 34 countries in sub-Saharan Africa, including Togo, have pledged to contribute to the restoration of 100 million hectares via the African Forest Landscape Restoration Initiative (AFR100) (Djenontin et al., 2022; Messinger and Winterbottom, 2016; Owusu et al., 2023). With a high rate of land degradation, estimated at 4.14% (or 23,490 hectares) per year, Togo has set the goal to restore 80% of its degraded land and reduce to 2% the degradation of land that remains intact by 2030 (MERF, 2018). The overall objective is to reverse both land degradation and the high annual rate of deforestation in Togo, which was 0.40% between 2015 and 2018, despite forests covering only 24.24% of the country's total land area (MERF, 2016). To achieve this ambitious goal, Togo has committed to plant one billion trees as part of a multi-pronged strategy to restore 1.4 million hectares (MERF, 2021, 2017). Further, Togo's forestry policy plans to preserve current forestry potential while promoting its expansion to increase forest cover up to 25% by 2030 and 30% by 2050 (MERF, 2021). This should be achieved through a viable, autonomous, and profitable forestry sector as Togo is one of the top six African countries with the highest mean score for restoration opportunity (Brancalion et al., 2019). In addition, several forest landscape management tools have been developed and a participatory approach that gives responsibility to local stakeholders, especially smallholder farmers (MERF, 2017), is being developed. As the strategy for the sustainable use and conservation of biodiversity, the national reforestation program are part of these tools (MERF, 2017, 2010). It is against this background that FLR activities are evaluated in this study, with special focus on adoption drivers that can foster achievement of the national agenda.

FLR is a planned process of regaining ecological functionality and enhancing human well-being across deforested or degraded landscapes (Mansourian et al., 2005; Sabogal et al., 2015; WWF and IUCN, 2000). According to Chazdon and Laestadius (2016), this definition remains vague to allow flexibility and adaptation of this approach to local contexts. Maginnis and Jackson (2006) emphasize that the main objective of FLR is not to re-establish a primitive forest but rather to make landscapes more resilient in order to improve their productive functions and support communities striving to increase and maintain the benefits they derive from landscape management. Although active tree planting is important in this approach, FLR should be understood as a set of practices that not only involves this activity but also restoring entire landscapes by providing a variety of benefits and uses to meet the current and future needs of communities (Lamb et al., 2012; Stanturf et al., 2015). Djenontin et al. (2022) state that FLR practices can be classified into tree-based restoration, which includes tree planting, assisted natural regeneration and agroforestry, and non-tree-based restoration founded on sustainable land management practices such as soil and water conservation techniques and conservation agriculture. Therefore, FLR approaches can differ depending on the specific local needs (context), the scale of intervention, conservation objectives, and available resources.

FLR practices address food productivity, soil and water conservation, and biodiversity preservation. Typically, these are implemented at the farm scale (Djenontin et al., 2022). Thus farmers, particularly smallholder farmers, in Sub-Sahara Africa are key stakeholders in FLR (Djenontin et al., 2018). As landowners farmers often control border forest areas or are integrated into forest landscapes, so their involvement is crucial to the implementation of sustainable land management practices that promote forest regeneration and ecosystem restoration. Their knowledge and local expertise can help to create context specific FLR interventions (Reyes-García et al., 2019). In Togo, the agricultural sector occupies a key position in the economy, as it contributes over 40% of the national income (Ali, 2021; Sonhaye, 2022). According to INSEED statistics for 2021, this sector comprises nearly 4 million farmers (mainly smallholder farmers) out of a total of 7 million inhabitants.

In Togo, as in many other countries globally, smallholder farmers are at the forefront of FLR practices through sustainable agrarian and natural resource management. Through their agricultural practices, smallholder farmers contribute to food production, with estimates showing for the case of Kenya and Tanzania as examples that they produce 63 and 69% of the food, respectively (Rapsomanikis, 2015). In Nepal, approximately 2.7 million smallholder farms are adopting sustainable practices aligned with FLR principles, such as agroforestry and organic farming, which are vital for local economies and food security (Rapsomanikis, 2015). In Peru, smallholder farmers are improving their livelihoods by incorporating climate-smart agriculture into their practices, essential for FLR (Nyoni et al., 2024). In Indonesia, smallholders are recognized as key agents in the implementation of community-based forest management initiatives, which also count as a key FLR approach (Fan and Rue, 2020). Focusing on smallholder adoption behavior is crucial as they are the main actors working in the agricultural sectors, providing up to 80% of food, taking up around 60% of land, and being a significant contribution to the overall economy (Hazell, 2020; Thiele et al., 2016). Thus, their adoption of FLR practices is key for a more successful implementation of FLR goals.

Despite the key role of farmers for success of FLR, studies on farmers adoption of FLR are still few. When adopted, these practices positively affect crop yields, soil fertility, food security, and resilience to climate change by smallholder farmers in Togo and elsewhere (De Pinto et al., 2020; Stanturf et al., 2015; Van Dexter and Visseren-Hamakers, 2018). Furthermore, the adoption of key FLR practices – including agroforestry, natural assisted regeneration, sustainable forest management, reforestation, conservation efforts, community forests creation, the promotion of responsible land-use practices, as well as sustainable soil and water conservation – remain poorly documented. Drivers such as gender, access to land, access to markets, access to credit, and access to extension services are critical determinants for sustainable technology strategies in agrarian systems (Ali, 2021, 2018, 2020; Arouna and Akpa, 2019; Yovo and Ganiyou, 2021). However, as a common challenge across many countries in the context of FLR, these drivers remain under-explored in Togo, especially with respect to smallholders' adoption behavior. The need to effectively support smallholder farmers by allowing them to adopt sustainable farming practices requires an assessment of the motivations behind the strategies being adopted (Ali, 2021). Understanding the drivers of FLR adoption could help promote higher and more diversified production, improve the well-being of smallholders, and strengthen resilience to climate change.

Previous studies document several drivers associated with socio-cultural, economic, ecological, and political aspects as well as those having a psychological influence on farmers' adoption decisions (Edwards-Jones, 2006; Kideghesho et al., 2007). To obtain a comprehensive model of adoption, both Adesina and Baidu-Forson (1995) and Rahm and Huffman (1986) recommended including drivers related to subjective perceptions of adopters alongside individual and family household characteristics (Jha et al., 2021, 2019). Understanding farmers' perceptions of land degradation and landscape management strategies is crucial to effectively target interventions aiming to preserve benefits from land tenure (Tesfahunegn, 2019). However, despite the growing interest and literature on FLR, it is still hard to find in-depth studies on factors driving the adoption of FLR practices; especially relating to countries like Togo. Perceptions of the importance of restoration practices on soil fertility, water quality improvement, climate change mitigation and adaptation, income enhancement, and food security remain under-documented. In addition, it is even more difficult to find studies that evaluate these factors comprehensively.

The main objective of this study is to improve the understanding of the factors that contribute to the successful adoption of FLR practices in Togo. More specifically, the study aims to characterize the socio-economic profiles of smallholder farmers, determine adoption levels of FLR practices, and identify the key determining drivers in adopting FLR practices in Togo. Three questions guide this research: (1) what is the socio-economic profile of smallholder farmers? (2) What is the adoption level of FLR practices? and (3) What are the drivers underlying FLR adoption by smallholder farmers in Togo? These descriptive and econometric analyses highlight promising FLR practices and identify drivers of their adoption. Data are collected from 494 smallholder farmers in the Tchamba prefecture, which serves as a reference region for ongoing FLR initiatives. The data include individual and household information, socio-economic indicators, biophysical characteristics, geographical characteristics, institutional drivers, as well as farmers' perceptions and intentions. Using logit regression and based on a conceptual framework including a mixed approach of the innovation diffusion model, the economic constraints model, the user context model, and the theory of planned behavior, the drivers behind the adoption of FLR practices are identified. The results can help practitioners and public authorities to better plan FLR-related activities, whereby key drivers can be promoted while those hindering adoption can be minimized in order to support smallholder farmers in the comprehensive and sustainable adoption of FLR practices.

