Maastricht University

Smallholder coffee farmers motivations and incentives for agroforestry implementation in Uganda

Andrei Ioneanu, Akshat Sungkur, Mate Balogh,
Antonio Hernandez Cerdo, Jorge Garcia Izquierdo
SBE - Business Analytics
University of Maastricht
Maastricht

July 22, 2025

Abstract

Agroforestry-based carbon farming represents an opportunity for smallholder coffee farmers to enhance soil quality, increase biodiversity, and generate additional income through carbon credits. This study explores the theoretical foundations, and key aspects influencing agroforestry adoption in coffee farms. It explores economic, social, and environmental incentives that influence farmer participation while highlighting existing barriers such as financial constraints, knowledge gaps, and policy implementation.

The findings underline the importance of integrating policy support with initiatives to ensure the sustainable implementation of agroforestry in Uganda's coffee sector. By addressing both economic viability and environmental sustainability, this research contributes to a deeper understanding of how carbon farming can be a feasible and attractive option for smallholder coffee growers.

Keywords: Agroforestry, Carbon Farming, Smallholder Farmers, Coffee Production, Sustainability, Knowledge Transfer, Economic Incentives

Contents

1 Introduction

Globally, the farming industry is suffering from soil degradation and biodiversity loss [Thorn et al., 2020], conventional farming practices being a significant driver of soil degradation, as they often lead to nutrient depletion, erosion, loss of soil organic matter, and affect the biodiversity of the land [Sollen-Norrlin et al., 2020]. In Uganda where coffee farming represents a critical part of the economy, soil degradation can have devastating impacts, causing yield instability, reducing household incomes, and increasing financial insecurity, with smallholder farmers being heavily impacted. [Castro et al., 2013] The report will follow the experience of 3 groups of smallholder farmers from rural Uganda who participate to the MISACI project. The project aims to improve agroforestry implementation and connect smallholder farmers in Uganda to the voluntary carbon market, in a project-based approach. It uses gamified motivation training at the farmer and community level to improve participation level and knowledge about the subject.

This paper aims to identify challenges and incentives that affect agroforestry adoption among smallholder coffee farmers. The report acknowledges the complex relationship between financial incentives, local knowledge, and implementation techniques, and explores them by implementing mixed methods to ensure a comprehensive understanding of the topic.

In order to find and evaluate the relevant research on the incentives for smallholder coffee growers that take part in agroforestry projects, this literature review will focus on a thematic and narrative methodology approach. With the searches being conducted on several platforms, including Google Scholar, Paper Digest, Elicit, and Cite, the process evaluation was methodical and comprehensive. To direct the search, terms like ”Uganda,” ”sustainability,” ”economic impact,” ”carbon coffee farming Uganda,” and ”farmer participation in carbon farming projects” were used. In order to reduce geographical bias and incorporate a greater variety of viewpoints, the search was purposefully expanded to include research from other coffee-producing locations, such as Brazil, even though the original focus was on Uganda.

Despite the methodical approach, the assessment encountered a few difficulties. Since limited research has been done on carbon farming in Uganda, the specificity of the subject made it challenging to find applicable studies. Moreover, only English-language articles were selected in order to preserve the review’s credibility and applicability, which may have imposed a language bias and excluded important contributions from non-English sources in this research. To guarantee the validity and scholarly rigor of the results, papers that were not published in respectable journals or that lacked enough citations were disqualified from being further investigated.

The review aimed to balance specificity and diversity by including insights from other similar contexts. Furthermore, guaranteeing that a variety of perspectives aid in understanding agroforestry incentives for Ugandan smallholder coffee growers, this method enhances the quality of the analysis.

