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EVALUATION OF THE ECOLOGICAL AND SOCIO-ECONOMIC IMPACTS OF AGROFORESTRY INTERVENTIONS ON SMALLHOLDER FARMS ADJACENT TO THE IBANDA-MAKERA NATURAL FORESTRY, KIREHE DISTRICT, RWANDA

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A thesis submitted in partial fulfillment of the requirements for the degree of Master in Biodiversity Conservation and Natural Resources Management

By

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Kigali, July 2024

DECLARATION

I declare and affirm that this thesis is the result of my own work carried out under the School of Sciences, College of Science and Technology, University of Rwanda for the Master of Science in Biodiversity Conservation and Natural Resources Management program. I declare that this thesis contains my findings and has not been submitted to any other institution anywhere for the award of any academic degree, diploma, or certificate. No portion of my dissertation has been copyrighted previously unless properly referenced.

Signature…… Date……

Marie Claire Twiragijimana

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APPROVAL

I certify that this research project entitled " **Evaluation of the ecological and socio-economic impacts of agroforestry interventions on smallholder farms adjacent to the Ibanda-Makera Natural Forestry, Kirehe District, Rwanda"** was done under my supervision and has been submitted for examination with my approval.

Prof Beth A. Kaplin (PhD)

Supervisor

On 10/10/2024

CERTIFICATION

It is hereby to confirm that this thesis entitled “Evaluation of the ecological and socio-economic impacts of agroforestry interventions on smallholder farms adjacent to the Ibanda-Makera Natural Forestry, Kirehe District, Rwanda submitted by Marie Claire Twiragijimana has been provided a certification from the School of Sciences.

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DEDICATION

I dedicate this dissertation to the almighty God for blessings, gifts of life, and strength in accomplishing this study. I have a special dedication to my supervisors for their guidance, patience, and belief in my abilities, I am dedicated to my husband and my family for their endless love, understanding, and unfailing support by having my background throughout this study.

Finally, I dedicate this thesis to my dear classmates and workmates who have shared their professional adventures with me. Their support, insightful discussions, and shared commitment to excellence have been invaluable throughout this journey. Thank you all for your encouragement and friendship.

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ABBREVIATIONS AND ACRONYMS

EbA	Ecosystem-based Adaptation
ES	Ecosystem Services
EPCOTGE	Environmental Protection Construction and General Service
REMA	Rwanda Environment Management Authority
GIS	Geographic Information System
GPS	Global Positioning System
LDCF II	Least Developed Countries Fund II
NAP	National Adaptation Planning
CoEB	Center of Excellence in Biodiversity Conservation and Natural Resources Management
GHG	Green House Gas
WRM	Water Resources Management

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ABSTRACT

Climate change disrupts ecosystem services and livelihoods for smallholder farmers, especially those adjacent to the Ibanda-Makera Natural Forest in Rwanda. This study assesses the ecological and socio-economic impacts of agroforestry interventions in this area. Ecosystem-based Adaptation (EbA) involves strategies that mitigate and adapt to climate change, enhancing resilience in vulnerable communities. This research focuses on evaluating the effectiveness of EbA intervention measures near Ibanda-Makera Natural Forest, Rwanda, which has been identified as climate-sensitive. The study examines how agroforestry practices enhance ecological conditions such as soil conservation, biodiversity conservation, and microclimate regulation critical for delivering ecosystem services (ES) that support climate resilience. Primary data were collected using structured interviews with closed and open-ended questions and Geospatial data from surveyed smallholder farms were collected using GPS devices. Results indicate successful growth of agroforestry trees, predominantly Grevillea robusta (46.42%), providing ES like firewood production (97%), soil erosion control (95%), stabilization (93%), climate regulation (88%), and aesthetic/recreational benefits (42%) to local communities. Socio-economic benefits include income generation, food security, and increased farm productivity, promoting adaptation among neighboring communities. The implemented EbA approach effectively controlled soil erosion (76%) through water canals, trenches, and terraces. The majority (98%) of respondents indicated that the primary beneficiaries of EbA intervention measures were local communities. However, 20% expressed dissatisfaction with the intervention's impact on livelihoods. Further research should raise awareness about EbA benefits and integrate local communities into implementation strategies, fostering climate resilience among Rwanda's smallholder farmers.

Key Word: *climate change, Ecosystem-based Adaptation, ecological impact, socio-economic impact, agroforestry trees and smallholder farm*

1. INTRODUCTION

1.1. Background

Forests are essential for global biodiversity, the functioning of the biosphere, and the livelihoods of millions of people worldwide. Forests occupy over 30% of the land area in the world, with only a third of the remaining relatively unaffected by anthropogenic activities (Jensen et al., 2021)**.** Agroforestry tree species serve a variety of social, economic, and ecological roles, including soil erosion control, carbon dioxide sinks, water conservation, improved climate conditions, and ecological resilience. The benefits of agroforestry systems are becoming more widely recognized on farms and landscape areas. Agroforestry systems incorporate trees into farms and have the potential to increase smallholders' resilience to both current and future climate threats including the effects of climate change (Lasco et al., 2014). Integrating trees into farming and pastoral landscapes through agroforestry is one of the most effective methods for climate mitigation and adaptation. It also aids in restoring degraded lands and offers nutritional and livelihood benefits to millions of people in sub-Saharan Africa (Bernard et al., 2019).

Agroforestry systems provide many benefits and improve the quality of life for farmers by giving access to food, timber, fodder, and fuelwood as well as access to various livelihood capital and agroforestry practices that promote biodiversity, generate economic gains, and help farmers in sustaining their livelihoods (Akter et al., 2022). Trees are a source of income for farmers, a medium and long-term investment, playing an essential part in rural development (Montagnini & Finney, 2011)**,** and contribute tremendous biological diversity found in forests, which are also very important for sustaining the livelihood of the nearby local community (Persha et al., 2010).

Agroforestry holds promise in climate change mitigation by boosting carbon storage resulting in reduced greenhouse gas emissions (GHG) (Mbow, Van Noordwijk, et al., 2014), and adaptation by improving the ability of agricultural lands to withstand drought and flood events. Farmers and investors are interested in planting agroforestry tree species as a business opportunity, with early rewards including firewood and fodder from trimming and thinning (Roberts et al., 2012). Indeed, the complex ecology of agroforestry ecosystems and their resilience to climate change can play a crucial role in improving the quality of life and socio-economic possibilities of local communities. The idea of "community ecosystem-based adaptation" was developed based on the strong

relationship between human and ecological systems in dealing with climate change adaptation (Roberts et al., 2012). Agroforestry is an effective solution to combat ecological problems related to climate change, and maintain food production in support of human livelihoods (Mukhlis et al., 2022). Moreover, ecosystem-based adaptation (EbA) approaches can help minimize social susceptibility to climate threats while creating long-term sustainability and conservation. EbA relies on the preservation and restoration of natural ecosystems to lower society's vulnerability to climate-related stresses and to maintain or strengthen the resilience of social-ecological systems (Pasquini & Cowling, 2015). At the same time, Eba is underpinned by the national adaptation planning process (NAP) as an adaptative mechanism to respond to the impacts of climate change.

Both EbA and NAP are potentially highly valuable approaches in Nature-based Solutions (NbS) to ensure that the integration of agroforestry complements the existing ecosystem and contributes to the environmental and socio-economic aspects. In Rwanda, EbA has been implemented in several landscapes, including agricultural systems (REMA, 2019). This research evaluated the ecological and socio-economic impact of agroforestry interventions on smallholder farmers and explored the potential benefits of integrating agroforestry into smallholder farms. They focused on the effectiveness of restoring ecosystems and improving community livelihoods in an EbA intervention area adjacent to the Ibanda-Makera Natural Forest in the Eastern Province of Rwanda.

1.2. Problem statement

The Rwanda Government's very positive attitude towards environmental issues and its favorable policy environment provides a strong foundation for the promotion and rapid adoption of Farmer Managed Natural Regeneration (FMNR). Individuals and communities are beginning to recognize the consequences of the decline of agroforestry tree species in the landscape. Loss of traditional medicines, lack of timber, lack of fodder and fuel wood, and the high impact of climate change are now seen as being directly related to the loss of tree species (Rinaudo, 2014). In Rwanda, the environment suffers from various forms of land degradation, soil erosion, deforestation, loss of biodiversity, and pollution (Ndayambaje, 2013). Deforestation occurs because of agricultural expansion, livestock farming, unsustainable fuel wood extraction, encroachment into forest lands, anthropogenic activities, forest fires, and overgrazing, all related to land degradation, erosion, and landslides (REMA 2009a).

There is a continual demand for fuel, wood, and other non-timber forest products from the Ibanda-Makera Natural Forest, which has created conflicts between local communities and the management of this forest. The Ibanda-Makera Natural Forest has degraded due to intense population pressure seeking firewood, grazing areas, medicinal plants, and engaging in poaching caused some native species in the Ibanda-Makera Natural Forest to become rare in the forest fragment (REMA, 2021). The Ibanda-Makera forest is gradually losing its original size and biodiversity and needs protection otherwise it will disappear completely. Rwanda's NAP (National Adaptation Planning Process) includes activities such as fencing, and the re-planting of native trees to restore the ecosystem (REMA, 2019).

The communities adjacent to Ibanda-Makera rely on the forest remnant to support their livelihoods, particularly because it supplies many of their needs, prevents soil erosion, fodder for animals, and medicinal plants, safeguards water catchments, and provides other goods and ecological services. The LDCF II aims to restore degraded savanna and forest ecosystems by planting agroforestry and indigenous species using the Ecosystem-based Adaptation (EbA) approach, to enhance the resilience of local communities to current and future impacts of climate change (REMA, 2023). There is a critical need for information about the ecological, and socio-economic management of agroforestry tree species in the buffer zone of Ibanda-Makera forest and to understand their potential to improve human well-being and contribute to Rwanda's economic development and climate change adaptation. This study will contribute to the sustainable management of agroforestry tree species and enhance ecosystem-based adaptation around the Ibanda-Makera Natural Forest in Rwanda

1.3. Objectives

1.3.1. General objectives

The primary goal of this research is to evaluate the ecological and socio-economic impacts of agroforestry interventions on smallholder farms adjacent to the Ibanda-Makera Natural Forest, Kirehe district, Rwanda.

1.3.2. Specific objectives

- To assess the species and status of agroforestry tree species on smallholder farms
- To assess the socio-economic benefits provided by agroforestry tree species and their contribution to climate adaptation.
- To assess the ecological benefits provided by agroforestry tree species and their contribution to climate adaptation.
- To assess the effects of EbA intervention approaches on the local community, specifically, agroforestry tree planting on farms for climate adaptation.

1.3.3. Research questions

- What are the species and status of agroforestry trees around the Ibanda-Makera Natural Forest?
- What are the socio-economic values and benefits provided by agroforestry tree species?
- What are the ecological values and benefits provided by agroforestry tree species?
- What are the effects of EbA interventions on local communities in the study site?

1.3.4. Hypothesis

- The diversity and status of agroforestry tree species on smallholder farms significantly contribute to the ecological and economic sustainability of local communities.
- Agroforestry tree species provide significant socio-economic benefits to smallholder farmers, enhancing their resilience and capacity for climate adaptation.
- The presence of agroforestry tree species provides significant ecological benefits that contribute to climate adaptation in agricultural landscapes.
- Ecosystem-based adaptation (EbA) interventions positively impact local communities by increasing resilience to climate change, leading to improved livelihoods and enhanced ecosystem health.

2. LITERATURE REVIEW

2.1. Agroforestry trees in smallholder farms and Ecosystem-based Adaptation

Agroforestry is one of the most conspicuous land use systems across landscapes and agroecological zones in Africa. Agroforestry addresses various on-farm adaptation needs provides ecosystem services and reduces human impacts on natural forests (Mbow, Smith, et al., 2014). The integration of climate change adaptation and mitigation objectives is facilitated by agroforestry and ecosystem conservation, which frequently cause large co-benefits for local ecosystems and biodiversity (Morton, 2007). There is increased interest in promoting the use of Ecosystem-based Adaptation (EbA) activities to help smallholder farmers adapt to climate change, however, there is insufficient data on what extent these strategies are utilized by smallholder farmers and what variables impact their usage (Harvey et al., 2017). Strengthening smallholder farmers' resilience to climate change is a critical issue that governments, legislators, funders, and practitioners are actively working to address (Dinesh et al., 2016).

The majority of smallholder farmers, particularly those in developing nations, have limited ability to adapt to climate change because of their low incomes, low educational attainment, small land areas, restricted access to markets and credit, and frequently continue to depend on outside help (Harvey et al., 2014). Developing supportive and integrated agriculture and climate change policies that specifically promote ecosystem-based adaptation practices as part of a larger agricultural adaptation program, as well as establishing and maintaining resilient and creative extension programs for smallholder farmers, are all necessary for the effective implementation of these practices. Additionally, a thorough understanding of farmer effectiveness and the factors that affect farmer adoption is necessary (Vignola et al., 2015).

Climate change and weather-related stresses, as well as environmental factors, might affect smallholder farmers. The benefits of agroforestry systems are becoming better understood on both a farm and landscape scale. One emerging benefit of agroforestry systems is the ability to increase smallholders' resilience to current and future climate risks, such as climate change (Lasco et al., 2014). The ecosystem-based adaptation (EbA) strategy is thought to be a successful way to mitigate the effects of climate change while maintaining the availability of ecosystem services essential to farming (Kissi et al., 2023).

2.2. Socio-economic benefits provided by agroforestry tree species

Globally, most rural communities rely on natural resources for their livelihoods. Agroforestry tree's availability, preference, and use are influenced by socio-economic perspective (Sirmah et al., 2017). Agroforestry is a sustainable and evolving approach to managing natural resources. It involves integrating trees and woody perennials into agricultural land to enhance productivity promote and generate social, economic, and environmental advantages (Dwivedi et al., 2007).

Agroforestry can enhance food security, boost smallholders' income, and promote cultural activities within the community from a socioeconomic perspective. The socio-economic advantages of agroforestry for smallholder farms lie in the implementation of a diverse agroecosystem, incorporating trees (for timber and fruits) and livestock. This approach offers alternative income sources for the community, fostering economic resilience. Additionally, agroforestry has the potential to serve as a solution to prevailing socioeconomic challenges (Duffy et al., 2021). There is a greater connection between socioeconomic perspectives and the presence of trees on farms than the relationship with their use, which is why agroforestry technology and practices need to be promoted (Sirmah et al., 2017).