2 Materials and methods

2.1 Theoretical framework

2.1.1 Adoption of FLR

Adoption is commonly described as the act by which the adopter chooses to implement and exploit an innovation. Innovation is defined by Rogers (2003) as an idea, a practice perceived as new, by an individual or other entity considering it. Based on these two concepts, this study considers smallholders as adopters if they apply one or more FLR practices for at least one year. Although multiple FLR practices can exist in parallel at one location, the application of one FLR practice is considered in this study to be an adoption. Restoration practices identified in the IUCN/WRI guide on assessing FLR opportunities at national or sub-national level are linked to the land use context, i.e., forest land practices for large-scale restoration (planted forests and woodlots, natural regeneration, silviculture) agricultural land practices for mosaic restoration (agroforestry, improved fallow), and conservation land and buffer zone practices for erosion control restoration, including watersheds (IUCN and WRI, 2014). In sub-Saharan African, restoration practices identified by Djenontin et al. (2018) include tree-based practices, sustainable land management practices, and conservation agriculture (Djenontin et al., 2018). Drawing on these works, we classify the different practices reported by smallholders in three main categories of practices as follows: (i) forest land restoration practices includes community forest creation, sacred forest enrichment, commercial forest plantation and reforestation; (ii) agrarian land restoration practices includes agroforestry and improved fallow and crop rotation systems; and (iii) water conservation and soil restoration practices includes mulching systems and soil amendment systems.

2.1.2 Theory and model of FLR adoption

In innovative technology adoption studies no single model or theory can fully analyze or explain farmers' decision-making processes in detail (Jha et al., 2021). To better understand farmer decision-making within the context of adopting FLR practices, a multifaceted and comprehensive approach is necessary. Consequently, this study combines the innovation diffusion model, the economic constraints model, and the user context model to explain those drivers that determine smallholder farmers' adoption of FLR practices. Each model contributes uniquely to understanding the drivers behind FLR adoption among smallholder farmers in this study. The innovation diffusion model, developed by Rogers in 1962, explains how technology is transferred from its origin to end users through a diffusion system. The adoption of technology within communities largely depends on the personal characteristics of each potential user. This model primarily focuses on the spread of innovation and the motivations behind the decision to accept or reject it (Rogers, 2003). This model is widely applied in several adoption studies independent of the context or the technology (Amare and Darr, 2020; Kabir et al., 2022; Maniraho et al., 2023). Based on the diffusion model, this study argues that driving factors including knowledge, attitudes, and social networks are behind the adoption of FLR practices. The economic constraints model highlights the influence of available resources on the adoption behavior of smallholder farmers. The economic constraints model considers how available resources influence the adoption behavior of smallholder farmers (Rogers et al., 2014). This model seeks to establish the relationship between resources availability and adoption behavior (Rogers et al., 2019). Hence this study suggests that these drivers – including, among others, financial capital, access to credit, land tenure, and infrastructure – play critical roles in determining whether farmers can adopt FLR practices. The user context model operates on the assumption that socio-economic, institutional, and agro-ecological conditions shape a farmer's decision to adopt FLR practices (Negatu and Parikh, 1999). This model acknowledges that external factors, like government policies, market access. or environmental conditions, also influence adoption decisions. As no single model or theory can fully analyze and explain the adoption process, this study integrates these three models, providing a comprehensive framework for analyzing FLR adoption. It considers multiple drivers, including socio-economic, environmental, institutional, and individual factors in shaping smallholder farmers' adoption of FLR practices.

To deepen the understanding of the drivers of adoption by smallholder farmers and to capture diversified aspects of FLR adequately, this study also considers the theory of planned behavior (TPB) by Ajzen (1991), which is an extension of the social-psychological theory of reasoned action (TRA) developed by Fishbein and Ajzen (1977). This theory, which is among the most relevant in adoption studies to understand farmers' behavior, Borges et al. (2015), state that attitudes toward behavior, subjective norms, and perceived behavioral control influence an individual's behavioral intention. Indeed, the manifestation of an intention through the implementation of the behavior results from the attitude toward the behavior, the subjective norms, and the perception of behavioral control (Ajzen, 1991). This study draws on these assumptions to explain the adoption of FLR by smallholder farmers in Tchamba Prefecture. This study assumes that individual and household, socio-economic, bio-geophysical, institutional, and perception drivers influence the adoption behavior of smallholder farmers. Appendix A lists all the drivers in the adoption model and a statistical summary.

2.1.3 Individual and household drivers

When evaluating the adoption of restoration or land management practices within forest landscapes, key explanatory drivers are age, gender of household head, education level, marital status, household size, and household income (Djenontin et al., 2018). Age shows mixed results as some studies report that younger farmers adopt agroforestry or land conservation practices more due to better access to information (Gebru et al., 2019), while others find older farmers more likely to adopt due to their experience (Adesina and Baidu-Forson, 1995; Bannister and Nair, 2003). Household head gender is another important factor, with male heads more likely to adopt agricultural technologies because of their greater access to resources and information (Dey, 1981; Sanou et al., 2019). Education positively impacts adoption, as it enhances farmers' capacity to adapt and innovate (Asfaw and Admassie, 2004; Feyisa, 2020). Marital status also influences adoption, with studies showing married farmers are more likely to adopt land management practices, possibly due to increased household stability and resource access (Kolapo et al., 2022; Oduniyi and Chagwiza, 2022). A positively significant relationship is found between household size and adoption of sustainable land management practices (Aminu et al., 2018; Kolapo et al., 2022; Sanou et al., 2019). Whether adoption of agroforestry or other sustainable land management practices, several studies show that smallholder farmers' income positively affects their adoption character (Adimassu et al., 2016; Moronge and Nyamweya, 2019). Similar influences of these variables are expected on the likelihood on FLR adoption.

2.1.4 Socio-economic drivers

Several socio-economic drivers can influence the adoption of FLR practices by smallholder farmers. These include access to credit and cooperative membership (Feyisa, 2020). Studies highlight that access to credit positively impacts the adoption of practices related to restoration and agricultural technologies (Beyene et al., 2019; Hagos and Zemedu, 2015; Tura et al., 2010), with a strong correlation between credit access and agroforestry adoption (Nicli et al., 2019; Rabe et al., 2021). Farmers accessing credit are more likely to adopt new technologies (Rabe et al., 2021). Jha et al. (2021) note that farmers who belong to a project, can rent land, and have a source of seedlings are subsequently more likely to adopt agroforestry. Synthesis work by Feyisa (2020) finds a significant positive association between access to credit, cooperative membership, and adaptation of agricultural technologies. Lambert and Ozioma (2012) show that a combination of income-generating activities significantly increases the likelihood of adoption on smallholder farms. Off-farm income is another significant factor, with positive effects on adoption (Biland et al., 2021; Coulibaly et al., 2017). However, off-farm income can draw attention away from farming activities, leading to a negative impact on agroforestry (Borges et al., 2015; Kassie et al., 2013; Obeng and Weber, 2014). Land ownership also plays a key role in adoption decisions, supporting long-term practices (Ahmad et al., 2023; Sebukyu and Mosango, 2012). However, in their study, Jha et al. (2021) find that land ownership, land conflicts, and property rights are not statistically significant for agroforestry practice. Based on these studies, similar influences of these drivers on the likelihood of FLR adoption are expected.

2.1.5 Biophysical and geographical drivers

Farm plot size shows a positive correlation with the adoption of restoration practices. According to the agroforestry study of Moronge and Nyamweya (2019), larger farms with more space are more likely to try and apply agroforestry. Thus, an increase in plot size increases the expected extent of land made available for restoration practices (Djenontin et al., 2022). These authors also highlight that when plots are considered to be severely degraded, the areas allocated for land restoration are more significant. The residential area's location is also a significant factor. Geographical location can influence the characteristics and practices of smallholders in terms of restoration, whether in agroforestry, natural assisted regeneration, or soil conservation practices (Djenontin et al., 2022).