2 Literature review

2.1 Agroforestry

Many coffee farmers around the world battle for their soil's vitality. In order to produce and harvest good quality and amounts of coffee, this is key. One method for this is to introduce agroforestry to the coffee plantation. The implementation of agroforestry in coffee farming systems can help mitigate some of the impacts. Agroforestry usually involves integrating trees with crops and livestock, resulting in a multi-use land. The practice is effective in reducing unbalanced production risks resulting from single-crop plantations such as coffee plantations, by improving biodiversity and soil quality. The byproduct of this practice can also provide farmers with additional income and diversify the source of income protecting smallholder farmers from over-reliance on a single crop. [Castro et al., 2013]. Agroforestry is the incorporation of tree plantation next to agriculture. The paper authored by Abdulkadir [Abdulkadir, 2024] discusses the importance of agroforestry in coffee production highlights the significant ecological and economic benefits of using such a system. In detail he discusses the effects of shading the coffee plantation during growth of the plant, on the productivity of the plant, the economical turn of the plant and on the quality of the coffee beverages. In these sections the paper discusses with sufficient support how natural shading and shading levels affect each and every aspect mentioned before, as well as further supporting the arguments with precise numerical data. In the following sections the author also discusses diseases and pests relating to shading level, however this section is not necessarily relevant for this research purpose. In section 2.3 and 2.4 the author discusses further effects of agroforestry and shading relating to the physiological effects and the effects on soil characteristics. Water usage of plants was discussed and important points were mentioned, mainly that "Coffee in unshaded plantations is normally more water-stressed than in shaded plants". Another key takeaway was mentioned from section 2.4.2 that "In an agroforestry system, the shade canopy may enhance soil fertility by decreasing runoff, nutrient and fertilizer drainage, and soil erosion". The author then discusses the points mentioned above and brings relevant research to support it further.

Another paper focusing on Agroforestry and its impact on soil fertilisation done by Sanchez et al. [Greenland et al., 1997] highlights the use of returning nutrients to the soil and its impact on soil function by increasing nutrient inputs, nutrient cycling and decreasing nutrient loss from soil function as well as overcoming rural poverty by the means of soil fertility replenishment, intensifying and diversifying land use, and enabling policies. The main takeaways from this paper is that the prosperity of the land is greatly protected with systems that incorporate agroforestry through replenishing, decreasing loss and enhanced cycling of nutritions and guarding the land with shade, as well as helping with soil fertility should be replenished using biological and chemical supplementation. The paper argues that agroforestry, while improving soil nutrients, can also help with farmers' livelihood as these trees help both with growing plantations while supplying various resources that can financially aid the farmers further. [Greenland et al., 1997] provides great insight into agroforestry and how it further supplements the land, although it is lacking in Uganda and coffee specific materials.

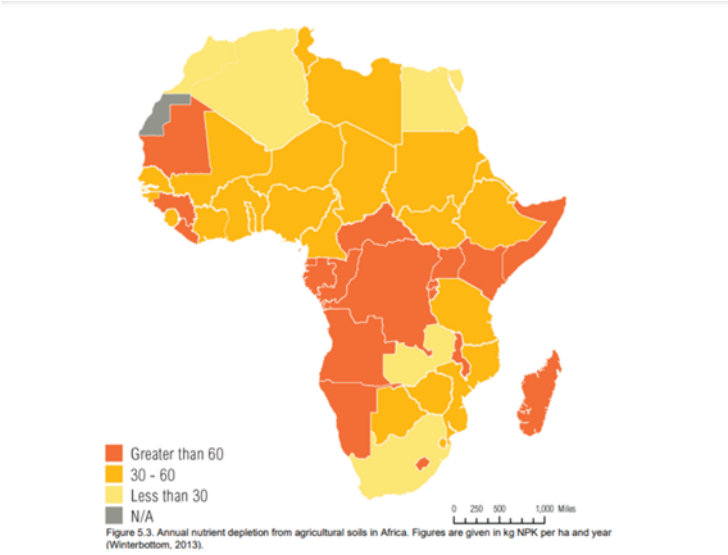

Figure 1: Nutrient depletion levels and need for Agroforestry over Africa

2.2 Adoption barriers

Despite the numerous benefits Agroforestry presents, farmers are still reluctant to implement such a system, facing many challenges that prevent them from easily incorporating Agroforestry into their practices. Tranchina et al. [Tranchina et al., 2024], is a recent systematic literature review that explores this subject by examining 90 literatures following a PRISMA framework methodology and determining the main challenges and limitations regarding agroforestry implementation. The paper categorizes obstacles into 3 main categories:

- **Technical & Environmental Factors** – Includes agronomic, environmental, and climatic aspects such as input availability, space limitations, natural constraints, labor requirements, and technical knowledge.
- **Socio-Economic Factors** – Covers social and financial aspects, including market-related challenges, access to credit, investment barriers, and social dynamics with neighbors or other stakeholders.
- **Policy & Regulatory Factors** – Includes legislative and subsidy-related aspects, such as land tenure issues, access to subsidies, legal frameworks, and project design considerations.