Moreover, research indicates that agroforestry represents a hopeful agroecological strategy for adapting to climate change due to the various additional advantages it offers beyond adaptation itself. These benefits encompass synergies with climate change mitigation by capturing carbon, improving food security and income prospects, delivering ecosystem services, and safeguarding biodiversity agroforestry practices have been shown to enhance farmers' adaptive capacity to climate variability by diversifying their livelihood options (Quandt et al., 2023).

2.3. Ecological benefits provided by agroforestry tree species

Agroforestry provides many ecosystem services, agroforestry is increasingly seen as part of a multifunctional working landscape that offers ecological services, environmental advantages, and economic goods (Jose, 2009). Several ecosystem services, including provisioning, regulating, cultural, and supporting benefits as well as environmental benefits, are provided by agroforestry, which also encourages eco-intensification through higher resource efficiency (Pantera et al., 2021). Agroforestry systems increase soil quality, preserve biodiversity, improve air and water quality, sequester carbon, mitigate climate change, and address food security and safety concerns and

also surpass monoculture systems in terms of environmental friendliness, social acceptability, and economic viability due to their diverse input and output (Mohd Salleh & Harun, 2013). Agroforestry has the potential to support multiple ecosystem services, habitat preservation for biodiversity, and the economic and social development of the communities that cultivate it (Willmott et al., 2023).

Moreover, agroforestry can help mitigate the adverse effects of climate change by sequestering carbon in biomass and soil organic matter (Montagnini & Nair, 2004). Recent research has also highlighted the role of agroforestry in enhancing ecosystem services such as water regulation, erosion control, and pest regulation. For example, shade trees in agroforestry systems can reduce soil temperature and moisture stress, thereby improving crop yields and reducing the risk of crop failure (Lin, 2014)

2.4. Perceptions of smallholder farmers about agroforestry tree planting on their farms

Agroforestry has been shown to have major beneficial effects on local farming systems' resilience, farmers' ability to adapt, and the variety of livelihood benefits it offers. Agroforestry's uptake is often uneven, exhibiting successes and failures (Jha et al., 2021). Farmers' attitudes towards a particular tree species can be influenced by their perceptions of how that species affects the cropland's capacity to provide commodities and services sustainably, collaborating closely with farmer groups on tree planting and agroforestry initiatives aims to address the situation by enhancing farmers' capabilities to boost farm productivity. The goal is to encourage farmers to embrace trees as a livelihood diversification strategy (Wanjira, 2019).

Farmers may view agroforestry practices favorably because they recognize the benefits of planting trees, as opposed to farming without trees, which is associated with several challenges such as limited financing availability, natural disasters, and a lack of assistance from local government agencies. Additionally, efforts should be made to educate farmers about the advantages of cultivating trees as opposed to just growing field crops only which can bring a change in farmer perception (Mahmood & Zubair, 2020). Agroforestry is also seen as beneficial for environmental services, including erosion prevention and enhanced soil fertility, thereby contributing to the augmentation of natural capital. Additionally, certain trees within agroforestry are potential natural pesticides (Hillbur, 2014).

The planting of trees on farms is a growing and widely embraced practice, delivering both environmental and socio-economic advantages to smallholder farmers. This is attributed to the various services and products that trees offer. For instance, trees can enhance crop productivity, positively influence the physical environment, and contribute to greater economic resilience in farmers' livelihoods. Additionally, trees provide numerous ecosystem services, including shelter, wind protection, erosion control, regulation of atmospheric gases, and protection of watersheds (Newman, 2021).

2.5. Ecosystem-based Adaptation approach to adapt to climate change

Agroforestry can serve as a form of ecosystem-based adaptation (EbA) by enhancing the resilience of farming systems to climate change impacts such as drought, flooding, and temperature extremes(Locatelli, Pavageau, et al., 2015). By diversifying agricultural production and improving ecosystem services, agroforestry can help smallholder farmers cope with changing environmental conditions and reduce their vulnerability to crop failures and income losses(Lindner et al., 2020).

Around the world, rapid climate change poses significant challenges to the sustainability of communities' livelihoods and socio-economic development, especially in developing countries. (Loewe & Rippin, 2015). The adverse impacts of climate change are observable across various sectors, encompassing the environment, health, education, food security, energy, and water resources (Andrade et al., 2014).

As national, international, and bilateral organizations, along with the processes they support, strategize on adapting to climate change, they require evidence to pinpoint where to concentrate adaptation efforts and allocate financial resources accordingly (Jones & Alves, 2012). Adapting to climate change involves strengthening the resilience of communities, ecosystems, and economies to flourish despite its challenges. Given that adaptation solutions frequently exist within nature, this has led to the emergence of ecosystem-based adaptation (EbA) as a component of broader adaptation strategies (Vignola et al., 2015), Ecosystem-based adaptation (EbA) strategies offer a diverse array of institutional, socio-cultural, ecological, and economic advantages. EbA approaches support the restoration and preservation of ecosystems, thereby fostering ecosystem health and vitality (Muthee et al., 2017).

A healthy ecosystem can withstand the impacts of climate change, safeguarding the provision of essential ecosystem services to communities and thereby helping alleviate poverty (Vasseur, Jones, 2015). Moreover, by enhancing the communities' ability to adapt to climate change (Mercer et al., 2012), the EbA approach promotes biodiversity conservation (Locatelli, Catterall, et al., 2015). There is an increasing recognition that the EbA approach offers optimal adaptation solutions, especially in poorer countries where numerous individuals rely on natural resources for daily sustenance and livelihoods. Numerous projects grounded in EbA are being expanded and executed by an increasing number of organizations across various countries, integrating the EbA approach into evolving climate change policy decision-making processes (Seddon et al., 2020).

In Rwanda, REMA implemented the project titled: "Building resilience of communities living in degraded forests, savannahs and wetlands of Rwanda through an Ecosystem-based Adaptation (EbA) approach"; abbreviated as LDCF II project an acronym for Least Developed Countries Fund to enhance the resilience of local communities in the intervention areas against anticipated climate change impacts (REMA, 2023). Throughout Africa, leveraging indigenous species can serve as an effective strategy for fostering climate-resilient ecosystems and steering communities toward pathways of development (Fandohan et al., 2013). Consequently, preference in restoration practices is given to beneficial tree species and their diversity, highlighting their intrinsic relationships with local biodiversity, as well as integrating relevant traditional knowledge and practices (REMA, 2019).

The EbA methodologies are perceived to optimize the efficacy of adaptation efforts by acknowledging that resilient ecosystems offer dual benefits, climate adaptation, and disaster risk reduction, alongside livelihood improvements. By capitalizing on the interconnections among ecosystem services, climate change, and biodiversity, EbA emerges as a sustainable development approach that concurrently fosters three outcomes: socio-economic benefits, climate change adaptation, and biodiversity conservation (Ernesta, 2019).

EbA promotes sustainability across a range of sectors, including agriculture, forestry, energy, and water, and could help countries meet the Sustainable Development Goals (SDGs) (Seddon et al., 2020). By enhancing the resilience of susceptible communities to extreme events like floods and

landslides, EbA aids countries in achieving the objectives outlined in the Sendai Framework for Disaster Risk Reduction (Woroniecki et al., 2019).

Evaluating the quality and efficiency of EbA strategies is crucial for gaining a deeper comprehension and optimizing its advantages while mitigating Climate change. Addressing this knowledge gap is essential for making informed projections about the potential efficacy of EbA measures in various scenarios and maximizing local adaptation benefits. An enhanced understanding of the effectiveness of EbA initiatives will bolster arguments for heightened donor investment and encourage governments to integrate EbA into pertinent ministries and budget allocations(Perrez, 2020).

3. METHODS

3.1. Description of the study area

The study took place in the Eastern Province of Rwanda, in Kirehe District, Mpanga Sector in Nyakabungo cell in five villages: Gikushya, Nyakabungo, Rushenyi, Cyamuhabura, and Isenga villages where Ibanda-Makera forest is located (Figure **1**). The district consists of regions in Rwanda's extreme southeast that border Tanzania and Burundi. The district is characterized by savanna, acacia trees, and a few natural forests, together with the presence of the Akagera River, which contributes to a temperate climate in the region (Hope & Mupenzi, 2020).

Ibanda -Makera are two forests, with Ibanda being in the south and close to the Akagera wetland while Makera is in the north on a hill covered in savannah and woodland plants in the eastern part of the country. Ibanda-Makera forest is located at -1.933764°, 30.034499°, and -1.933764°,30.034499° on the grid, and its approximate area is 169ha (Vital et al., 2023), Ibanda-Makera has altitude of 1300 m and has average annual temperature is 23.80 °C, the annual mean rainfall of 1130mm (Bizuru et al., 2011). It is a gallery forest linked with woodland and savannah in the eastern part (Ibanda), and with papyrus swamp in the southern region (Makera) (REMA, 2019). In addition, the Makera forest is a remnant forest that has remained intact despite the pressure from farmers cultivating its surroundings (Bizuru et al., 2011), therefore the anthropogenic activities contribute to the degradation of Ibanda- Makera Natural Forest where the community has farms adjacent to Ibanda-Makera extending their farms by cutting bushes of Makera forest for agricultural purposes.

The planting of trees and the implementation of erosion control ditches in the buffer zone of Ibanda-Makera Natural Forest were created to decrease runoff and mitigate soil erosion (REMA, 2023). The degradation of the Ibanda-Makera forest is attributed to intense population pressure driven by activities such as firewood collection, grazing, medicinal plant harvesting, and poaching. These illegal activities have resulted in the loss of biodiversity, diminished ecosystem services, habitat destruction for wildlife, and contributed to climate change impacts (REMA, 2021). NAP strategy aims to reduce pressure on the forest from wood extraction, forage collection, food production, medicine use, and fuelwood gathering (Habakubaho, 2021). Agroforestry is being

expanded to the adjacent agricultural regions by planting trees on the hills near the forest to benefit the local community.

The Local Development and Climate Fund (LDCF) is overseeing comprehensive initiatives to address these challenges. These include planting agroforestry trees and building soil erosion control structures like ditches, terraces, and water ponds to manage water flow from nearby hills and prevent soil erosion. Local labor is actively involved to ensure community engagement and ownership. With the Facilitation of the LDCFII and Rwanda Environment Management Authority (REMA), proposed Ecosystem-based Adaptation (EbA) interventions, referred to as the "NAP project initiative underscores collective efforts to combat climate change challenges, enhance resilience in the Ibanda-Makera Natural Forest, and benefit the local community" (Habakubaho, 2021).

A total of 204 farms were surveyed where the project of REMA (LCDFII) planted agroforestry trees around the Ibanda-Makera Natural Forest (Figure 1).

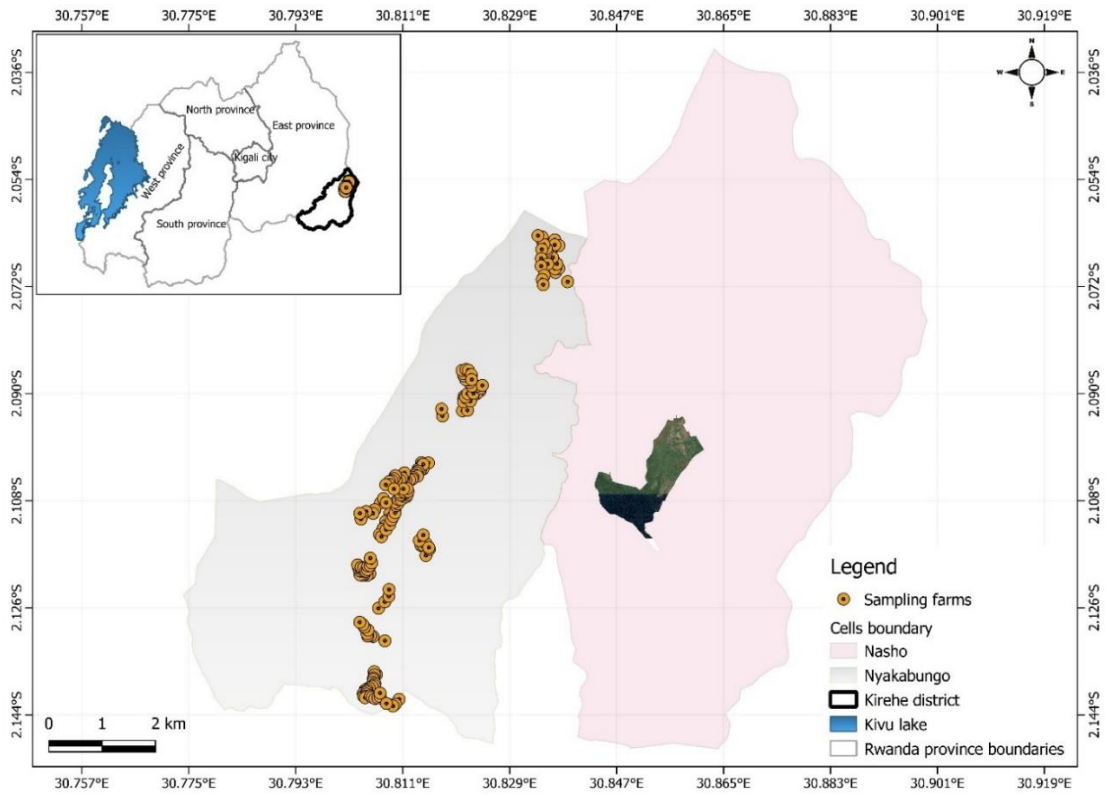

Figure 1: Distribution map of agroforestry trees planted by the respondents

3.2. Sampling methods

3.2.1. Determining sample size for the farm survey

Data were collected from five villages of Nyakabungo cell adjacent to the Ibanda-Makera Natural Forest within the area where REMA's LCDF II project planted agroforestry trees on smallholder farms (Table 1). The total number of households in these five villages is 416 from which the sample size of 204 was calculated using Yamane's (1973) formula:

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

Where: n sample size N =population size e=standard error (the level of precision 5%) and confidence interval of 95%

Table 1: Distribution of surveyed households.