2.1.6 Institutional drivers

An effective extension system is essential to disseminate information and promote the adoption of new agricultural technologies among smallholder farmers (Suvedi et al., 2017). Studies show how contact with support or coaching services offers farmers the opportunity to benefit from advantages such as access to information and advice regarding new agroforestry innovations and technology management (Adesina et al., 2000; Suvedi et al., 2017). Further analysis by Adesina et al. (2000) conclude that adopter access to extension services is positively related to adoption. However, Pender and Gebremedhin (2008) find that contact with an extension program is not as significantly related to input use or land management practices. Drawing on the potential source of extension services, whether from government or project partners Suvedi et al. (2017) and Bhatta et al. (2008) argue that the quality and delivery of extension services benefit positively from the presence of research and extension projects associated with development partners. Alternatively, supervisors or trainers from development project partners play more effective roles in informing, training, and supporting local farmers to adopt better restoration practices than agents from government support services (Chowa et al., 2013). However, contact with extension agents is expected to have a positive effect on adoption, as the availability of information stimulates adoption (Borges et al., 2015; Voh, 1982). Further, Suvedi et al. (2017) finds that frequent visits by extension agents can also increase farmers' participation in extension programs and pave the way for adoption. Indeed, the lack of information and the limited number of visits by these agents are underlying causes of the lack of effective extension services, which subsequently influences adoption decisions (Suvedi et al., 2017).

2.1.7 Perception attitudes and intentions of smallholder farmers

Understanding local stakeholders' perceptions and their connection to the landscape and its natural resources is an essential element for successful FLR restoration (Maioli et al., 2021). Few studies focus on farmers' decisions regarding tree planting and their perceptions influencing these decisions (Arnold and Dewees, 1998; Dove, 2003). Zubair and Garforth (2006) find that the perception of restoring or specifically planting trees positively affects the attitude of smallholder farmers when it generates socio-economic and ecological benefits for households. Coulibaly et al. (2017) show that the perception of land degradation encourages farmers to adopt fertilizer trees. Risk aversion also plays a significant role in adoption decisions (Canales et al., 2015). Knowledge is essential, as Rogers (2003) suggests that understanding FLR practices initiates the adoption process. Farmers' awareness of FLR benefits can directly influence their decision to adopt. Additionally, intrinsic motivation is key to sustained adoption and farmers should rely on their own intrinsic motivation to undertake efforts for implementing adoption practices (De Graaff et al., 2008). Further, appropriate motivational systems seem to stimulate farmers' willingness to invest in restoration practices (Djenontin et al., 2022). Thus, motivation remains a key driver in the successful restoration of degraded ecosystems.

2.2 Study area

This study took place in Tchamba prefecture, located in the central region of Togo (Figure 1). This region is located in the Central Plains ecological zone, characterized by a topography built on the crystalline granite-gneiss of the structural unit of the Benino-Togolese plain. With a red silty-clay texture and showing ferruginous concretions, this structural unit comprises metamorphic rocks and shallow tropical ferruginous soils (Adjonou et al., 2010). The climate in the region is Sudano-Guinean, with a rainy season from April to October and a dry season from November to April (Adjonou et al., 2010). Average annual rainfall ranges from 1,000 mm to more than 1,500 mm (Kissao et al., 2009), while the average annual temperature fluctuates between 20°C and 36°C (Sokemawu, 2015). Its varied mosaic comprises dry forests and open forests: its vegetation cover is characterized by patches of scattered semi-deciduous forests with forest galleries and Guinean savannahs featuring trees and shrubs. However, land use in the area is dominated by crops and fallow land (52.27%), open forests and wooded savannahs (19.32%), forest and agroforestry plantations (7.09%), and dense forests and gallery forests (13.70%) (Hounkpati et al., 2024). Ten cantons make up the prefecture, with a population estimated at 100,980 men and 99,605 women (INSEED, 2022). This mainly rural population has an estimated density of 49 people per km^2 (IWP/AFR100/GIZ, 2020). The most important socio-economic activities are agriculture and livestock farming. Agriculture is essentially focused on food crops, with a predominance of cereals (80%) over tubers and root crops (20%) (Hunyet, 2021). However, as Tchamba is facing much land degradation and forest loss relating to uncontrolled land use and illegal logging, FLR activities are being prioritized to counteract negative trends (Hounkpati et al., 2024; MERF, 2018). Although other prefectures in the region are affected by these problems (Kombate et al., 2020), Tchamba stands out because of the intensity of these activities, making it a critical site for FLR intervention. Given this, and to support the implementation of FLR approaches as part of Togo's commitment to the Bonn challenge, the prefecture of Tchamba was chosen. Five of the ten cantons (Affem-Boussou, Alibi 1, Bago, Goubi and Koussountou) have been selected by the global project on FLR implemented by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ Forests4Future, F4F), targeting community forests, participatory mapping, and a prefectorial assessment of the potential for wood and non-wood products. Based on this and under contract with GIZ-F4F-Togo the Deutsche Forst service GmbH (DFS) started its field activities in these areas since September 2020 in these five cantons that represent the F4F intervention zone (GIZ F4F), where the project aims to rebuild productive forests and landscapes while also improving forest governance (Hunyet, 2021) based on a system that includes a range of information and training programs, monitoring, and local extension services. The choice of these cantons draws on previous work undertaken by the REDD+ Readiness and Forest Rehabilitation Support Programm in Togo (ProREDD) and the International Forest Policy (Internationale Waldpolitik, IWP), which led to the management of 4 community forests with a multipurpose vocation covering a total forest area of 15,838 ha in the Alibi1, Bago, Goubi and Koussountou cantons (Hunyet, 2021). The five other cantons (Balanka, Kaboli, Kri-Kri, Larini, Tchamba,) represent the non F4F project zone.

2.3 Data collection

Using a pre-designed digital questionnaire integrated on tablets via KoboCollect application and administered offline, the household survey collected data in August and September 2021. Individual and household information was collected to identify those drivers underlying the adoption of FLR practices. Relevant socio-economic information that could affect household adoption was also collected. In addition, to collect information on the full range of determining drivers, information on biophysical and institutional details, on agricultural practices used to support landscape restoration, as well as on perception, attitude, and preferences for innovation were collected (Edwards-Jones, 2006; Kideghesho et al., 2007). Smallholder farmers from all ten cantons of Tchamba prefecture (five beneficiary cantons and five non-beneficiary cantons of the F4F FLR project) were the sampling frame. Based on a confidence level of 95% and a margin of error of 5% (Krejcie and Morgan, 1970), the sample size was estimated to be 494. The estimated sample was split by canton (Tchamba (116); Larini (27); Affem (23); Krikri (18); Alibi I (28) Koussountou (62); Balanka (30); Kaboli (82), Goubi (27), Bago (81)) and village according to demographic weight while respecting proportionality (Scheaffer