Sectors	**Cells**	**Villages**	**Total number of households**	**Sample size**
Mpanga	Nyakabungo	Gikushya	124	61
		Nyakabungo	80	39
		Rushenyi	88	43
		Cyamuhabura	61	30
		Isenga	63	31
Total			416	204

Data were gathered through structured interviews that included both closed and open-ended questions for all respondents. Additionally, geospatial data for each targeted smallholder farm was recorded by capturing GPS coordinates with a manual GPS device.

Before beginning the interview, I spent 10 minutes explaining my research to the respondents and then provided a brief overview of the Ibanda-Makera Natural Forest management and the NAP project to ensure common understanding. Each respondent allocated one hour for me to complete the questionnaire.

The respondents' demographic profile indicated an average age of 48 years (± 13), with most farmers' ages ranging between 35 and 61 years (Table 2). The respondents who participated were 73% males and 27% females. Their educational backgrounds were divided into primary school, secondary school or TVET, university or other higher institutions, and those who never attended school. Among 204 respondents, 35.3% had completed primary school and none of the respondents had attained a university or college (Table 2). Most of the respondents, whose ages ranged from 25 and 55 years lived near the Ibanda-Makera Natural Forest and the average age was 40 years with a standard deviation of ±15 years (Table 2).

Table 2: Respondents by age, gender, and education status

		Mean	Standard Deviation	Range	N	%
Age		48	13	57		
Gender	Female				56	27.5
	Male				148	72.5
Period of respondent lived in the area		40	15	68		
Education completed	Never went to school.				94	46.1
	Primary school				72	35.3
	Secondary school or TVET				38	18.6

3.2.2. Ecological and socio-economic benefits of agroforestry tree species and perceptions of local farmers about the tree plantings

The methodology involved assessing the socio-economic and ecological benefits provided by agroforestry tree species on farms near the Ibanda-Makera Natural Forest, focusing on their contribution to climate adaptation. Data collection utilized structured interviews where respondents with plots aligned with REMA's LCDF II project interventions were surveyed. The questionnaire included sections on farmers' perceptions of various agroforestry tree species planted

on their farms. Information gathered included benefits derived from these trees and their socio-economic impacts. Emphasis was placed on the community's role in conserving and managing the Ibanda-Makera Natural Forest. I also asked them guided questions on their perception of the agroforestry planting in their farms for the management and conservation of the Ibanda-Makera Natural Forest.

3.2.3. Assessment of the species and status of agroforestry trees

The study sampled the status and species of agroforestry tree species planted in smallholder farms near the Ibanda-Makera Natural Forest. This involved documenting the number and types of species present on each farm, along with their relative abundance. Priority was given to farms participating in REMA/LCDFII agroforestry tree-planting initiatives. GPS coordinates were recorded for each surveyed farm and then used to create a map depicting the surveyed areas and samples. The map was generated using QGIS software.

3.2.4. Data analysis

All data were analyzed using R software (r version 4.3.3 development core team, 2024). I used QGIS software for geospatial data. Narrative analysis was used for qualitative data where I identified themes patterns and examples from the interviews. Statistical tests were conducted on the survey's open and closed responses, which were categorized and coded. Frequencies from these coded categories were calculated and are shown in bar chart figures, which are further described according to the research objectives. Data from focus group discussions were qualitatively analyzed alongside the information gathered from the household survey. The species and status of agroforestry trees and the ecological and socio-economic benefits of agroforestry tree species analyzed R. and the analysis of the perceptions of locals.

4. RESULTS

4.1. Understanding climate change and Ecosystem-based Adaptation (EbA)

Almost 86% of respondents knew about climate change (Table 3), but their explanations about climate change varied (Table 4). Many respondents said that climate change was a result of changing weather patterns, which occurred when there was a lot of sun or rain. It's interesting that one person mentioned planting trees with mixed crops, resulted in climate change, and explained that trees moderate temperature and reduce heat stress during the summer season. Interestingly, 46.5% of participants were knowledgeable about the accomplishments of EbA projects (Table 3). Furthermore, 39.2% of respondents had heard about the Ecosystem-based Adaptation project.

Table 3:Respondents' knowledge about climate change and the EbA project in their area.

		Respondent number (N)	**Percentage of respondents**
Do you know what climate change is?	No	29	14.2
	Yes	175	85.8
Have you heard of the Ecosystem-based Adaptation projects implemented in this district?	No	124	60.8
	Yes	80	39.2
Do you know what the EbA projects are supposed to accomplish?	No	109	53.4
	Yes	95	46.6

Table 4: Identified themes from discussion with the local community about their understanding of climate change.

Themes	**Examples**
Alternation of sun and rain	34 Farmers say that they are currently experiencing prolonged periods of rainfall, whereas in previous years, they experienced extended periods of excessive sunlight. For example, one elder farmer said that there was a time for heavy rainfall that led to the deterioration of land but did not remember the year.
Change in weather variation	Prolonged Weather Changes: 48 respondents associate climate change with extended periods of altered weather conditions, such as excessive sunshine or rainfall persisting for a year or more
	Temperature and Precipitation Variability: 7 Participants mentioned variations in temperature and rainfall as key indicators of climate change, emphasizing their occurrence over extended periods.
	Three respondents noted that climate change is due to natural variations in weather conditions over time, while others suggested that human activities play role in worsening these changes. Alterations in weather conditions, including temperature fluctuations and changes in rainfall patterns and or wind, lasting for considerable periods for example one respondent mentioned that in 2016 there was the occurrence of too much sun which lasted nearly 2 years.
Change in the timing of rain or sun.	82 respondents mentioned that climate change is the change of time due to too much sun and heavy rain such as the occurrence of prolonged sun followed by rain, indicating a perception of shifts in weather patterns.
Occurrence of too much sun	One respondent noted that in 2023, there was a significant occurrence of prolonged periods of intense sunlight, marked by an extended duration of unusually high sun exposure.

4.4. Assessment of agroforestry tree species on smallholder farms in the study area

Participants were questioned about their understanding of agroforestry, the existence of agroforestry trees on their farmland, the types, and numbers of trees they have planted, and their perceptions of agroforestry tree planting in the study area. All respondents were familiar with agroforestry trees, mentioning that they have trees on their farms.

4.4.1. Definition of the agroforestry

Agroforestry trees were defined by 86.7% of respondents, with 62.7% describing agroforestry as the combination of trees and crops in the same agricultural land (Table 5). Others characterized it as the mixture of crops, trees, and livestock and emphasized that agroforestry trees are planted to control soil erosion, prevent landslides, protect soil, and conserve the land. They highlighted that these trees operate in a mutualistic system that does not adversely affect crops. On the other hand, 13.3% of respondents said that they unrecognized agroforestry and indicated they did not understand its meaning, others mentioned that they had no idea about agroforestry.

Table 5: Knowledge of respondents about the definition of agroforestry

Themes	Examples
Landslide and erosion control	Eighty-five respondents stated that agroforestry involves planting trees to control landslides and erosion. Tree planting for soil protection
Plant trees with crops on the same farmland	Ninety-eight farmers noted that agroforestry, which involves integrating trees with crops on the same land, provides numerous benefits. It fosters a mutually supportive relationship between trees and crops, enhancing soil productivity while allowing them to thrive together. Grevillea and Calliandra are examples of commonly used agroforestry trees, often planted along terraces on farms.
Combining trees, crops, and livestock	17 farmers said that agroforestry is the combination or integration of trees with crops and livestock in the same agricultural land
Trees do not harm crops.	4 farmers mentioned that the trees do not affect crops negatively. Trees are planted for soil conservation and are not harmful to crops.

4.4.2. Types of agroforestry species in their farmland

The respondents were asked to specify the type of agroforestry trees in their farms and their numbers (Figure 3). Findings indicated that all the farms surveyed incorporated agroforestry trees, with *Grevillea robusta* being the most commonly planted species. Specifically, 56.42% of respondents reported having *Grevillea robusta* on their farmland, while 33.52% have *Calliandra Calothyrsus*. Further, *Cedrela serrata* and *Maesopsis eminii* make up less than 5.03% of the trees on their farms

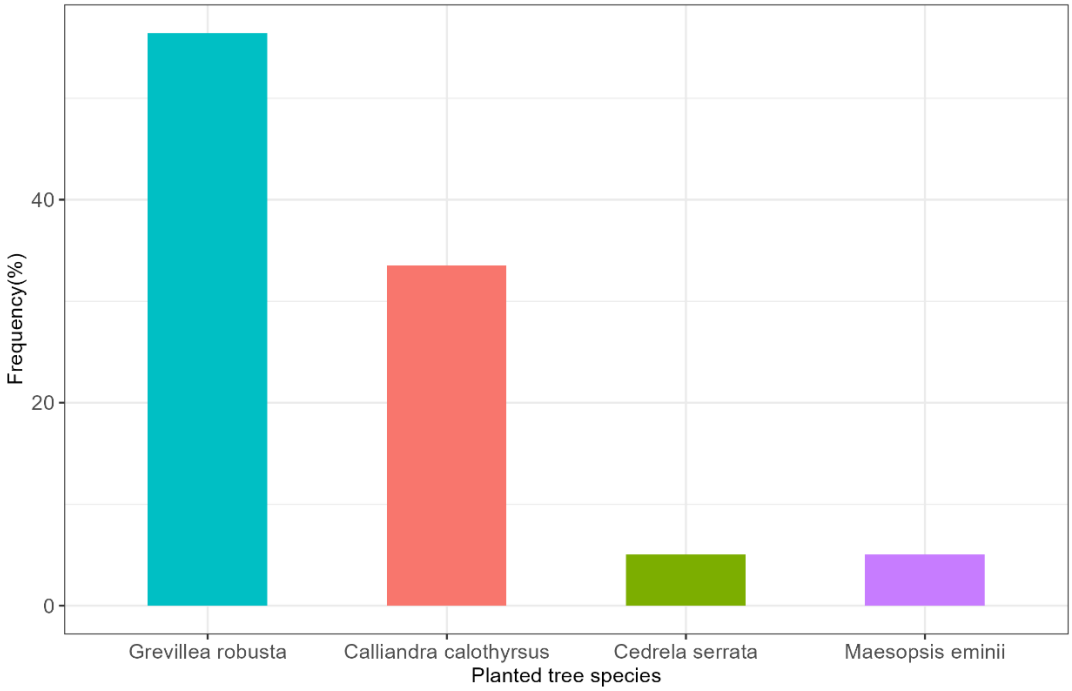

Figure 2: Agroforestry species that respondents have in their farmland.

4.4.3. Local community perception and understanding of agroforestry trees planted in the study area

Many agroforestry tree species were introduced in the farmland near the Ibanda-Makera Natural Forest by the LDCF II (REMA) project including *Grevillea robusta*, *Calliandra callotylosus*, *Cedrela serrata*, *Acacia spp*, and respondents were asked about the planting of these species in the study area (Figure 4), the individuals or entities responsible for planting agroforestry in the vicinity of the study area (Figure 5), the purposes of these species, and when the trees were planted (Figure 6). Most farmers indicated that *Grevillea robusta* was planted for timber, firewood, and stakes

production (Figure 4). Most farmers indicated that *Calliandra calothyrsus* was planted for fodder production, and *Acacia Spp* for shade and firewood, but most farmers did not know why *Cedrela serrata* was planted. Interestingly only one species planted as part of agroforestry interventions was a native tree species (*Acacia* sp) while all others were exotic.

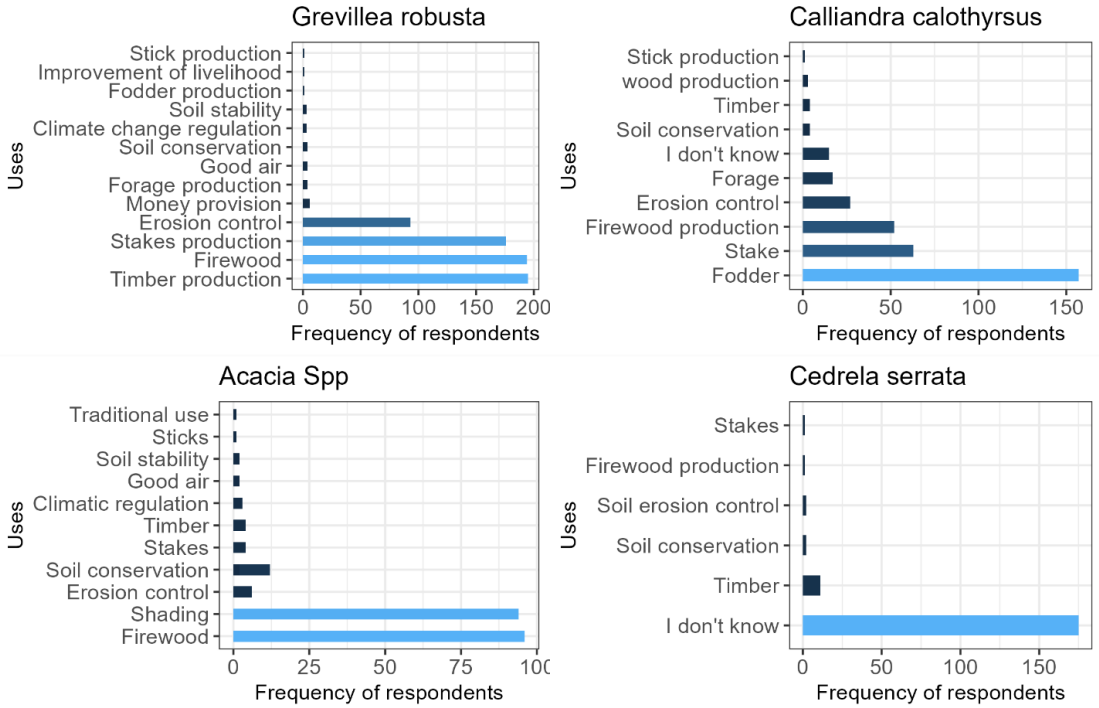

Figure 3: Community perception on the uses of agroforestry tree species planted in the study area

The EPCOTGE company was the most mentioned entity that planted many *G. robusta*, *C. calothyrsus*, and *C. serrata* plants (Figure 5). 20 respondents indicated that many *Acacia* plants were planted by the local community themselves. Interestingly, the LDCF II (REMA) project was mentioned as the second entity of planting agroforestry trees in the study area, covering *G. robusta, C. calothyrsus, and C. serrata,* but not *Acacia spp*.