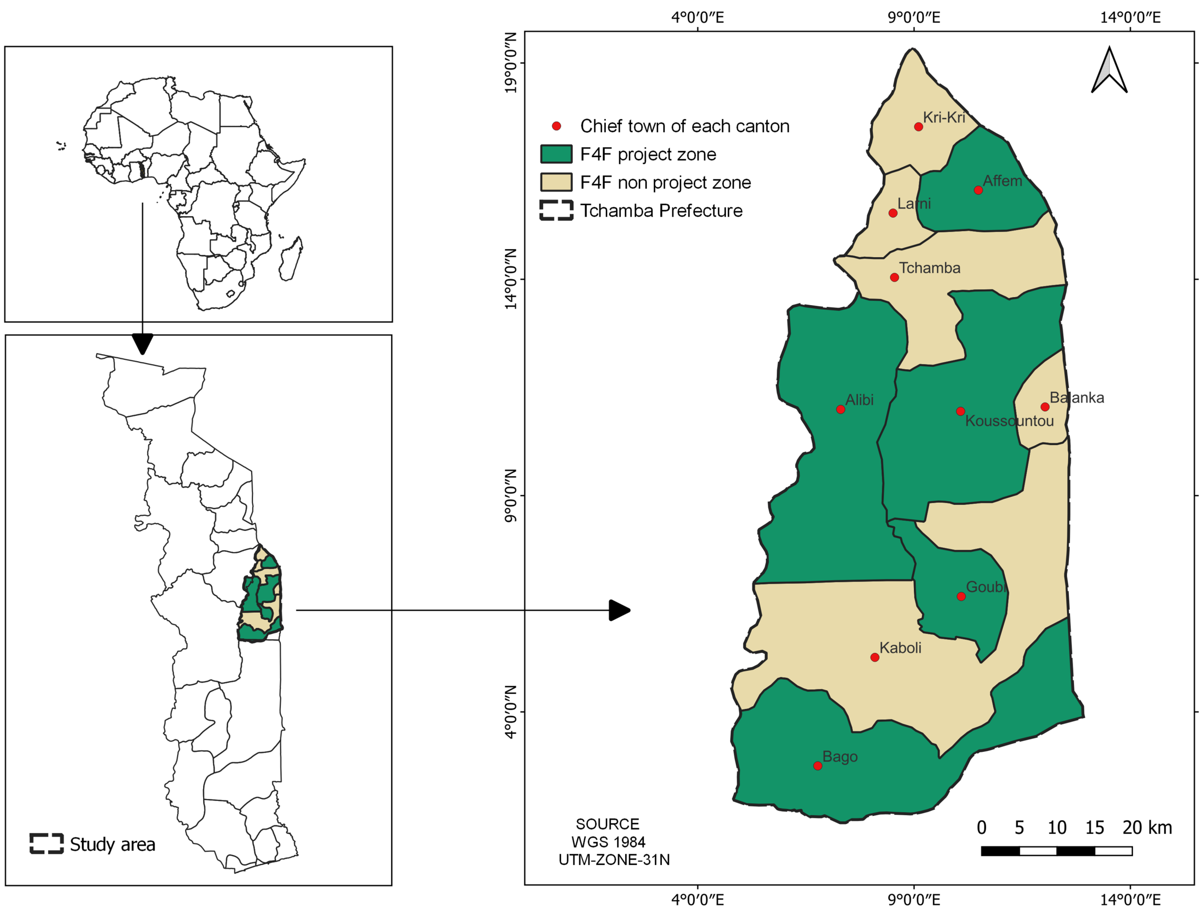

FIGURE 1
Location of the study area.

et al., 1990). While the ten villages surveyed were chosen based on whether or not they were involved in the F4F project, the households were selected at random within the villages from among smallholders during our survey.

2.4 Data analysis

2.4.1 Descriptive statistics

The first stage of the analyses assesses the socio-economic profiles and underlying characteristics of smallholder farmers in the prefecture using descriptive statistics. Frequency distributions and percentages are used for categorical drivers, while mean, minimum, maximum, and standard deviation are used for continuous drivers (Matavel et al., 2022). Welch's *t*-test is used to compare the averages of smallholder farmers in the project area to those in the non-project area due to the disparities in sample sizes (Sakai, 2016). Descriptive statistics were produced using STATA software.

2.4.2 Econometrics model

Econometric analysis was used to establish the influence of explanatory drivers on smallholder farmers' adoption of FLR practices. To enable insightful interpretation and practical use of the results, model selection and variable specification are fundamental elements of the adoption analysis process. For model selection and based on appropriate fit, the logit model was used as it considered one of the promising models currently available and well fit to a binary output (Hensher and Greene, 2003; Jha et al., 2021). The logit model generates a binary output of the dependent factor with the value 1 indicating whether adoption has occurred and 0 if adoption has not occurred (Shakya and Flinn, 1985). In this study the value 1 was assigned to smallholder farmers adopting FLR practices while the value 0 was assigned to non-adopters. In this scenario, where the dependent factor is binary, the logistic function is specifically suited to modelling and predicting the probability of belonging to a particular category. Using the forward and backward method, the independent drivers were added and removed sequentially to identify the significant drivers in the model. The logit model's independent variables and their potential impact on smallholder farmer households' adoption of FLR practices are summarized in Table 1. To ensure the validity of the results, correlation analysis and variance inflation factor (VIF) were performed to test whether or not there was multicollinearity. To assess the goodness of fit of the logistic regression model, the Hosmer-Lemeshow statistical test was used. Indeed, when the *p*-value of the test is less than 0.05, the model does not fit the data well. Further, to evaluate the performance of classification of the model, parameters such rate of correct classification and the area

TABLE 1 Summary of potential adoption drivers and expected outcome of FLR.

Type of variable	Symbol	Drivers	Description and drivers' measurement	Expected effect on adoption	References
Individual and Household	X1	Age	Age of the household head	Positive/Negative	Bannister and Nair (2003), Gebru et al. (2019), and Muneer (2008)
	X2	Gender	Gender of head of household	Positive	Dey (1981), Kolapo et al. (2022), and Sanou et al. (2019)
	X3	Education	Education level of head of household	Positive	Asfaw and Admassie (2004), Feyisa (2020), and Sanou et al. (2019)
	X4	Residence status	Residence status of head of household	Positive	Djenontin et al. (2022)
	X5	Marital status	Marital status of head of household	Positive	Babalola and Olayemi (2013), Kolapo et al. (2022), and Oduniyi and Chagwiza (2022)
	X6	Household size	Total number of people living in the household	Positive/ Negative	Aminu et al. (2018), Kolapo et al. (2022), Sanou et al. (2019), and Van Song et al. (2020)
	X7	Household income	Annual Income reported by head of household	Positive	Adimassu et al. (2016) and Moronge and Nyamweya (2019)
Socio-Economic	X8	Access to micro-credits	Accessibility to micro-finance credits	Positive	Beyene et al. (2019), Hagos and Zemedu (2015), and Rabe et al. (2021)
	X9	membership in social organization	membership of local cooperative or association	Positive	Feyisa (2020)
	X10	Involvement in a FLR project	household part of the local FLR project	Positive	Jha et al. (2021) and Parwada et al. (2010)
	X11	Income generating activities	Number of income-generating activities	Positive	Lambert and Ozioma (2012)
	X12	Access to off-farm income	Access to off-farm income	Positive/Negative	Coulibaly et al. (2017), Kassie et al. (2013), and Obeng and Weber (2014)
	X13	Land ownership	Land ownership by household head	Positive/Negative	Ahmad et al. (2023), Jha et al. (2021), and Sebukyu and Mosango (2012)
Biophysical	X14	Plot size	Plot size	Positive/Negative	Djenontin et al. (2022) and Moronge and Nyamweya (2019)
Geographical	X15	Adopter's living zone	Territory residence of household	Positive	Djenontin et al. (2022)
Institutional	X16	Access to extension services	Access to support and extension services for technician/animator	Positive	Adesina et al. (2000), Bhatta et al. (2008), and Suvedi et al. (2017)
	X17	Intervention frequency of farm technician/animator	Number of farm technician/animator training per month?	Positive	Suvedi et al. (2017)

(Continued)

10.3389/fsufs.2024.1425797

TABLE 1 (Continued)

Type of variable	Symbol	Drivers	Description and drivers' measurement	Expected effect on adoption	References
Perceptions attitude and intentions	X18	Perception of restoration practices	Perception of the benefits behind restoration practices (tree planting)	Positive	Maioli et al. (2021) and Yoder et al. (2019)
	X19	Perception of restoration need	Perception of restoration need (tree planting) due to land degradation	Positive	Arnold and Dewees (1998) and Dove (2003)
	X20	Attitude toward risk	Attitude toward risk of applying restoration innovations	Positive	Coulibaly et al. (2017), Messinger and Winterbottom (2016), and Zubair and Garforth (2006)
	X21	Awareness of restoration practices in the area	State of awareness of FLR practices in the area	Positive	Rogers et al. (2014) and Rogers (2003)
	X22	Motivation for maintaining restoration practices	Motivation to continue restoration practices without project support	Positive	De Graaff et al. (2008) and Djenontin et al. (2022)
	X23	Land allocation for FLR practices	Availability to allocate land for FLR practices by the head of households	Positive	Djenontin et al. (2022) and Moronge and Nyamweya (2019)
	X24	Perception of restoration practices in soil fertility	Perception of the importance of restoration practices in soil fertility	Positive	Abera and Belachew (2011) and Bezabih et al. (2016)
	X25	Perception of restoration practices in water quality	Perception of the importance of restoration practices in water quality	Positive	van Marwijk et al. (2012) and Wargyawati et al. (2024)
	X26	Perception of restoration practices to climate change	Perception of the importance of restoration practices to climate change	Positive	Jørgensen and Termansen (2016)
	X27	Perception of restoration practices in income	Perception of the importance of restoration practices in income	Positive	Djenontin et al. (2022, 2018)
	X28	Perception of restoration practices in food security	Perception of the importance of restoration practices in food security	Positive	Conde et al. (2022), Debray et al. (2019), and Galeana-Pizaña et al. (2021).

under the receiver operating characteristic (ROC) curve after the logit were performed.