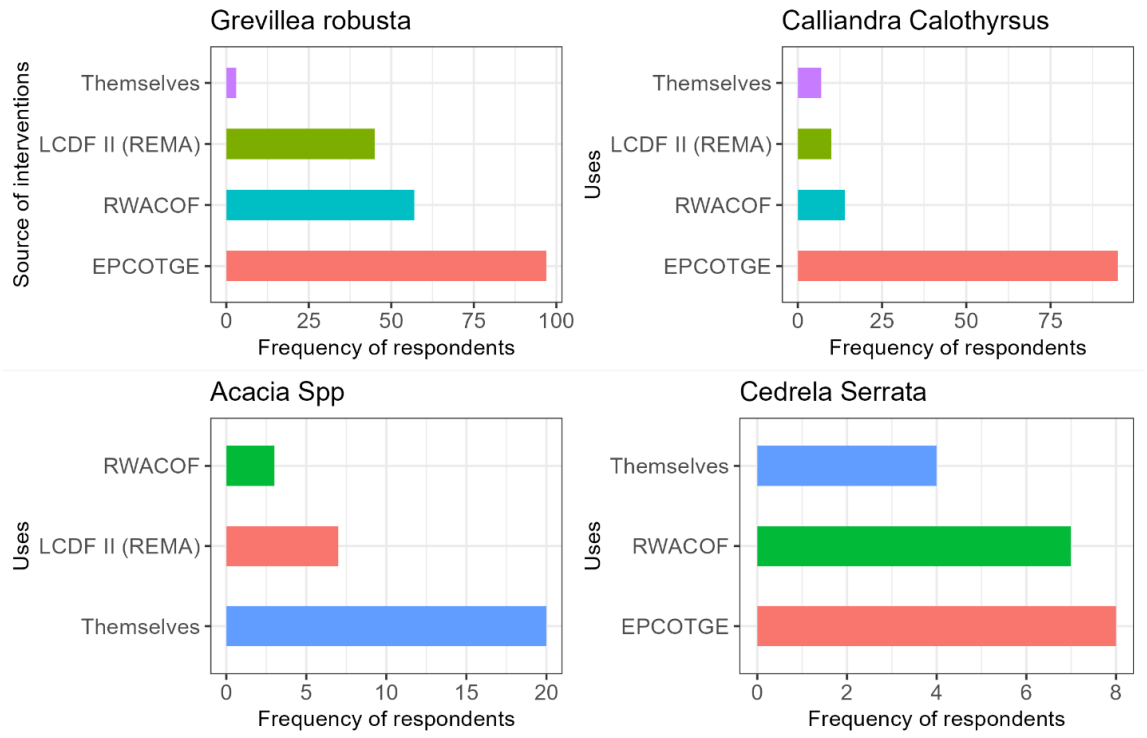

Figure 4*: Responsible entities or individuals of planted agroforestry trees in the study area*

Respondents indicated that *Calliandra calothyrsus* (82), *Grevillea robusta* (68), *Acacia* (45), and *Cedrela serrata* (3) were initially planted in 2018, and replacements were added throughout the year (Figure 6).

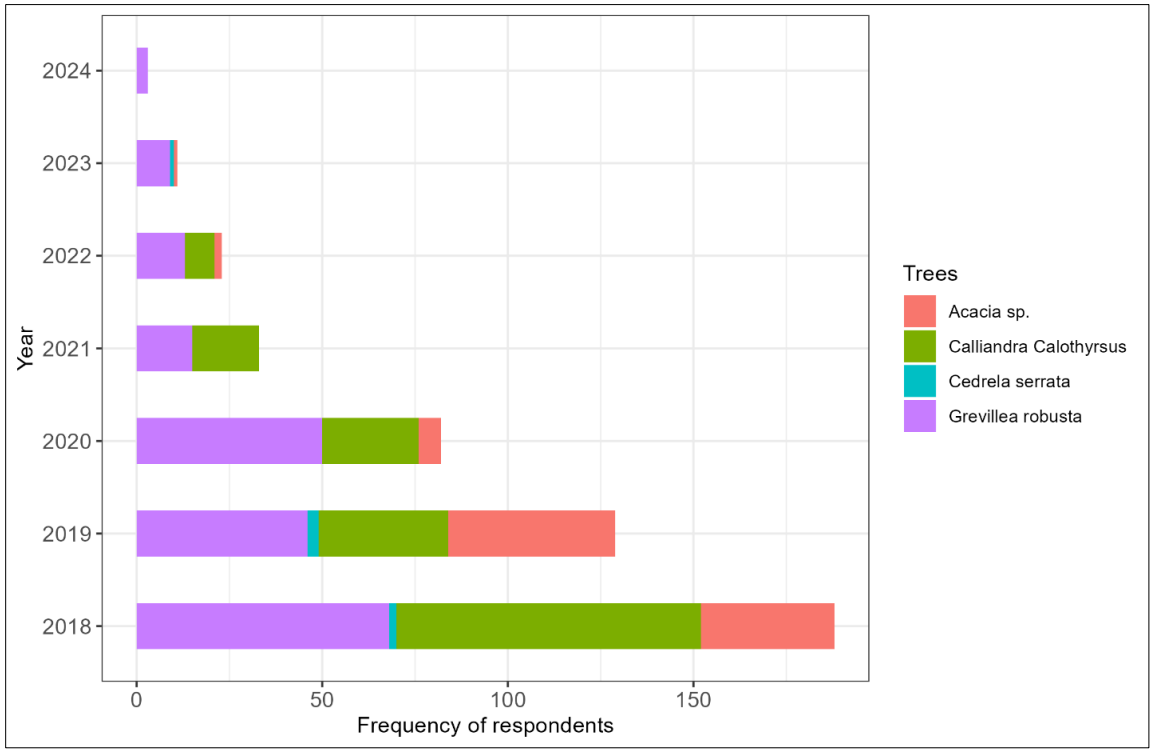

Figure 5: Period of planted agroforestry tree species in the study area

4.5. Organization and institution funding the planting of agroforestry trees

Respondents were asked to mention the organization that funded the project of agroforestry tree plantation, and almost 52% mentioned that LDCF II (REMA) was the sponsor of agroforestry tree plantation in the area around the Ibanda-Makera Natural Forest (Figure 7).

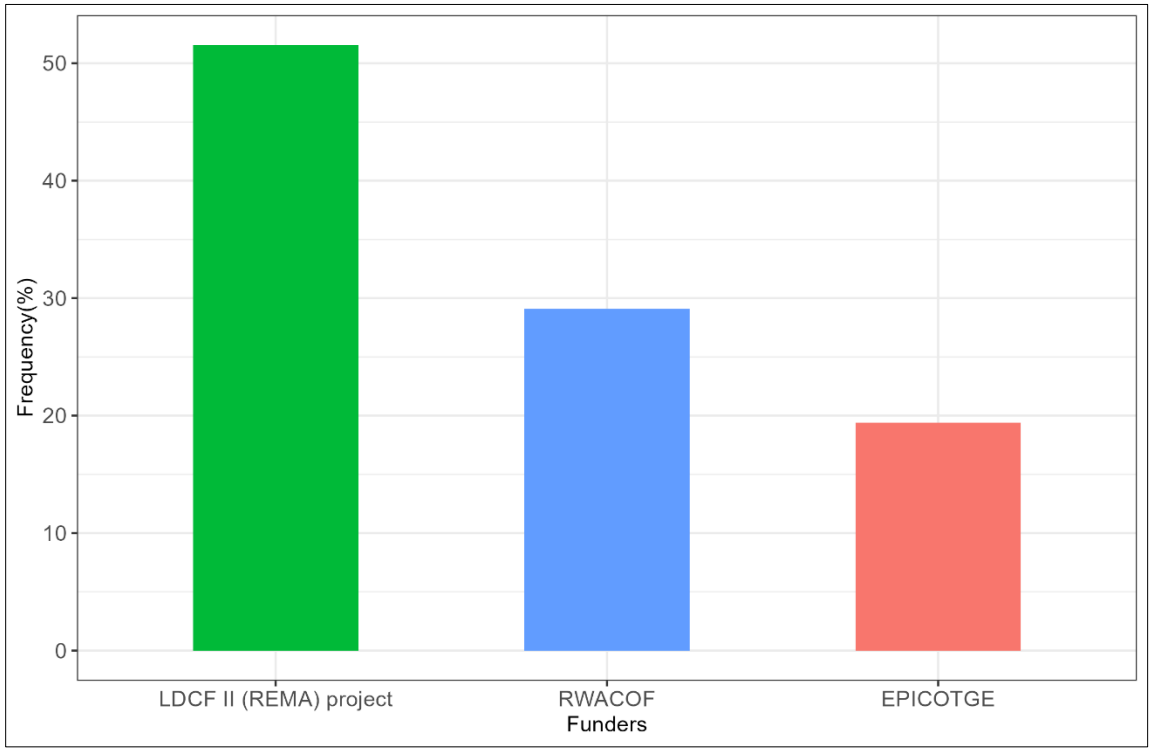

Figure 6: Funders of agroforestry tree planting in the study area.

4.6. Importance of planting agroforestry trees on farms around Ibanda-Makera Natural Forest

When respondents were asked about the reasons why agroforestry trees were planted in their farmland, 41% highlighted soil erosion control as the primary purpose and they mentioned that landslide control and satisfying local community livelihoods were the main importance (Figure 8).

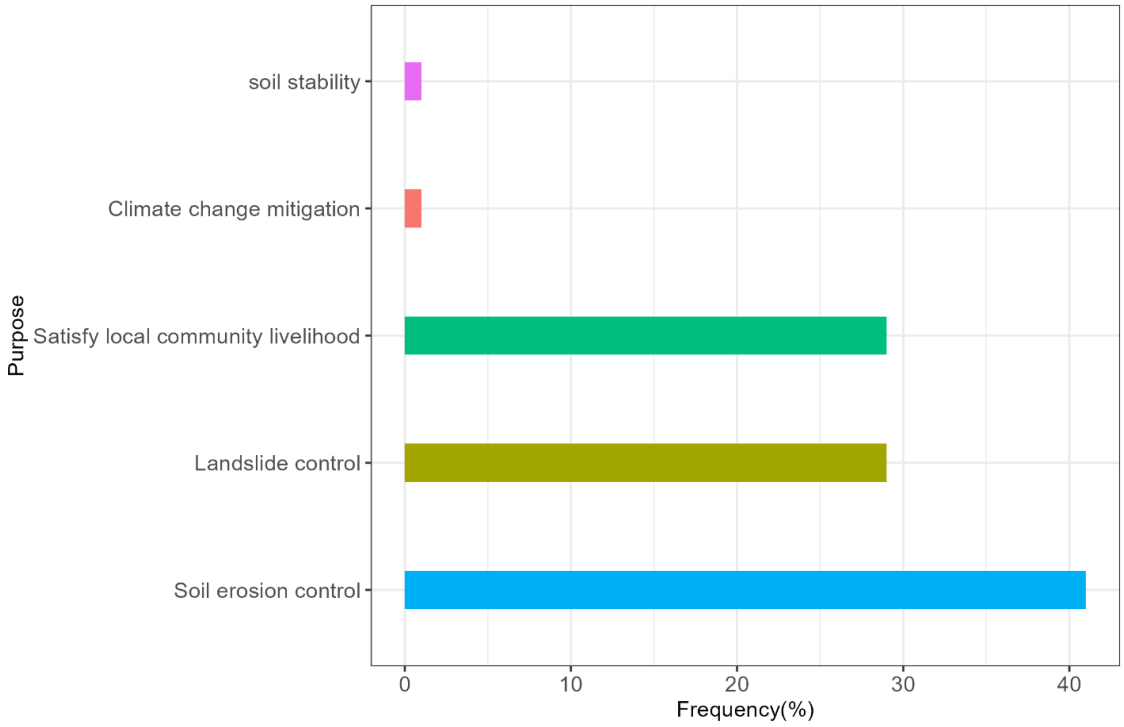

Figure 7: Local community perception about the reasons why agroforestry trees are planted on their farms

4.7. Ecological and socio-economic benefits provided by agroforestry plantation in the study area

Respondents were also asked to specify the benefits of the agroforestry tree plantation for the ecological and socio-economic resilience of the local communities in the study area (Figure 9). Climate change adaptation (shade, windbreaks, and microclimatic regulation) (13.8%) and timber (13.6%) dominated as socio-economic benefits and for ecological benefits, 42.4% of respondents mentioned that enhancing ecosystem services were the greatest benefits of planting the agroforestry trees in their farmland.

Additionally, with socio-economic benefits, over 11% of respondents highlighted various advantages. This included increasing farm productivity through integrating crops, livestock, and trees, increasing food security, employment opportunities by tree planting, maintenance, and harvesting creating livelihood opportunities through the sale of timber and fruits, and generating income by money provision (Figure 9). Respondents highlighted biodiversity conservation by providing habitats for various plant and animal species—and soil conservation as the primary ecological benefits of planting agroforestry trees in the smallholder farms near the Ibanda-Makera forest (Figure 9). Other benefits were mentioned less frequently by respondents.