Based on the adequacy of the study objectives and the type of analysis model, it is crucial to correctly specify the regression model. In this study, the probability of adoption or non-adoption of FLR practices by smallholder farmers is expressed by the following logit model equation:

$$Logit\left(Y\right)=\ln\left(\frac{p}{1-p}\right)=\beta_0+\beta_1X_1+\beta_2X_2+_{\dots}+\beta_kX_k$$

- Y represents adoption, i.e., the discrete dependent factor that indicates the smallholder farmer's decision whether or not to adopt the FLR practice, with 1 = adopter and 0 = non-adopter.
- p is the probability that the binary dependent factor is equal to 1. The equation can be rearranged to solve p, and have the functional of the logistic model (probability of success) as follows:

$$p=\frac{1}{1+e^{-\left(\beta_0+\beta_1X_1+\beta_2X_2+_{\dots}+\beta_kX_k\right)}}$$

- *ln* is the natural logarithm function;
- β_0 is the intercept;
- β_1, β_2, …, βk are the coefficients associated to the independent drivers X1, X2, …, Xk respectively; and
- X1, …, X28 = the independent drivers. The definitions and summary statistics for independent drivers (X1 to X28) are provided in Appendix A.

3 Results

3.1 Socio-economic characteristics of smallholder farmers

The results show that the average age of household heads in the prefecture is 42 years (Table 2). In the F4F-FLR intervention zone, 72.99% of households are headed by men; it is 85.60% in the non-intervention zone, a significant difference ($p < 0.001$). According to the results summarized in Table 2, educational status was 84.82% in the non-intervention zone and 74.26% in the intervention zone ($p < 0.001$). In contrast, the F4F-FLR intervention zone had more non-natives than the non- intervention zone ($p < 0.001$) i.e., 63% versus 35% (Appendix A). Most householders have a partner, and the average household size is 7 persons. In terms of access to credit, in F4F-FLR intervention zone, 14.34% of households have access to credit, while only 5.4% in the non- intervention zone ($p < 0.001$). With a statically significant difference ($p < 0.001$), more households (41.35%) are involved in FLR activities in the F4F-FLR intervention zone than households (7%) in the non-intervention zone. Moreover, although the average of the land ownership is low, at only 30% of households at the prefectural level, the land ownership of households in the F4F-FLR intervention zone (39.29%) is higher than land ownership in non-intervention zone (21.94%) ($p < 0.001$). However, there is no statistically significant difference between zones, in terms of number of activities generating income, marital status, membership in social organizations, and access to off-farm income (Table 2).

3.2 FLR practices and activities adopted by smallholder farmers

The results show an adoption rate of FLR practices of 43.62%. However, this adoption rate varies significantly between the intervention zone (61.18%), and the non-intervention zone (37.45%) ($p < 0.001$). Regarding adoption practices, the results show that agrarian land restoration practices are the most widely adopted, especially the improved fallow and crop rotation system, practiced by 33.40%, followed by agroforestry, practiced by 32.19% of smallholder farmers in the area (Figure 2). Among forest land restoration practices in the study area, reforestation is adopted at a rate of 13.36%, followed by the community forest creation at 8.7%, commercial forest plantation at 7.29%, and sacred forest enrichment at 2.83%. Water conservation and soils restoration practices, such as mulching (2.23%) and soil amendment (0.81%), are less widely adopted by smallholder farmers. FLR practice adoption rates in the intervention zone are significantly higher than in the non-intervention zone (Table 3) ($p < 0.001$). Respectively, the percentages are 42.19% against 29.29% for the improved fallow and crop rotation system, 45.14% against 20.23% for agroforestry, 24.05% against 3.5% for reforestation, 12.65% against 5.05% for community forest creation, and 4.21% against 0.38% for mulching system. Notably, agroforestry is the most widely adopted practice in both zones. However, the results show no significant difference in the adoption of practices such as commercial forest plantation, sacred forest enrichment, and soil amendment systems between both zones (Table 3).

3.3 Potential drivers affecting FLR adoption

The econometric results reported in Table 4 attest the relevance and goodness of fit of the logit model used to determine the influence of explanatory drivers on the adoption of FLR practices by smallholder farmers. As confirmation, the p-value from the Hosmer-Lemeshow test is 0.7769, significantly higher than 0.05. This result implies the good fit of the model to the data. Furthermore, the results indicate a good rate of correct classification of the model (78.34%). Furthermore, the ROC curve after logit is 0.8755. This value, between 0.8 and 0.9, also indicates a good classification of the model in the context of this study.

Correlation matrix values among the independent variables ranged from −0.70 to 0.65. Typically, correlation coefficients greater than 0.8 or less than −0.8 are considered indicative of potential multicollinearity; unlike in our study (Supplementary material S1). Values of the VIF obtained were between 1.06 and 2.06, indicating that the variance of the regression coefficients was not significantly increased as a result of the multicollinearity (Supplementary material S1). As these values are less than 5, it does not indicate a correlation of concern. In addition, the values for tolerance (the inverse of VIF), ranging from 0.42 to 0.93, are relatively high and greater than 0.1 (Supplementary material S1). This confirms the idea that there is no problematic multicollinearity among the 28 variables in our model.

TABLE 2 Socioeconomic characteristics of smallholders' farmers.

Drivers	Prefecture level (*n* = 494)		FLR intervention zone (*n* = 237)		FLR non-intervention zone (*n* = 257)		Significance	
	Average	SD	Average	SD	Average	SD	*p* (|T| > t|)	
Age	41.85	0.57	41.025	12.97	42.626	12.41	0.1617	
Gender	0.79	0.01	0.7299	0.44	0.8560	0.35	0.0005	***
Education	0.79	0.01	0.7426	0.43	0.8482	0.35	0.0035	***
Residence status	1.64	0.02	1.7130	0.45	1.5875	0.51	0.0044	***
Household size	6.94	0.22	6.4767	3.79	7.3813	5.76	0.0417	**
Access to micro-credits	0.09	0.01	0.1434	0.35	0.0544	0.22	0.0008	***
Involvement in a FLR project	0.23	0.01	0.4135	0.049	0.0700	0.25	0.0001	***
Income generating activities	1.33	0.06	1.3755	1.45	1.2957	1.33	0.5259	
Land ownership	0.30	0.02	0.2194	0.41	0.3929	0.48	0.0001	***
Marital status	0.88	0.01	0.89	0.31	0.87	0.33	0.6103	
Membership in social organization	0.43	0.02	0.44	0.49	0.42	0.49	0.5457	
Access to off-farm income	0.9	0.01	0.91	0.27	0.89	0.3	0.3426	

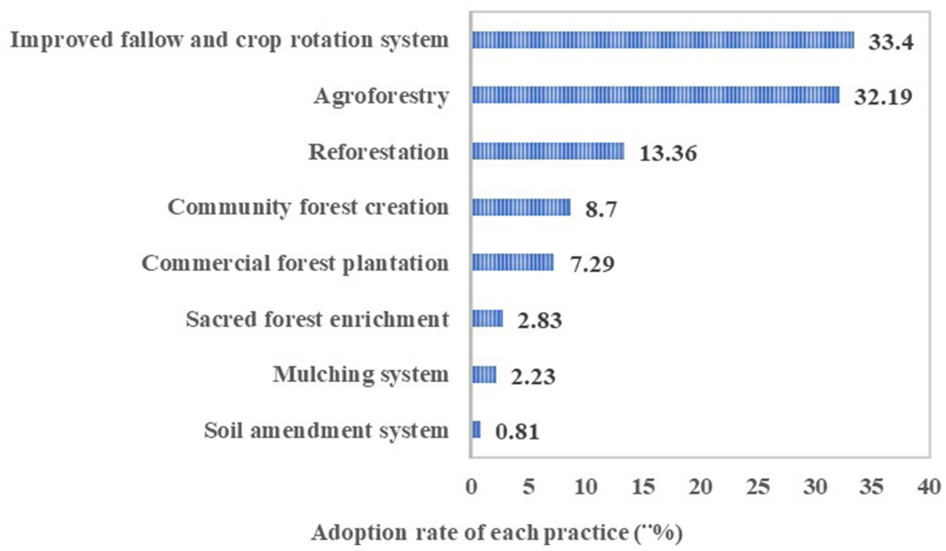

FIGURE 2
FLR practices adoption rates in the Tchamba prefecture.

Among the 28 explanatory drivers examined in this study, ten significantly explain the adoption of FLR practices by smallholder farmers in Tchamba prefecture (Table 4). No individual and household drivers are found among the explanatory drivers. The explanatory drivers include socio-economic drivers, such as membership in social organizations, involvement in a FLR projects, and land ownership. The results also highlight the importance of biophysical and geographical drivers, including plot size and adoption zone, as well as institutional drivers, such as access to extension services, in explaining the adoption of FLR practices in the prefecture. The drivers of perceptions, attitudes, and intentions – especially the perception of restoration practices, the perception of restoration need, the motivation for maintaining restoration practices, and the perception of restoration practices in food security – are also part of this wide range of explanatory drivers. The significance of all these drivers is presented in Table 4.

Regarding socio-economic drivers, the results of this study show that membership in social organizations ($p < 0.001$) and involvement in a FLR project ($p < 0.001$) are significantly and positively correlated with the adoption of FLR practices by smallholder farmers. These results suggest that smallholder farmers who are members of social organizations and involved in restoration activities have greater access to information, training, and various resources related to FLR practices and are more likely to adopt

TABLE 3 FLR practices adopted by smallholders.

FLR practices	F4F-FLR intervention zone (n = 237)		Non F4F-FLR intervention zone (n = 257)		Significance	
	Average	SD	Average	SD	p (|T| > |t|)	
Improved fallow and crop rotation system	0.4219	0.49	0.2529	0.43	0.0001	***
Agroforestry	0.4514	0.49	0.2023	0.40	0.0000	***
Reforestation	0.2405	0.42	0.0350	0.18	0.0000	***
Community forest creation	0.1265	0.33	0.0505	0.21	0.0027	***
Commercial forest plantation	0.0632	0.24	0.0817	0.27	0.4324	
Sacred forest enrichment	0.0253	0.15	0.0311	0.17	0.6981	
Mulching system	0.0421	0.20	0.0038	0.06	0.0039	***
Soil amendment system	0.0168	0.12	0.00	0.00	0.0366	

*** Significant at $p < 0.01$ (99%); ** Significant at $p < 0.05$ (95%); * Significant at $p < 0.1$ (90%) level.

them. The involvement of smallholders in the FLR project makes them more aware of the importance and effectiveness of the practices, thus making them more willing to adopt these practices. In addition, land ownership by smallholder farmers had a significantly ($p < 0.001$) positive influence on the adoption of FLR practices (Table 4).

In the case of biophysical and geographical drivers, the results reveal a positive and significant correlation between the adoption of FLR practices and two specific drivers: the plot size ($p < 0.05$) and the adopter's living zone ($p < 0.01$). Among these two drivers, the significance is more evident for the adopter's living zone (threshold of 0.01) than for the plot size (threshold of 0.05).

At the institutional level, only access to the extension service positively explains ($p < 0.01$) the adoption of FLR practices by smallholder famers (Table 4). This suggests that the services of local technicians or facilitators create favorable conditions that encourage smallholder farmers to implement FLR practices.

In terms of perceptions, attitudes and intentions, the analyses show that the adoption of FRL practices by smallholder farmers is significantly, but negatively, influenced by their perception of restoration practices ($p < 0.05$) and by their motivation for maintaining restoration practices ($p < 0.001$). The analysis of the coefficients (β_0) associated to these drivers indicates that the decision to adopt FLR practices by smallholder farmers decreases by 0.36 when their perception of the restoration practice increases by 1 and, secondly, this decision decreases by 3.77 when their motivation to maintain restoration practices increases by 1. However, perception of restoration needs ($p < 0.05$) and perception of restoration practices in food security ($p < 0.01$) have a significant and positive effect on the adoption of FLR practices in the area (Table 4).

4 Discussion

This study analyses the profile of smallholder farmers, assessing the level of adoption of forest landscape restoration practices and identifying the main drivers of successful adoption of FLR practices by smallholder farmers in Tchamba prefecture. This approach is essential as it enables understanding of the specific motivations, needs, and constraints of smallholder farmers. In this way, it is possible to design effective interventions adapted to local realities, thus avoiding failure in the participatory FLR process; these typically arise due to the non-involvement of the local community (Höhl et al., 2020).

The findings show an average rate of FLR practice adoption of 43.62% in the study area, although men dominate household management. The smallholder farmers most engaged are mainly non-natives who do not have, unfortunately, land ownership rights (Appendix A). This situation, combined with the low rate of household access to agricultural credit in the prefecture, could probably explain this moderate level of FLR practice adoption. A study on the adoption of Good Agricultural Practices (GAP) in Indonesia confirms that access to credit can hinder the full adoption of these practices (Royan, 2023).

Regarding FLR practices, it is observed that agricultural land restoration practices, such as improved fallow and crop rotation systems and agroforestry, are the most widely adopted. These practices are acknowledged for improving soil fertility and agricultural productivity while contributing to ecological restoration (De Pinto et al., 2020; van Noordwijk et al., 2022). In the context of FLR, the improved fallow system, improved by crop rotation, is notably the most appropriate to implement on intermittently managed land, while agroforestry is more suitable for permanently managed land, according to IUCN and WRI (2014). The improved fallow land practice, except that it implies direct intervention by the farmers, is similar to the natural managed regeneration practice, which aims to produce food, conserve soil, and safeguard biodiversity (Haglund et al., 2011). This practice is essential to forest and landscape restoration when applied in appropriate areas (Chazdon and Laestadius, 2016). Indeed, the fallow period produce various non-timber forest products (Wangpakapattanawong et al., 2010). It promotes biodiversity conservation and could be a sustainable system if the fallow period is sufficiently long (Rerkasem et al., 2009; Sahoo et al., 2020). Thus, this practice, although it does not really focus on tree planting, is part of conservation agriculture and could contribute to a resilient landscape and meet FLR objectives, which according to Maginnis and Jackson (2006) is not necessarily to restore the original landscape, but to improve its productive functions to support communities that depend on it. However, it would be wise to use this practice to reverse degradation trends and establish transformative restoration systems that supplement conservation and sustainable production approaches (Brancalion et al., 2019; Chazdon and Brancalion, 2019). Since there are no silver bullets in FLR (Mansourian

TABLE 4 Results of the logit model for the adoption of FLR practices Tchamba prefecture.

Drivers	Coefficient	*p*-value	Significance
Socio-Economic			
membership in social organization	0.998	0.000	***
Involvement in a FLR project	2.143	0.000	***
Land ownership	1.088	0.000	***
Biophysical and geographical			
Plot size	0.123	0.012	**
Adopter's living zone	0.747	0.006	***
Institutional			
Access to extension services	0.823	0.008	***
Perceptions, attitudes, and intentions			
Perception of restoration practices	−0.366	0.050	**
Perception of restoration need	0.903	0.047	**
Motivation for maintaining restoration practices	−3.777	0.000	***
Perception of restoration practices in food security	0.527	0.002	***
Hosmer and Lemeshow test	0.7769		
Pseudo R-squared	0.3543		
Prediction statistics (correctly classified)	78.34%		
ROC curve after logit	0.8755		
Number of observations used in the model	494		

Only significant variables are shown. *** Significant at $p < 0.01$ (99%); ** Significant at $p < 0.05$ (95%); * Significant at $p < 0.1$ (90%) level.

et al., 2005) and as FLR practices need to be suited to the socio-ecological conditions of local communities, improved fallows and crop rotations must be an important component of FLR, in the same way as natural assisted regeneration (Chazdon and Laestadius, 2016). The results also show that agroforestry is the second most widely adopted practice. This practice, which provides permanent tree cover (Sahoo et al., 2020) in agricultural farming, is increasingly being adopted by smallholders in the prefecture, especially cashew-based agroforestry. In the prefecture, several incentives are promoting this multi-purpose practice, including improving food security, enhancing the resilience of farming systems, increasing carbon sequestration, and combating climate change (Aertsens et al., 2013; Musa et al., 2018; Sahoo et al., 2020). The presence of the cashew fruit and nut processing company (Cajou Espoir) in the area promotes local access to outlets and contributes significantly to the mobilization of cooperatives and associations around cashew planting and production in particular. Tebonou et al. (2014) show that significant income is generated by this activity in the region. With a minimum wage of around 384,000 in Togo, the average economic return of 417,000 CFA francs per hectare per year confirms the fact that agroforestry is an approach that will likely generate benefits for humans (César et al., 2021). In addition, restoration projects in the zone, particularly F4F, are promoting cashew nut-based agroforestry practices and other value chain species such as shea (*Vitellaria paradoxa*) and African locust (*Parkia biglobosa*). Consequently, these types of agroforestry based on fruit and fertilizer species are potential ways of contributing to the restoration of forest landscapes (Sahoo et al., 2020).