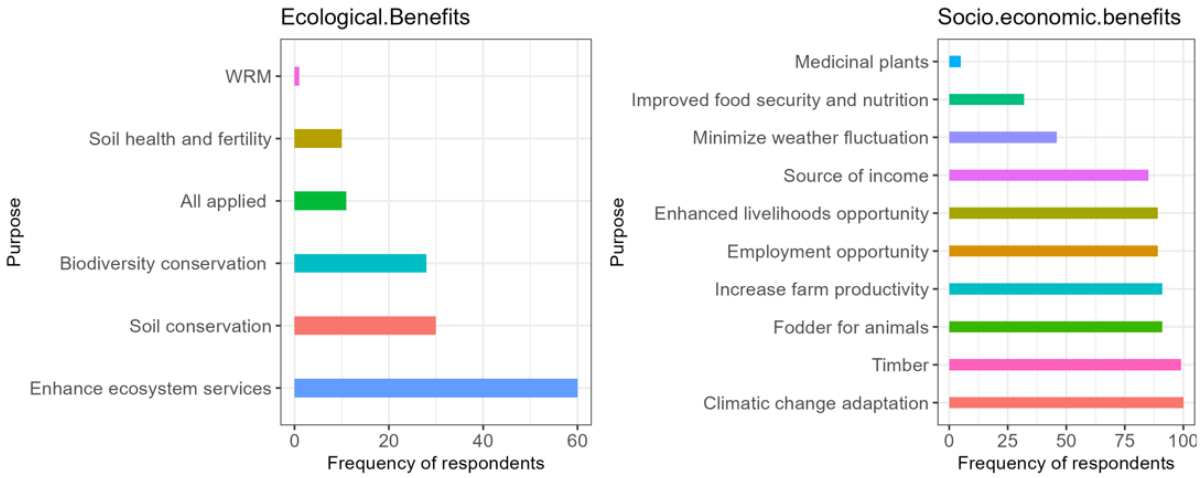

Figure 8: Perceptions of local community on ecological and socio-economic benefits of the agroforestry tree plantation.

4.8. Ownership of agroforestry trees planted in farmlands around the Ibanda-Makera Natural Forest

The respondents were asked to specify who they believe owns the agroforestry trees planted in their farmland, and nearly 97% indicated that these trees were planted and owned by the farmers themselves (Figure 14).

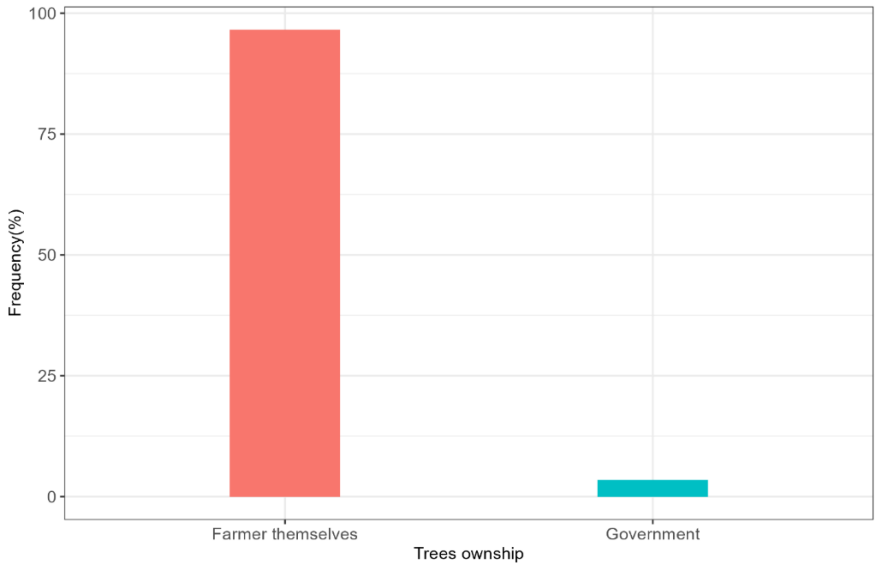

Figure 9: The perceptions of respondents about the ownership of agroforestry trees planted on their farms

4.9. Ecosystem services provided by agroforestry trees planted in the study area

Respondents were asked whether they were permitted to cut planted agroforestry trees for personal use, and nearly all (99%) stated that they were not allowed to do so (Table 6).

Table 6: *Perceptions held by the local community about their right to cut and use the planted agroforestry trees on their farmland*

	Answer	N	%
Local communities right to cut the planted agroforestry trees whatever they want for personal use or needs	Yes	2	0.98%
	No	202	99.02%

The study surveyed respondents on the ecosystem services provided by agroforestry trees on their farms and categorized them into provisioning, regulating, supporting, and cultural services (Figure 10). Results showed strong agreement among respondents regarding certain provisioning services such as firewood (97%) and stakes production (93%). Regulating services like soil erosion control (95%) followed by air quality and local climate regulation were also strongly agreed upon. Supporting services such as soil stabilization and fertility (93%) received strong agreement. However, cultural services like landscape beauty and recreation (42%) scored high in agreement among respondents.

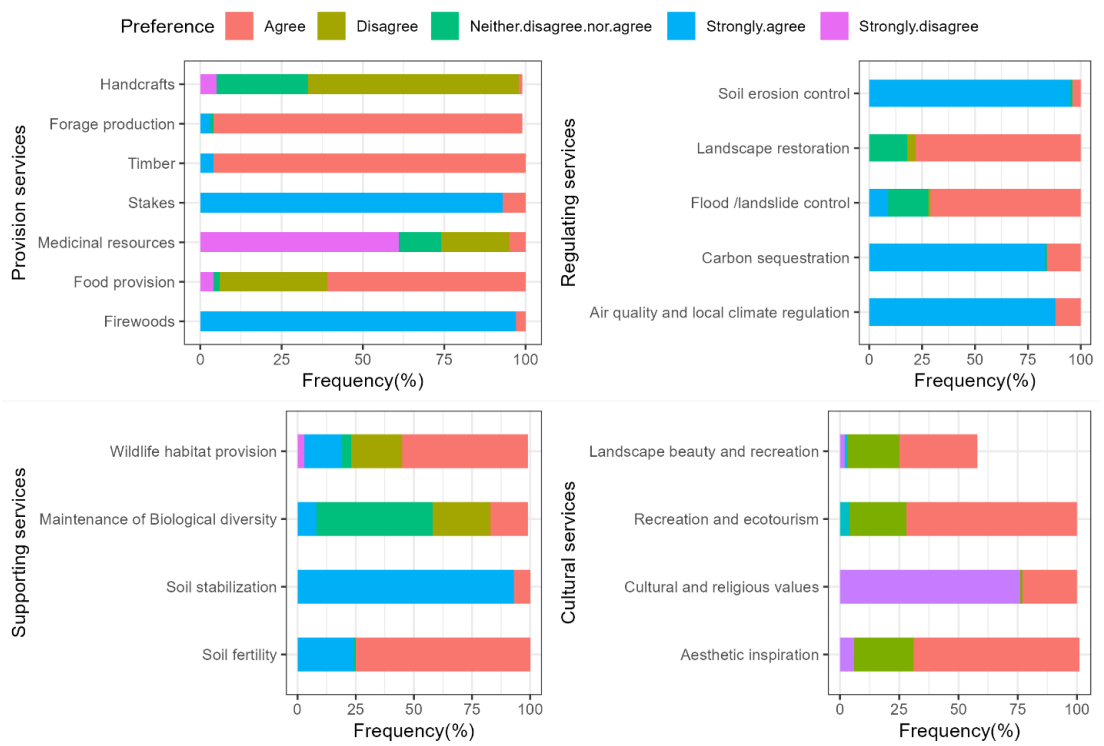

Figure 10: Agroforestry tree contribution to ecosystem services

4.10. Identification of EbA-based restoration measures in the study area

Respondents were asked about which institutions they believe were involved in developing EbA intervention measures, the effectiveness of these measures, and which interventions benefited these measures for the resilience of local communities to climate change in the study area. These EbA measures were classified into several categories: promoting agroforestry trees, incorporating local knowledge and traditional practices, controlling erosion through the construction of water

canals, trenches, and terraces, planting native tree species, and implementing community-based conservation and traditional practices, erosion control by building water canals, trenches, and terraces, planting of native tree species, and community-based conservation.

4.10.1. Knowledge of the local community about the institutional development of the EbA intervention measures

Respondents were asked about the institutions responsible for developing EbA intervention measures (Figure 11). 36% of respondents mentioned LCDF (REMA) as the project responsible for promoting agroforestry trees. Other institutions received fewer mentions, and many respondents were unsure about the organizations behind the remaining EbA interventions.

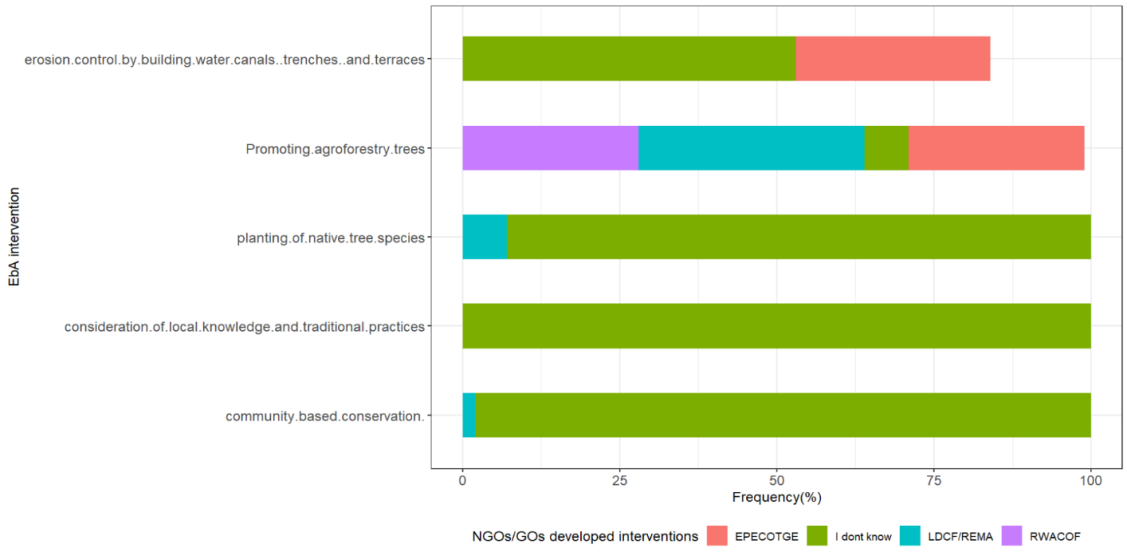

Figure 11: Institution responsible for the development of EbA intervention measures in the study area

4.10.2. Local community perceptions about the effectiveness of the implemented EbA measures

Respondents were asked about the effectiveness of the implemented EbA intervention measures. Among the listed measures in Figure 12, erosion control by building water canals, trenches, and terraces (76%) was mentioned frequently, followed by the promotion of agroforestry trees (66%) which were considered very effective by respondents. However, many respondents stated that

they were not aware of the consideration of local knowledge in effective EbA strategies, or planting of native tree species.

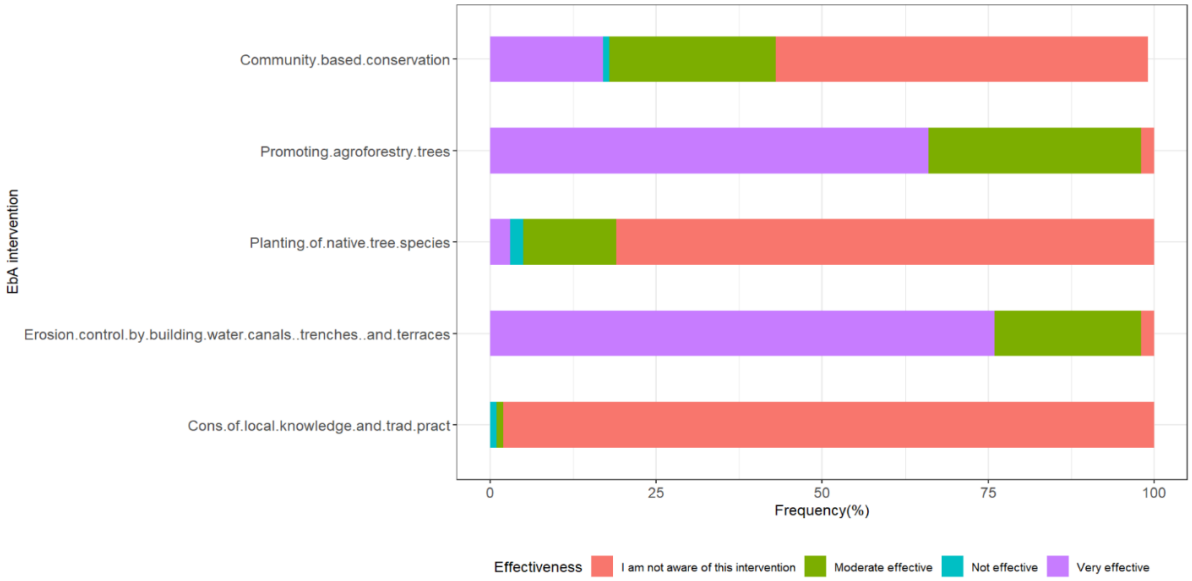

Figure 12: Local community perceptions about the effectiveness of EbA intervention measures

4.10.3. Perceived beneficiaries of the EbA interventions in the Study Area

Respondents were asked about who benefits from the EbA intervention measures (Figure 13). Most (98%) respondents indicated that the primary beneficiaries would be local communities, by promoting agroforestry trees, followed by erosion control by building water, canals, trenches, and terraces (96%).

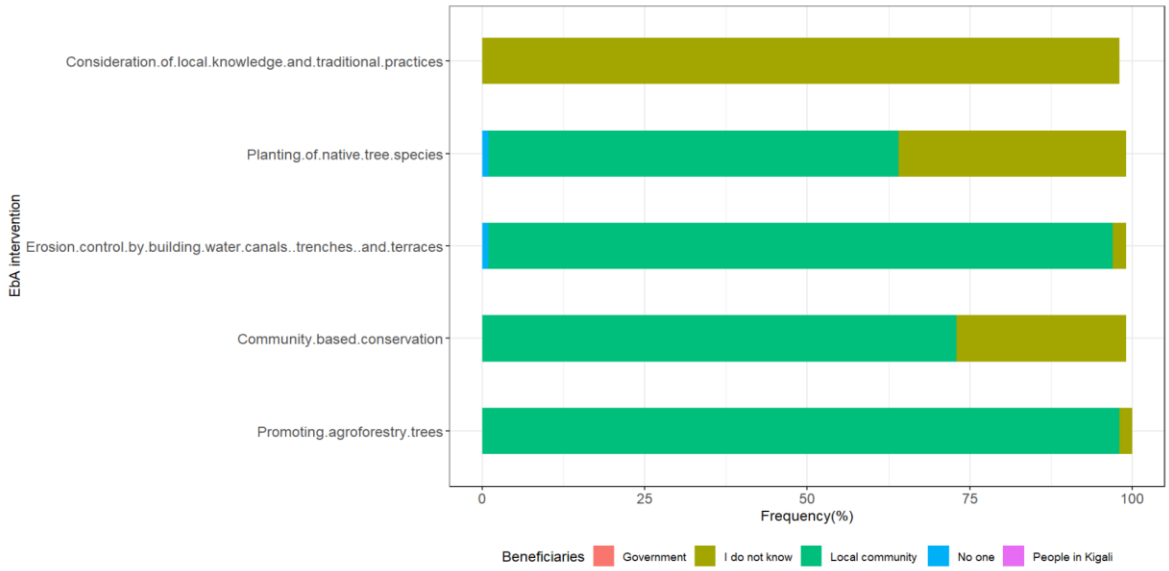

Figure 13: Proportion of respondents who are beneficiaries of the implemented EbA intervention measures.

4.11. Perception of the local community about the conservation and management of agroforestry trees planted in the study area

Table 7 presents the identification of the perception of the local community on conserving the management and preserving the Ibanda-Makera buffer zone by planting agroforestry trees; 22.1% of the respondents stated that they were satisfied with the management of the Ibanda-Makera forest. Most respondents (96.1%) reported that the implemented EbA intervention has no negative effects. However, a few respondents mentioned that there was an impact such as a lack of firewood because the local community is not allowed to enter the forest and a lack of access to timber for use in construction. About 80% of the respondents stated that their livelihoods were improved by the EbA interventions while 20% reported that their livelihoods were not improved (Table 7).

Table 7: Perceptions of the local community about the conservation and management of agroforestry intervention in the study area

		N	%
Satisfaction of the local community about the management of Ibanda-Makera Natural Forest	Satisfied	45	22.1
	Unsatisfied	159	77.9
The improvements in community livelihood due to EbA implementation measures for restoring the Ibanda-Makera Natural Forest	No	41	20.1
	Yes	163	79.9
Any negative impacts on community livelihoods from the implementation of EbA measures	No	196	96.1
	Yes	8	3.9
Any other alternative interventions respondents proposed for the Ibanda-Makera to mitigate or solve problems of climate change, flooding, and soil erosion events	No	166	81.4
	Yes	38	18.6

Respondents provided numerous insights on how their livelihoods have improved, which were summarized into themes including tourism, income generation, climate regulation, soil conservation, biodiversity conservation, and medicinal resources (Table 8).

Table 8: Improvements in local community livelihood from the implementation of EbA measures in the study area

Themes	**Explanations**
Tourism and Income Generation	69 Responses highlighted that tourism generates income through paying money from the visitors. e.g. buying food, and honey
Climate Regulation	26 responses mention the role of Ibanda-Makera in climate regulation, including mitigating climate change effects and regulating climate patterns. E.g. source of rainfall
Soil Conservation and Stability	77 respondents mentioned that Ibanda-Makera improves their livelihood due to the contribution of soil conservation through practices such as responsible land management, reforestation, agroforestry planting trees in the area near the Ibanda-Makera Natural Forest and erosion control measures, which are essential for preserving ecosystems and supporting agricultural productivity.
Biodiversity Conservation	7 Responses highlighted the Ibanda-Makera Natural Forest's role in conserving biodiversity by providing habitats for animals and preserving natural ecosystems.
Medicinal Resources	2responses mentioned that Ibanda-Makera improves their livelihood by providing medicinal resources, such as plants for traditional medicine.
Employment Opportunities	32 responses emphasize the employment opportunities created by the planting of agroforestry trees around the Ibanda-Makera Natural Forest, particularly in local communities, and another project operating in proximity to the Ibanda-Makera Natural Forest, offering employment opportunities for residents in rural and remote areas.
Rainfall Attraction	19 responses discussed trees potentially attract rainfall, which can benefit agricultural productivity and ecosystem health, water resource management **E.g.** fetching of water.

Some respondents indicated that Ibanda-Makera has not improved their livelihoods; they stated that the forest is for government control and ownership. The repeated use of phrases like "it is for the government" suggests people believe the government controls the resources. The frequent mention of "government control" (e.g., "it is for government," "government controls it") highlights a

widespread perception of government authority in decision-making and oversight. Additionally, references to features like the "protected forest" and benefits attributed solely to the government.

Table 9 represents some alternative interventions proposed for the Ibanda-Makera to mitigate or solve problems of climate change, flooding, and soil erosion events. Almost 20% of respondents suggested alternative interventions for the Ibanda-Makera to help mitigate or solve issues related to flooding, soil erosion, and climate change. Among them, many respondents mentioned the need for fencing to prevent animals from encroaching into farmlands surrounding the natural forest, thereby safeguarding crops from damage.

Table 9: Alternative interventions proposed for the Ibanda-Makera to mitigate or solve problems of climate change, flooding, and soil erosion events.

Themes	**Explanations**
Fencing to protect agricultural resources	19 respondents emphasize the importance of putting up fences around Ibanda-Makera to prevent animals or monsters from damaging crops in surrounding farms.
Planting native trees and other trees	8 Planting native tree species and other trees is highlighted as a measure to contribute to backing the original and conservation of the Ibanda-Makera Natural Forest.
Enhancing Security Measures	6 respondents suggest the need for additional security measures, such as security guards, to complement fencing efforts.
Tourism and Economic Benefits	5 respondents mentioned the potential economic benefits of tourism associated with environmental protection are mentioned by some respondents and protecting natural resources can attract tourists interested in wildlife observation.

4.12. Purpose of protecting the Ibanda-Makera Natural Forest buffer zone

An overwhelming 99.5% of respondents emphasized climate change regulation as the main objective of protecting the Ibanda-Makera Natural Forest (Figure 15). Additionally, biodiversity

conservation (98.53%) and the restoration of Ibanda Makera (97.06%) were responded also as significant purposes. Notably, climate change regulation, biodiversity conservation, and the restoration of Ibanda-Makera emerged as the top priorities based on the highest number of responses in the protection of the Ibanda-Makera forest.

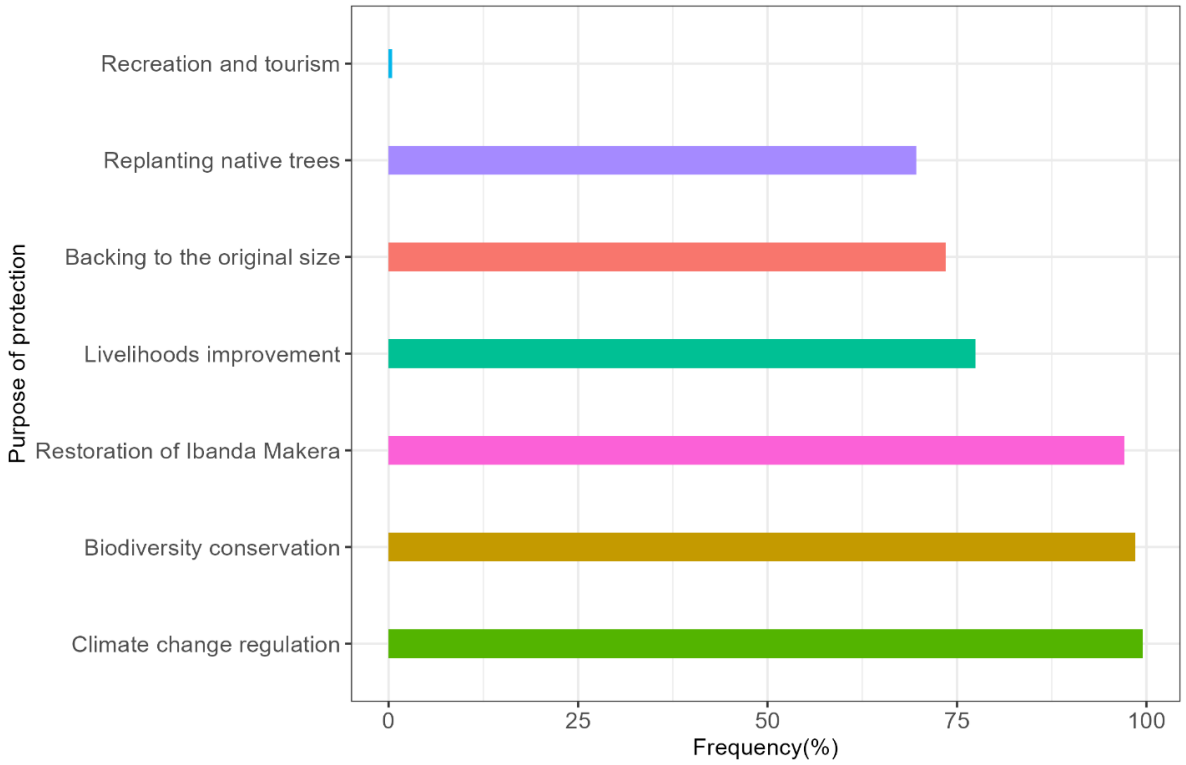

Figure 14: Local community perceptions about the purposes of protecting the Ibanda-Makera Natural Forest.

5. DISCUSSION

Agroforestry plays a pivotal role in Ecosystem-based Adaptation (EbA). This study assessed the ecological and socio-economic impacts of agroforestry interventions on smallholder farms adjacent to the Ibanda-Makera Natural Forest, focusing on tree status and agroforestry species planted under the REMA (LDCF) project and examining both ecological contributions and socio-economic impacts in terms of EbA. Additionally, the study explores smallholder farmers' perceptions of agroforestry practices on their farms. The research findings underscored a significant awareness among farmers about climate change, characterized by prolonged periods of unusual weather patterns such as excessive sunlight observed in 2016 and prolonged sunlight in 2023. Farmers attributed these changes to both natural variations and human activities, reflecting climate change as a pressing ecological and social challenge (Dietz et al., 2020). The study highlights farmers' recognition of the positive impacts of EbA projects in the study area,

5.1. Types and status of agroforestry trees in the study area

Agroforestry, where trees and woody perennials are cultivated alongside crops or livestock, is increasingly utilized to address these challenges facing the rural economy (Mahmood & Zubair, 2020). Agroforestry plays a crucial role in conserving soil through various methods. By strategically planting trees and shrubs within agricultural areas, agroforestry reduces soil erosion caused by wind and water impact(Nayak et al., 2023). In this study, Respondents defined agroforestry as the practice of combining trees with crops on the same land to enhance soil productivity, where both trees and crops grow together without negatively affecting crop growth. Interviews with local community members on their farms revealed that *Grevillea robusta, Calliandra calothyrsus, Cedrela serrata*, and *Maesopsis eminii* were part of the REMA (LCDF) project's planting efforts. *Grevillea robusta* emerged as the predominant species, valued for its contributions to timber production, firewood, stakes, erosion control, landslide prevention, and supporting local livelihoods through animal fodder, timber, firewood, and shading. Tree roots stabilize the soil, preventing erosion and providing protection against landslides in hilly terrain. Moreover, agroforestry often includes species with deep roots that enhance soil structure and increase water infiltration, further reducing soil erosion (Nayak et al., 2023). Tree planting began in 2018, with replacements for deceased trees occurring in 2019 and ongoing throughout the year, showing robust growth and survival. Respondents indicated that the planted trees were owned by

local community members. The respondents highlighted soil erosion control as the primary purpose, and they mentioned that landslide control and satisfying local community livelihoods were the major importance. Agroforestry is highly valuable due to its multiple benefits in supplying food and essential resources, including fuelwood, materials for stakes, fibers, timber, medicinal extracts, oils, fruits, and animal fodder (Sobola & Amadi, 2017). Previous studies on the status of agroforestry trees in smallholder farms and Ecosystem-based Adaptation were documented in the literature review (Harvey et al., 2017); Lasco et al., 2014; Locatelli, Pavageau, et al., 2015; Mbow, Smith, et al., 2014; Lasco et al., 2014).

5.2. Ecological and socio-economic benefits of agroforestry of planting agroforestry and contribution to climate change adaptation

Respondents highlighted the dual benefits of agroforestry tree plantations for ecological and socio-economic resilience within local communities. Socio-economic benefits such as climate change adaptation through strategies like shade, windbreaks, and microclimatic regulation, as well as timber production, fodder for animals, increased farm productivity, employment opportunities, livelihood enhancement, and income generation were emphasized. Recent research underscores agroforestry's potential to enhance income for smallholders, strengthen food security, promote gender equality, and stimulate cultural activities in rural areas (Mukhlis & Rizaludin, 2022a). Agroforestry also plays a crucial role in mitigating soil erosion, improving soil quality, increasing vegetative cover, boosting land productivity, and elevating farmers' living standards through sustained farm productivity(Mukhlis & Rizaludin, 2022b). Ecologically, the practice enhances ecosystem services by conserving biodiversity and preserving soil, making it pivotal for smallholder farms. Agroforestry further enhances ecosystem services by improving soil structure, increasing carbon sequestration, and enhancing water retention (Mukhlis & Rizaludin, 2022a).