Although practices adopted in the area are more inclined to agroecological restoration, reforestation (13.36%), community forest creation (8.7%), and commercial forest plantation (7.29%) should not be neglected among the practices adopted by small farmers. However, their level of adoption remains relatively low. In the prefecture, reforestation usually consists of planting monospecific trees (Teack, Gmelina, for example), which generally aim to secure land tenure and whose benefits are more profitable for companies in the case of commercial forest plantations. According to Andersson et al. (2016) and Lindenmayer et al. (2012), these practices often have limited potential to contribute to the overall objectives of FLR as they focus more on a single environmental value, thus negatively affecting the key ecosystem functions of the landscape. Nevertheless, community forest creation practice, although not really adopted at the individual level by smallholder farmers, is growing in the Tchamba prefecture. Unlike reforestation or commercial forest plantations, this practice integrates and improves the social, economic, and environmental aspects of forest management and should be seen as a powerful tool in FLR (Baynes et al., 2015; Chhetri et al., 2013). It is one of the FLR initiatives involving community groups or groups of smallholders (Ota et al., 2020). In Tchamba, its emergence is largely due to the cultural importance that local people attach to this essentially inclusive and participatory approach with regard to forest governance. As well as being a key practice for FLR, the practice of community forest creation represents not just a cultural and natural heritage but also a place of communion for the local people (Hounkpati et al., 2022). Beyond this identity dimension, Baynes et al. (2015) identify key drivers underlying the success of community forestry practices like governance, benefits, socio-economic and gender equity, property rights, and public support. These drivers are in line with the principles of FLR (Besseau et al., 2018), hence the need to promote community forest creation practices in the Tchamba prefecture. Although non-tree technologies are also essential for restoring agrarian landscapes, the mulching system (2.23%) and the soil amendment system (0.81%) are essentially not adopted by smallholders in the Tchamba prefecture.

While the literature highlights the importance of individual and household drivers in the adoption of restorative practices, this study finds that none of the seven individual or household drivers considered are significant. The socio-economic characteristics of smallholder farmers could influence the individual and household drivers, making them less relevant or significant. While studying drivers of agroforestry adoption by smallholder farmers in Tanzania, Jha et al. (2021) find similar results. In contrast, Djenontin et al. (2022) highlight that gender and age are drivers favoring restoration practices at the individual level. The results show that households headed by men dominate land restoration and the underlying decisions about land management practices. At the same time, older smallholders are more likely to invest in farmland restoration, while younger people face potential barriers to engaging in restoration practices. All these works underline the importance of taking into account the full range of drivers encompassing the several dimensions and characteristics of smallholder farmers (Edwards-Jones, 2006; Kideghesho et al., 2007).

Socio-economic drivers – namely membership in a social organization, involvement in a FLR project, and land ownership – are drivers that positively support the adoption of FLR practices by smallholder farmers. Membership in a social organization as well as involvement in a FLR project suggest that smallholder farmers have multifaceted support ranging from information, training, financial, and technical resources on FLR practices. For example, due to the individual criteria that limit access to agricultural credit in Togo and the need to mobilize prior savings representing a third of the amount of the credit, membership in a social organization or financial solidarity group remains a key element in access to credit (Julien et al., 2021; Sossou et al., 2017). Thus, credit is granted by microfinance institutions to small groups of 4 to 6 people who make a joint commitment, based on trust, mutual knowledge, and repayment of the credit by the whole group (Julien et al., 2021). In Malawi, it has been shown that the development of social groups and membership of economic cooperatives helps farmers to adopt practices such as agroforestry, managed natural regeneration, and manure spreading, while at the same time strengthening their ability to obtain the resources needed for FLR (Djenontin et al., 2022). In addition, in the study area and especially in the F4F project area, a financial incentive mechanism rewards the best farmers for engaging in FLR based on the results obtained. These measures create a virtuous circle where commitment to FLR is reinforced by the benefits and resources offered by this project. The driving force behind land ownership in this study is that it offers a range of benefits that encourage landowners to adopt FLR practices. For example, agroforestry practices could increase the value of land ownership by improving land productivity, while reforestation or commercial forest plantations could provide security of tenure; both of these represent a long-term investment. Indeed, given that land rights and tenure security affect how the costs and benefits of FLR are distributed, these play a crucial role in encouraging landowners and land users to invest in FLR practices (McLain et al., 2021; Robinson et al., 2018). In the context of this study, land tenure is based on customary law, which determines whether land is used collectively or individually. Nevertheless, this situation is more favorable to community restoration practices, as reflected in the growth of community forest initiatives in every canton of the prefecture. In contrast to individual practice, native landowners who are less active in individual restoration activities lease these lands to active non-natives, while prohibiting them from planting perennial trees, which is considered as authority rights and management rights (Sikor et al., 2017). To resolve this issue, initiatives such as memorandums of understanding drafted and signed by stakeholders and local authorities allow non-natives to establish agroforestry plantations on leased land while recognizing the land ownership rights of natives. Membership in a social organization or financial group helps smallholders access credit, enabling them to adopt FLR practices. F4F's financial incentives, where the best farmers are rewarded for engaging in FLR, also promote these practices. The economic constraints model emphasizes the importance of the resources available to farmers, which directly influences their behavior in adopting new practices (Rogers et al., 2019). Indeed, our study shows that factors such as financial resources, access to credit and economic incentives, as well as land ownership, play a crucial role in farmers' ability to integrate these new practices. These results, which are similar to those of Jha et al. (2021, 2019), confirm that the adoption of new technologies or methods is often conditioned by the availability of economic resources.

The plot size, adopter's living zone (biophysical and geographical drivers) and access to the extension service (institutional driver) create favorable conditions that encourage smallholders to implement FLR practices. The study shows that the average size of smallholder farms, of which 63% are non-native, is 3.45 ha. This emphasizes that the real holders of large estates in the area are not really included in the FLR practice in the area. Yet farmers with larger plots can devote more of their land to tree planting without compromising the amount of land needed for short-term crops (Frayer et al., 2014; Schuren and Snelder, 2008). However, Djenontin et al. (2022) show that the spatial fragmentation of land seems to hamper restoration efforts. Large plots of land appear to be more suitable to agroforestry practices or commercial forest plantations. Therefore, it is essential to consolidate land ownership in order to encourage practices based on tree plantations more specifically. This is clearly demonstrated by a positive correlation between plot size and the area restored by agroforestry in many other countries, such as Malawi and Kenya (Djenontin et al., 2022; Moronge and Nyamweya, 2019). On the other hand, it appears that land restoration practices based on manure or compost are difficult to apply to large landholdings (Nyanga et al., 2016). This highlights the specific and contextual aspects of FLR. The study also reveals that smallholder farmers living in the area where FLR practices are carried out are directly impacted by the benefits of these initiatives. In the study area, the F4F project, whose aim is to contribute to wooded and fertile landscapes while increasing the incomes of those who manage these landscapes, is being implemented in five of the 10 cantons of the prefecture – this is known as the FLR project area. Thus, the FLR practices identified in this study are more widely adopted in the project area than in the non-project area. The exposure to successful models, access to resources, training, knowledge, support, and/or incentives may justify this situation. These findings are in line with those of Djenontin et al. (2022), who established that geographical location influences the characteristics and practices of smallholders regarding FLR. In terms of resources, the study highlights the positive impact of access to extension services for smallholders in the area. This suggests that access to extension services by smallholder farmers is critical for adoption, as these services offer farmers the opportunity to access information and advice on new agroforestry innovations and technology management (Adesina et al., 2000; Suvedi et al., 2017). Unlike the public extension service, the F4F project has set up a group of trained extension agents known as "encadrants" or "animateurs." The distinctive feature of this extension service, which makes it efficient, is that these agents are drawn from the local population, live in the region, and are available at any time. This system is beneficial to smallholder farmers in the area, aligning with the findings of Suvedi et al. (2017) who argue that an effective extension system is essential to disseminate information and encourage adoption of new agricultural technologies among smallholder farming communities. The positive impact of access to extension services, in particular the role of communication channels in the diffusion of new technologies, and the fact that extension agents are drawn from the local population and available at any time, suggest that the community's social system is a critical component in the diffusion process. These features are key drivers of innovation diffusion model. Thus, considering the main assumption underlying the model of innovation diffusion according to which adoption is determined by the factors that affect the diffusion of information to the adopter (Dissanayake et al., 2022), our previous results support and confirm the theory of innovation diffusion.

Contrary to the hypothesis that a positive perception of FLR through tree planting could encourage its adoption (Zubair and Garforth, 2006), the results of this study reveal a negative correlation. The low rate of reforestation or commercial forest planting, the strong competition from agroforestry practices in the region, the high proportion of non-natives who mainly rent land from natives among the respondents, land-use conflicts, and long-term investments are all reasons that may explain this negative perception of restoration through tree planting. Being a multifaceted process adapted to local contexts, FLR could explain these results. Thus, to avoid a total conversion of the area into an agroforestry landscape and to secure the delicate and complex balance between the social, economic, and ecological aspects of the area, it is crucial to explain the concrete benefits of tree planting activities to the local community as well as to landowners and land users. Indeed, if local communities do not perceive tangible benefits, they may be less inclined to engage in these activities (Höhl et al., 2020). Similarly, it appears that the motivation to maintain restoration practices negatively affects the sustainability of FLR practices in the prefecture. This result contradicts the findings of De Graaff et al. (2008) and (Djenontin et al., 2022), who show that motivation plays a crucial role in the adoption of FLR practices, since it is a driver that positively and continuously influences these practices. However, the negative correlation between, for example, perceptions of tree planting and the adoption of FLR practices does not seem to align with the idea that intention leads to behavior. This suggests that positive attitudes alone may not be enough if perceived control or external constraints (land conflicts) are significant external factors. The perception of the need for FLR and its relevance to food security significantly affects whether smallholder farmers actually adopt FLR practices. In the prefecture, most smallholder farmers are often dependent on natural resources for their livelihoods. In addition, the perceived benefits of FLR practices, among which agroecological practices are the most adopted according to the respondents, could also explain these results. Studies conducted in Guatemala (Calderón et al., 2018), Peru (Conde et al., 2022), Mexico (Galeana-Pizaña et al., 2021) and sub-Saharan Africa (Debray et al., 2019) confirm that agroecological practices within agroforestry systems improve food security and the living conditions of smallholder farmers. The fact smallholder farmers perceive FLR as beneficial, especially in terms of food security, aligns with the attitudinal component of TPB and indicates that positive attitudes can foster intention and subsequent behavior, supporting TPB (Negatu and Parikh, 1999). In Malawi, Meijer et al. (2015) shows similar results among farmers, where attitudes toward tree planting are mainly positive, encouraging tree planting behavior. The mix of support and refutation in our study indicates that while the TPB can explain certain aspects of farmers' decisions, a complexity of factors challenges the assumption that intention always leads to behavior. This contrasting result is related to the belief that the prediction of intention varies across behaviours, situations and cultures (Ajzen, 1991). However, the positive impact of both perception of restoration needs and perception of restoration practices on food security are in line with those of Martínez-García et al. (2013) who find that the adoption of improved grassland management practices by farmers in Mexico is influenced by their perception of the practice. Similar to other studies using attitude or subjective norms to explain the adoption decision (Buyinza et al., 2020; Sok et al., 2021), we find that the previous perceptions are significant, confirming the TBP theory. Also, considering all the results, it is clear that smallholder farmers involved in cooperatives and restoration activities are more aware of the importance of these practices and more willing to adopt them. Furthermore, factors such as the agro-ecological context, exposure to innovations in FLR project areas, land ownership, assistance from local technicians or facilitators, and the positive perception of farmers toward FLR practices confirm the validity of the user context model. Indeed, the end-user context model, also known as the adoption perception model (Negatu and Parikh, 1999), assumes that characterization of the agro-ecological, socio-economic and institutional contexts of potential users is a useful factor in determining the decision to adopt a technology.

Although the results discussed in this study are relevant, it is crucial to recognize some limitations. Despite a representative sample of 494 small holders, most are non-native. This could reduce the generalizability of the results to the whole population, as non-native smallholders may not capture the local and context-specific dynamics crucial for understanding the adoption of specific FLR practices. Thus, random sampling does not allow us to take into account a significant number of native landowners in the prefecture. Considering that non-natives can have different knowledge, practices and perceptions of FLR than natives, a more exhaustive stratification of the sample would be necessary for a holistic analysis. Additionally, given the dynamic character of the dimensions and drivers used in this study, it is likely that other drivers not taken into account, such as climate drivers, could play a significant role in the adoption of FLR. Therefore, it is recommended to monitor these drivers over a longer timeframe in order to assess the long-term effectiveness of both identified and unidentified drivers. We assume our results to be also applicable to other rural areas with similar site conditions defined by mixed landscapes. However, in the region with drier climates and more extensive savannah ecosystems, and in the southern regions with more forest cover and higher rainfall, the adoption of FLR practices could be influenced differently. Thus, socio-economic, environmental and human factors may lead to particular FLR techniques being adopted more or less frequently in these regions.

5 Conclusion

In a growing dynamic of restoring ecological functionality and improving human well-being, FLR has proven to be an increasingly indispensable process. To highlight the drivers of FLR in Togo, this study presents a model for the adoption of FLR practices based on data collected from 494 smallholder farmers in Tchamba prefecture. The socio-economic profile of smallholder farmers, the FLR practices adopted were outlined, and the significant drivers were discussed. The system of improved fallow and crop rotation, agroforestry, reforestation, community forest creation, and commercial forest planting are the most widely adopted FLR practices among the respondents. However, the trend in practices adopted in the study area is more toward agro-ecological restoration. The study also shows an average adoption rate (43.62%) for these practices and calls for the strengthening of mechanisms that promote these practices among smallholders in the area. Due to the multifaceted aspect of FLR, a series of drivers including individual and household, socio-economic, biophysical, geographical, institutional, perception, and intention dimensions were used in the logical regression model. The results show that smallholder farmers who are members of social organization and involved in restoration activities have a higher awareness of the importance of restoration and willingness to adopt practices. Similar observations are made for farmers living in a zone with close FLR contact increasing smallholder farmers' adoption. Property rights due to the land ownership and plot sizes also support the adoption of FLR practices. In addition, the services of local technicians or facilitators create favorable conditions that encourage smallholders to implement FLR practices. Perception of restoration practices and need, motivation for maintaining restoration practices, and relevance for food security significantly affect whether smallholder farmers adopt FLR practices. These results suggest that stakeholders should consider the multi-faceted aspects of FLR practices to increase agroforestry practice through training and access to seedlings, support reforestation and community forest creation by incentivizing smallholder participation through subsidies or technical assistance, clarifying and strengthening smallholders' land rights, and deploying more local technicians for long-term benefits of smallholder's farmers in Togo.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author Katharina.Loehr@zalf.de.

Author contributions

KH: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Software, Validation, Visualization, Writing – original draft, Writing – review & editing. HM: Validation, Visualization, Writing – review & editing. KA: Supervision, Validation, Visualization, Writing – review & editing. KK: Supervision, Validation, Visualization, Writing – review & editing. SS: Funding acquisition, Resources, Supervision, Validation, Visualization, Writing – review & editing. KL: Funding acquisition, Resources, Supervision, Validation, Visualization, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fsufs.2024.1425797/full#supplementary-material

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