5.3. Ecosystem services provided by agroforestry tree planting in the study area

Several ecosystem services, including provisioning, regulating, cultural, and supporting benefits as well as environmental benefits, are provided by agroforestry (Pantera et al., 2021). The study surveyed respondents on the ecosystem services provided by agroforestry trees on their farms, categorized into provisioning, regulating, supporting, and cultural services. Results showed strong agreement among respondents regarding certain provisioning services such as firewood and stakes

production. For regulating services, soil erosion control and air quality were also highly valued. For Supporting services, soil stabilization and fertility received positive recognition. However, cultural services, landscape beauty, and recreation scored high in agreement among respondents. Agroforestry systems, which integrate trees, crops, and animals, offer numerous benefits including improved soil fertility, reduced erosion, enhanced water quality, increased biodiversity, aesthetic improvements, and carbon sequestration. These benefits are observed across spatial and temporal scales (Jose, 2013). Compared to monoculture systems, agroforestry systems excel in terms of environmental sustainability, social acceptance, and economic viability due to their diverse inputs and outputs, contributing positively to soil quality, biodiversity conservation, air and water quality, carbon mitigation, and addressing food security concerns (Mohd Salleh & Harun, 2013; Jose, 2009; Quandt et al., 2023). Agroforestry is a versatile approach that enhances biodiversity conservation while promoting economic and social development within local communities (Willmott et al., 2023)

5.4. Perceptions of smallholder farmers about agroforestry tree planting on their farms and the implemented EbA intervention measure

Planted agroforestry trees are important for many reasons. Plantation in the farms adjacent to the Ibanda-Makera Natural Forest acts as erosion control and landslide through infrastructure like water canals, trenches, and terraces was widely recognized as highly effective, followed closely by the promotion of agroforestry trees. A recent study highlighted that Agroforestry provides environmental benefits such as erosion prevention, improved soil fertility, and natural pest control, enhancing natural capital through diverse ecosystem services like shelter, wind protection, and watershed conservation (Hillbur, 2014; Newman, 2021). The study identified the LDCF (REMA) project as a prominent institution responsible for promoting agroforestry trees within EbA intervention measures and the research indicated that local communities were most beneficiaries of EbA intervention measures, particularly through the promotion of agroforestry trees and Erosion control measures but the findings indicated that, they were not aware of the consideration of local knowledge in effective EbA strategies, or planting of native tree species. An enhanced understanding of the effectiveness of EbA initiatives will bolster arguments for heightened donor investment and encourage governments to integrate EbA into pertinent ministries and budget allocations (Perrez, 2020). Ecosystem-based adaptation (EbA) uses biodiversity and ecosystem

services to help communities adapt to climate change impacts. Agroforestry can function as a type of ecosystem-based adaptation (EbA) by bolstering the resilience of agricultural systems against climate change effects like droughts, floods, and extreme temperatures (Locatelli, Pavageau, et al., 2015). Ecosystem-based adaptation (EbA) strategies offer a diverse array of institutional, socio-cultural, ecological, and economic advantages. EbA approaches support the restoration and preservation of ecosystems, thereby fostering ecosystem health and vitality (Muthee et al., 2017). EbA activities include protecting, restoring, and managing ecosystems, processes, and biodiversity. This approach also involves implementing specific agricultural practices like mulching, terracing, and establishing tree plantations (Donatti et al., 2020) to complement or substitute other adaptation options."

Ecosystem-based adaptation (EbA) strengthens community resilience and minimizes vulnerabilities by using biodiversity and ecosystem services fairly. It prioritizes the needs of people who depend on natural resources and are highly affected by climate change. EbA delivers direct and indirect advantages that enhance resilience, including better food security, risk reduction, access to clean water and medicines, and local climate control. Moreover, it often creates additional benefits vital for sustainable development, such as carbon capture, habitat restoration, and availability of medicinal resources. EbA measures are economically viable and can supplement or replace other adaptation strategies.

Respondents mentioned that there was an impact such as a lack of firewood because the local community is not allowed to enter the forest and a lack of access to timber for use in construction. However, the implemented EbA intervention measure increases the livelihood of the local community.

6. CONCLUSION AND RECOMMENDATIONS

6.1. Conclusion

This study has focused on evaluating the agroforestry tree plantations as an ecosystem-based adaptation (EbA) strategy for local community farms neighboring the Ibanda-Makera Natural Forest, aiming to mitigate the diverse impacts of climate change. The predominant species identified in these agroforestry systems was *Grevillea robusta*. Currently, these plantations provide crucial ecosystem services including soil erosion and landslide control, air quality improvement, climate regulation, and a sustainable supply of stakes and firewood for daily community needs. Local communities perceive that agroforestry tree plantations have bolstered socio-ecological resilience against climate change impacts. However, inadequate follow-up and maintenance have resulted in some planted trees perishing. Respondents also highlighted both positive and negative effects of the EbA intervention. Positive outcomes include enhanced livelihoods, while negative effects include restricted access to timber from the Ibanda-Makera Natural Forest, particularly affecting nearby communities due to firewood shortages.

To address these challenges, community members recommend planting native tree species and implementing sustainable forest management practices to restore and conserve the Ibanda-Makera Natural Forest. They advocate for controlled access to gather firewood, fetch water, and harvest trees for construction purposes. Awareness of EbA interventions remains limited among a significant portion of the local population. Additionally, the study identified supplementary EbA measures introduced after the establishment of agroforestry plantations, such as fruit tree cultivation for food security and the implementation of trenches and terraces by the EPCOTGE company to mitigate soil erosion and landslides. There is a recognized need for continuous engagement with local communities to enhance comprehension of EbA interventions and to incorporate traditional practices that support EbA implementation.

This study underscores the critical importance of policymakers acknowledging the effectiveness of EbA interventions and integrating EbA principles into national and international climate adaptation policies, such as national adaptation plans, to fortify resilience within vulnerable communities.

6.2. Recommendation

The study proposes various measures to support the conservation of the Ibanda-Makera Natural Forest and its adjacent area. These measures include:

- Establishing a buffer zone to protect adjacent farms from wildlife and promoting the cultivation of native and medicinal plant species outside the forest to reduce human encroachment.
- Increasing agroforestry plantations near homesteads reduces the demand for timber and firewood, thereby enhancing forest protection. Additionally, planting fruit trees in agroforestry systems near homes can enhance food security.
- Encouraging environmentally sustainable lifestyles and developing legal frameworks to deter illegal activities.
- Emphasizing the planting of resilient native tree species in the buffer zone of the Ibanda-Makera Natural Forest, specifically suited to the Eastern Province, to ensure sustainable management and biodiversity conservation.

Moreover, the study highlights the effectiveness of traditional knowledge as a strategy for Ecosystem-based Adaptation (EbA) and emphasizes raising awareness among local community farmers about the potential of agroforestry as an EbA strategy in Rwanda. It proposes the creation of monitoring and evaluation frameworks tailored to assess the impact of agroforestry interventions in achieving EbA objectives, which will provide crucial data for policymakers and program managers. Lastly, the study advocates for capacity building among farmers, extension services, and local authorities to underscore the importance of EbA initiatives.

REFERENCES

Akter, R., Hasan, M. K., Kabir, K. H., Darr, D., & Roshni, N. A. (2022). Agroforestry systems and their impact on livelihood improvement of tribal farmers in a tropical moist deciduous forest in Bangladesh. *Trees, Forests and People*, *9*(August), 100315. https://doi.org/10.1016/j.tfp.2022.100315

Andrade, C., Fraga, H., & Santos, J. A. (2014). Climate change multi-model projections for temperature extremes in Portugal. *Atmospheric Science Letters*, *15*(2), 149–156. https://doi.org/10.1002/asl2.485

Bernard, F., Bourne, M., Garrity, D., Neely, C., & Chomba., S. (2019). *Policy Gaps and Opportunities for Scaling Agroforestry in sub-Saharan Africa: Recommendations from a policy review and recent practice*. *August*, 1–12. chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://regreeningafrica.org/wp-content/uploads/2019/11/PolicyBrief_RegreeningAfrica_web_single-pages-1.pdf

Bizuru, E., Nyandwi, E., Nshutiyayesu, S., & Kabuyenge, J. P. (2011). Inventory and mapping of threatened remnant terrestrial ecosystems outside protected areas through Rwanda. *Final Report*, 65. http://www.biodiv.be/rwanda/implementation/rapport-et-documents-nationaux/inventory-and-mapping-threatened-remnant-terrestrial-ecosystems-outside/download/en/2/inventory-and-mapping-of-threatened-remnant-terrestrial-ecosystems-outside-protected-areas-thro

Dietz, T., Shwom, R. L., & Whitley, C. T. (2020). Climate change and society. *Annual Review of Sociology*, *46*, 135–158. https://doi.org/10.1146/annurev-soc-121919-054614

Dinesh, D., Vermeulen, S., Bacudo, I., Martinez-Baron, D., Castro-Nunez, A., Hedger, M., Huyer, S., Iversen, P., Laure, A., Loboguerrero Rodriguez, A.-M., Martius, C., Neufeldt, H., Nyasimi, M., Richards, M., & Wollenberg, L. (2016). *Options for agriculture at Marrakech climate talks: messages for SBSTA 45 agriculture negotiators*. *16*. https://www.cifor.org/library/6194/

Donatti, C. I., Harvey, C. A., Hole, D., Panfil, S. N., & Schurman, H. (2020). Indicators to measure the climate change adaptation outcomes of ecosystem-based adaptation. *Climatic Change*, *158*(3–4), 413–433. https://doi.org/10.1007/s10584-019-02565-9

Duffy, C., Toth, G. G., Hagan, R. P. O., McKeown, P. C., Rahman, S. A., Widyaningsih, Y., Sunderland, T. C. H., & Spillane, C. (2021). Agroforestry contributions to smallholder farmer food security in Indonesia. *Agroforestry Systems*, *95*(6), 1109–1124. https://doi.org/10.1007/s10457-021-00632-8

Dwivedi, R. P., Kareemulla, K., Singh, R., Rizvi, R. H., & Chauhan, J. (2007). Socio-economic analysis of agroforestry systems in Western Uttar Pradesh. *Indian Research J. Ext. Edu*, *7*(2–3), 18–22. http://www.seea.org.in/vol7-2-3-2007/06.pdf

Fandohan, B., Gouwakinnou, G. N., Fonton, N. H., Sinsin, B., & Liu, J. (2013). Impact des changements climatiques sur la répartition géographique des aires favorables à la culture et à la conservation des fruitiers sous-utilisés : cas du tamarinier au Bénin. *Revue de Biotechnologie, Agronomie, Société et Environnement*, *Volume 17*(numéro 3), 450–462. http://popups.ulg.ac.be/Base/document.php?id=10186

Habakubaho, T. (2021). *Building the capacity of Rwanda ' 's government to advance the National Adaptation Planning Process Feasibility Study*. *January*.

Harvey, C. A., Martínez-Rodríguez, M. R., Cárdenas, J. M., Avelino, J., Rapidel, B., Vignola, R., Donatti, C. I., & Vilchez-Mendoza, S. (2017). The use of Ecosystem-based Adaptation practices by smallholder farmers in Central America. *Agriculture, Ecosystems and Environment*, *246*(November 2016), 279–290. https://doi.org/10.1016/j.agee.2017.04.018

Harvey, C. A., Rakotobe, Z. L., Rao, N. S., Dave, R., Razafimahatratra, H., Rabarijohn, R. H., Rajaofara, H., & MacKinnon, J. L. (2014). Extreme vulnerability of smallholder farmers to agricultural risks and climate change in Madagascar. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *369*(1639). https://doi.org/10.1098/rstb.2013.0089

Hillbur, S. (2014). *Farmer's perceptions of agroforestry*. *2014*, 42.

Hope, K., & Mupenzi, C. (2020). Impact of Agriculture Practices on Poverty Reduction Case of Irrigation in Kirehe District of Rwanda. *East African Journal of Science and Technology*, *11*(1), 92–109. http://eajournal.unilak.ac.rw/EAJST

Jensen, D. A., Rao, M., Zhang, J., Grøn, M., Tian, S., Ma, K., & Svenning, J. C. (2021). The potential for using rare, native species in reforestation– A case study of yews (Taxaceae) in China. *Forest Ecology and Management*, *482*(November 2020). https://doi.org/10.1016/j.foreco.2020.118816

Jones, G. V., & Alves, F. (2012). Impact of climate change on wine production: A global overview and regional assessment in the Douro valley of Portugal. *International Journal of Global Warming*, *4*(3–4), 383–406. https://doi.org/10.1504/IJGW.2012.049448

Jose, S. (2009). Agroforestry for ecosystem services and environmental benefits: An overview. *Agroforestry Systems*, *76*(1), 1–10. https://doi.org/10.1007/s10457-009-9229-7

Jose, S. (2013). *Agroforestry for ecosystem services and environmental benefits : An overview Agroforestry for ecosystem services and environmental benefits : an overview*. *December*. https://doi.org/10.1007/s10457-009-9229-7

Kissi, A. E., Villamor, G. B., & Abbey, G. A. (2023). Ecosystem-Based Adaptation Practices of Smallholder Farmers in the Oti Basin, Togo: Probing Their Effectiveness and Co-Benefits. *Ecologies*, *4*(3), 535–551. https://doi.org/10.3390/ecologies4030035

Lasco, R. D., Delfino, R. J. P., Catacutan, D. C., Simelton, E. S., & Wilson, D. M. (2014). Climate risk adaptation by smallholder farmers: The roles of trees and agroforestry. *Current Opinion in Environmental Sustainability*, *6*(1), 83–88. https://doi.org/10.1016/j.cosust.2013.11.013

Lin, B. B. (2014). Proteomics Potential and Its Contribution toward Sustainable Agriculture. *Agroecology, Ecosystems, and Sustainability*, *January*, 168–197. https://doi.org/10.1201/b17775-12

Lindner, M., Nikinmaa, L., Brang, P., Cantarello, E., & Seidl, R. (2020). Enhancing resilience to address challenges in forest management. *How to Balance Forestry and Biodiversity Conservation? A View across Europe*, *November*, 147–155.

Locatelli, B., Catterall, C. P., Imbach, P., Kumar, C., Lasco, R., Marín-Spiotta, E., Mercer, B., Powers, J. S., Schwartz, N., & Uriarte, M. (2015). Tropical reforestation and climate change: Beyond carbon. *Restoration Ecology*, *23*(4), 337–343. https://doi.org/10.1111/rec.12209

Locatelli, B., Pavageau, C., Pramova, E., & Di Gregorio, M. (2015). Integrating climate change mitigation and adaptation in agriculture and forestry: Opportunities and trade-offs. *Wiley Interdisciplinary Reviews: Climate Change*, *6*(6), 585–598. https://doi.org/10.1002/wcc.357

Loewe, M., & Rippin, N. (2015). The Sustainable Development Goals of the Post-2015 Agenda: Comments on the OWG and SDSN Proposals. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.2567302

Mahmood, M. I., & Zubair, M. (2020). Farmer's Perception of and Factors Influencing Agroforestry Practices in the Indus River Basin, Pakistan. *Small-Scale Forestry*, *19*(1), 107–122. https://doi.org/10.1007/s11842-020-09434-9

Mbow, C., Smith, P., Skole, D., Duguma, L., & Bustamante, M. (2014). Achieving mitigation and adaptation to climate change through sustainable agroforestry practices in Africa. *Current Opinion in Environmental Sustainability*, *6*(1), 8–14. https://doi.org/10.1016/j.cosust.2013.09.002

Mbow, C., Van Noordwijk, M., Luedeling, E., Neufeldt, H., Minang, P. A., & Kowero, G. (2014). Agroforestry solutions to address food security and climate change challenges in Africa. *Current Opinion in Environmental Sustainability*, *6*(1), 61–67. https://doi.org/10.1016/j.cosust.2013.10.014

Mercer, J., Kelman, I., Alfthan, B., & Kurvits, T. (2012). Ecosystem-based adaptation to climate change in Caribbean small island developing states: Integrating local and external knowledge. *Sustainability*, *4*(8), 1908–1932. https://doi.org/10.3390/su4081908

Mohd Salleh, A., & Harun, N. Z. (2013). The environmental benefits of agroforestry systems about social sustainability. *International Conference on Green Concept in Architecture and Environment, May*, 301–317.

Montagnini, F., & Finney, C. (2011). Payments for environmental services in Latin America as a tool for restoration and rural development. In *Ambio* (Vol. 40, Issue 3). https://doi.org/10.1007/s13280-010-0114-4

Montagnini, F., & Nair, P. K. R. (2004). Carbon sequestration: An underexploited environmental

benefit of agroforestry systems. *Agroforestry Systems*, *61–62*(1–3), 281–295. https://doi.org/10.1023/B:AGFO.0000029005.92691.79

Morton, J. F. (2007). The impact of climate change on smallholder and subsistence agriculture. *Proceedings of the National Academy of Sciences of the United States of America*, *104*(50), 19680–19685. https://doi.org/10.1073/pnas.0701855104

Mukhlis, I., & Rizaludin, M. S. (2022a). *Understanding Socio-Economic and Environmental Impacts of Agroforestry Understanding Socio-Economic and Environmental Impacts of Agroforestry on Rural Communities*. *March*.

Mukhlis, I., & Rizaludin, M. S. (2022b). *Understanding Socio-Economic and Environmental Impacts of Agroforestry Understanding Socio-Economic and Environmental Impacts of Agroforestry on Rural Communities*. *April*.

Mukhlis, I., Syamsu Rizaludin, M., & Hidayah, I. (2022). Understanding Socio-Economic and Environmental Impacts of Agroforestry on Rural Communities. *Forests*, *13*(4), 1–13. https://doi.org/10.3390/f13040556

Muthee, K., Mbow, C., Macharia, G., & Leal Filho, W. (2017). Ecosystem-Based Adaptation (EbA) as an Adaptation Strategy in Burkina Faso and Mali. *Climate Change Management*, *March*, 205–215. https://doi.org/10.1007/978-3-319-49520-0_13

Nayak, P., Upadhyay, L., Jammu, T., Pancholi, R., & Yousuf, M. (2023). *The Role of Agroforestry in Soil Conservation and Sustainable Crop Production : A Comprehensive Review*. *November*. https://doi.org/10.9734/IJECC/2023/v13i113478

Newman, J. (2021). Smallholder Farmers in Rwanda; survey of tree species, tree crown cover and motivations for planting. *Green Education: An A-to-Z Guide*, *November*. https://doi.org/10.4135/9781412974615.n116

Pantera, Mosquera-Losada, M. R., Herzog, F., & den Herder, M. (2021). Agroforestry and the environment. *Agroforestry Systems*, *95*(5), 767–774. https://doi.org/10.1007/s10457-021-00640-8

Pasquini, L., & Cowling, R. M. (2015). Opportunities and challenges for mainstreaming ecosystem-based adaptation in local government: evidence from the Western Cape, South Africa. *Environment, Development and Sustainability*, *17*(5), 1121–1140. https://doi.org/10.1007/s10668-014-9594-x

Perrez, F. X. (2020). The role of the United Nations Environment Assembly in emerging issues of international environmental law. *Sustainability (Switzerland)*, *12*(14), 20–21. https://doi.org/10.3390/su12145680

Persha, L., Fischer, H., Chhatre, A., Agrawal, A., & Benson, C. (2010). Biodiversity conservation and livelihoods in human-dominated landscapes: Forest commons in South Asia. *Biological Conservation*, *143*(12), 2918–2925. https://doi.org/10.1016/j.biocon.2010.03.003

Protected, S. O. F. (n.d.). *State of protected and conserved areas in Eastern and Southern Africa* (Issue 1).

Quandt, A., Neufeldt, H., & Gorman, K. (2023). Climate change adaptation through agroforestry: opportunities and gaps. *Current Opinion in Environmental Sustainability*, *60*, 101244. https://doi.org/10.1016/j.cosust.2022.101244

REMA. (2019). *Building resilience of communities living in degraded forests, savannahs, and wetlands of Rwanda through an Ecosystem-based Adaptation (EbA) approach project*.

REMA. (2021). *Research report ROLE Importance of Ibanda Makera environmental conservation in the eastern part of Rwanda*. *December*.

REMA. (2023). *REPORT REMA*. *June*, 1–9.

Roberts, D., Boon, R., Diederichs, N., Douwes, E., Govender, N., Mcinnes, A., Mclean, C., O'Donoghue, S., & Spires, M. (2012). Exploring ecosystem-based adaptation in Durban, South Africa: "learning-by-doing" at the local government coal face. *Environment and Urbanization*, *24*(1), 167–195. https://doi.org/10.1177/0956247811431412

S. Ernesta, S. S. (2019). *Occasional Paper Ecosystem-based Adaptation in South African Coastal*

Cities. *May*, 0–39. https://www.jstor.org/stable/resrep28396

Seddon, N., Daniels, E., Davis, R., Chausson, A., Harris, R., Hou-Jones, X., Huq, S., Kapos, V., Mace, G. M., Rizvi, A. R., Reid, H., Roe, D., Turner, B., & Wicander, S. (2020). Global recognition of the importance of nature-based solutions to the impacts of climate change. *Global Sustainability*, *3*. https://doi.org/10.1017/sus.2020.8

Sirmah, P., Mengich, E., Rotich, J., & Odwori, P. O. (2017). Agroforestry trees in Kapsaret, Kenya: Socio-economic perspectives influencing availability, preference, and utilization 2. *International Journal of Agroforestry and Silviculture*, *5*(5), 315–325. https://www.researchgate.net/publication/330442124

Sobola, O. O., & Amadi, D. (2017). *The Role of Agroforestry in Environmental Sustainability The Role of Agroforestry in Environmental Sustainability*. *May 2015*. https://doi.org/10.9790/2380-08512025

Vasseur, L., Jones, M. (2015). Adaptation and resilience in the face of climate change : protecting the conditions of emergence through good governance. *(IUCN, Climate Change Adaptation Group Leader/Brock University)*, 1–3.

Vignola, R., Harvey, C. A., Bautista-Solis, P., Avelino, J., Rapidel, B., Donatti, C., & Martinez, R. (2015). Ecosystem-based adaptation for smallholder farmers: Definitions, opportunities and constraints. *Agriculture, Ecosystems and Environment*, *211*, 126–132. https://doi.org/10.1016/j.agee.2015.05.013

Wanjira, E. (2019). Smallholder Farmers' Perception and Practice of on-Farm Tree Species Diversification in Siaya County, Western Kenya. *Research Gate*, *3*, 148. https://doi.org/10.13140/RG.2.2.26405.73441

Willmott, A., Willmott, M., Grass, I., Lusiana, B., & Cotter, M. (2023). Harnessing the socio-ecological benefits of agroforestry diversification in social forestry with functional and phylogenetic tools. *Environmental Development*, *47*(June), 100881. https://doi.org/10.1016/j.envdev.2023.100881

Woroniecki, S., Wamsler, C., & Boyd, E. (2019). The promises and pitfalls of ecosystem-based

adaptation to climate change as a vehicle for social empowerment. *Ecology and Society*, *24*(2). https://doi.org/10.5751/ES-10854-240204

Annex 1: COMMUNITY SURVEY

Topic: Evaluation of the ecological and socio-economic impacts of agroforestry interventions on smallholder farms adjacent to the Ibanda-Makera Natural Forestry, Kirehe District, Rwanda

My name is ……

This survey seeks to evaluate the agroforestry plantation on smallholder farms and their impact on the livelihoods of the community and Ecosystem Adaptation (EbA) measures carried out by the Rwanda Environmental Management Authority (REMA).

I hereby request your opinion and contribution to the interview that help me to assess the status of planted agroforestry trees in the region and how EbA intervention measures have contributed to climate change adaptation as well as the improvements of community livelihoods.

This information will be used in the improvement and adaptation to climate change adaptation and mitigation.

Informed consent:

I agree to be my interviewee. I understand that all information I provide for this study will be treated confidentially. I understand that in any report on the results of this research, my identity will remain anonymous.

SECTION A

Date…….

District/sector/cell/village……

Respondents number……

Age……...

Gender: Male or Females……

How long do you live in this area?...

Latitude: Longitude:

Education completed.

A. Primary school

B. Secondary school or TVET

C. University or other high institution

D. Never went to school.

GET A COMMON UNDERSTANDING OF THE EbA PROJECT

1. Do you know what climate change is?
a. yes
b. No

If yes, what is meant by climate change?.....

2. Have you observed changes in the weather?
a. Yes
b. No

If yes, what have you observed?.....

3. Have you heard of the Ecosystem-based Adaptation projects implemented in this district?
   a. Yes
   b. No
4. Do you know what the EbA projects are supposed to accomplish?

a. Yes
b. No

Professional Activities

ASSESSMENT OF AGROFORESTRY TREE PLANTATION

a. What does agroforestry mean to you?
b. Are there trees planted in your farmland?
c. What species are they and how many? (For each species, indicate the number on their land)
d. What is a good agroforestry species?
e. Who planted the agroforestry trees?

1. LDCF II(REMA) project 2. Government 3. Self-sponsored 4. Others(specify)

Species name

Species name	Who planted it? LDCF II (REMA) project Government Self-sponsored Others (Specify)	Used for agroforestry	When planted
Greveria Robusta			
Alnus acuminata			
Calliandra callotirosis			
Leucena Lecosifala			
Acacia			

Others			

f. What species of agroforestry species do you have on your farm?

g. What organization or institution funded the planting?

1. LDCF II (REMA) 2. Government 3. Self-sponsored 4. Others(specify)

h. What are the ecological and socio-economic benefits of planting agroforestry?

A. Socio-economic values of planting agroforestry trees (all that apply)

1. Increase farm productivity (smallholder farmers by integrating crops, livestock, and trees, increase food security)
2. Source of income(money)
3. Improved food security and nutrition
4. Enhanced livelihood opportunities (sales of timber, fruits)
5. Climatic change adaptation (provide shade, windbreaks, and microclimatic regulation
6. reducing the impacts of extreme weather events on crops
7. Employment opportunities (tree planting, maintenance, and harvesting)
8. Timber
9. Fodder for animals
10. Medicinal plants
11. Other
12. None
13. All are applied.

B. Ecological benefits of planting agroforestry trees

1. Biodiversity conservation (creating habitat for various plant and animal species)
2. Soil health and fertility
3. Water resource management
4. Enhance ecosystem services.
5. Soil conservation
6. Other
7. None
8. All are applied.

i. Who is the owner of the trees?

1. Government 2. Local community 3. Myself 4. I don't know 5. Other (specify)

j. Why were trees planted on your farmland?

1. Soil erosion control 2. Landslide control 3. Satisfy local community livelihood 4. Other (specify)

g. Are you allowed to cut the planted agroforestry trees whatever you want for personal use or needs?

h. What are the benefits obtained from agroforestry trees?

Please select the number below that represents where the agroforestry contributed to one of the following listed goods and services.

	Strongly disagree (1)	**Disagree (2)**	**Neither disagree nor agree (3)**	**Agree (4)**	**Strongly agree (5)**
Provisional services					
1. Food provision					
2. Forage production					
3. Timber (construction materials)					
5. Handcrafts					
6. Firewoods					
7. Stakes					
8. Medicinal resources					
9.Others(specify)					
Regulating services					
Landscape restoration					
Carbon sequestration					
Air quality and local climate regulation					
Flood /landslide control					
Soil erosion control					

Others(specify)					
Supporting Services					
Wildlife habitat provision					
Maintenance of Biological Diversity					
3. Soil fertility					
4. soil stabilization					
Cultural services					
Landscape beauty and recreation (landscape restoration)					
Recreation and ecotourism					
Cultural and religious values					
Aesthetic inspiration					
Other (specify					

h. From the agroforestry trees, does the local community need to expand into new areas of agroforestry trees? A. Yes B. No

G. Identification of EbA-based restoration measures in the study areas.

EbA intervention measures	Code(**V**)	What institution do you think developed this	How useful is this intervention?	Who benefits from this intervention? Local community

		intervention in this area? Name of the institution I don't know	Very effective Moderate effective Not effective I am not aware of this intervention.	People in Kigali Government No one I don't know.
Promoting agroforestry trees				
Consideration of local knowledge and traditional practices				
Erosion control by building water canals, trenches, and terraces				
Planting of native tree species				
Community-based conservation				
Others? (Specify)				

Perception of the local community about the conservation and the management of agroforestry intervention in the study area

1. What is the purpose of protecting the Ibanda Makera Natural Forest buffer zone?

a) Climate change regulation
b) Biodiversity conservation
c) Restoration of Ibanda-Makera
d) Replanting native trees
e) Backing to the original size
f) Improvements in local community livelihoods
g) Others(specify)
h) I don’t know.

2. What is your satisfaction with the way Ibanda Makera natural forest is managed?

a) Satisfied

b) Unsatisfied

Explain why you are satisfied or unsatisfied

……

……

3. Do you think the EbA implementation measures for restoring the Ibanda Makera natural forest have improved your livelihoods?

a) Yes

b) No

If yes, what are the 3 or 4 improvements in your livelihoods? Specify

……

……

If not, why not?

4. Are there any negative impacts on your livelihoods from the implementation of EbA measures?

a) Yes

b) No

If yes, what are those impacts?

5. Do you think there are other alternative interventions you would propose for the Ibanda Makera to mitigate or solve problems of climate change, flooding, and soil erosion events?