The paper also specifically highlights 5 frequent challenges that need to be addressed: I. Limited technical knowledge, experience, and knowledge diffusion necessary for agroforestry implementation. II. Socioeconomic challenges, including market access, supply chain issues, and employment in agroforestry. III. High labor and time demands for establishing and maintaining agroforestry systems. IV. Upfront economic investment and limited access to capital for system establishment. V. Insufficient technical support for implementation and maintenance. However, these findings are not entirely reliable for this research, as the scope of this paper extends beyond coffee farmers

and examines the broader implications for farmers cultivating multiple crop types. This raises the possibility of crop-specific obstacles or less precise results. To address this limitation, the report analyzes research specifically focused on coffee farmers and conducted a cross-examination to determine whether the findings were consistent in both studies. These challenges align with the findings of [Buyinza et al., 2020], which specifically examine smallholder coffee farmers in Uganda. The paper explores the motivation for farmers to implement agroforestry and highlights that the main obstacles for adoption are: prolonged return on investment after planting those trees , limited labour, resources, and lack of training suggesting that the findings are reliable and applicable in this case. Further solutions must consider these aspects when approaching possible incentives. The incentives must emphasize the smallholder farmers' struggles and provide a method that considers the relationship between training, local knowledge and economic incentives to ensure a seamless and effective implementation.

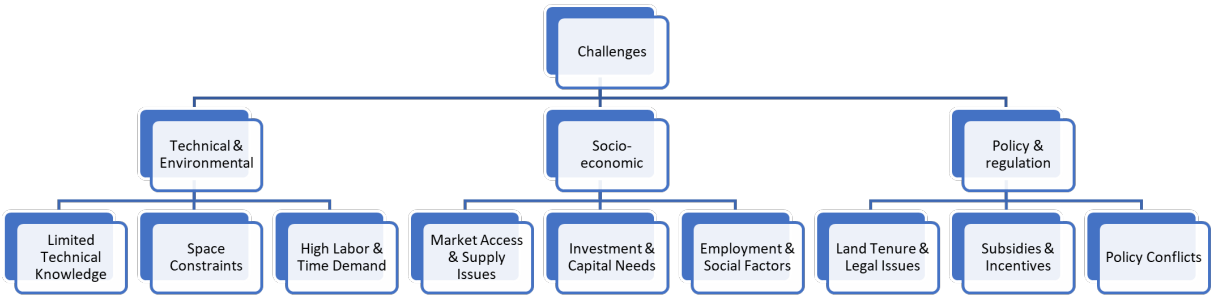

Figure 2: Hierarchical summary table for barriers to adoption

2.3 Socio-economic incentives

Socio-economic incentives aim to help farmers a way to overcome the barriers to entry. The incentives provide significant social advantages in Uganda, where agroforestry provides a secure and sustainable way for farmers to grow their crops, ensuring food security for their families. [Murali K. V. and C., 2015] However, the development of agroforestry requires strong, well-structured financial incentives that promote its adoption. Financial institutions tend to retract to agroforestry projects because the yield in financial returns requires long-term commitment, making it less attractive to lenders. For farmers who are willing to implement agroforestry practices, proper financial mechanisms that provide the necessary funding and risk mitigation must be

put in place to get past these obstacles. [K V et al., 2025] One approach for facilitating this funding is international help such as the Dream Fund of the Dutch Postcode Lottery which has invested €12.7 million to help 100,000 farmers, including those in Uganda, integrate agroforestry systems for sequestering carbon. This program improves food security while assisting farmers in making money through carbon markets on top of other current incentives available in Uganda. [Network, 2025] Farmers also receive financial help from the government to purchase tree seedlings, improve soil quality, and acquire necessary tools. Tax incentives are also made on machinery, discounting 6% out of any machinery, equipment, and seedlings total above $22,500 encouraging the farmers to invest in better equipment. [Authority, 2016] Tax exemptions include tools such as grain cleaners and sorters, ploughs, disk harrows, agricultural tractors, and weeders. Import duty for big vehicles is also nil.[Authority, 2016] Insurance schemes, such as the Uganda Agriculture Insurance Scheme (UAIS) cover various agricultural activities protecting against the risk of weather conditions, pests and diseases, and landslides, protecting risk-averse farmers. [Authority, 2024] Other bodies that are active in Uganda are Payments for Ecosystem Services (PES) and Climate-Smart Agriculture(CSA). PES services are notably providing payment credits for carbon sequestration and biodiversity conservation and providing compensation for watershed protection. [(UNEP), 2014] The carbon market offers a system through which farmers can earn carbon credits which they can sell later in these. Uganda for example, has established policies to help farmers to access carbon financing, thanks to CSA and practices such as agroforestry for sustainable land management. However, for smallholder farmers this poses a huge challenge as revenues from this tend to be low and verification of it is yet limited, meaning that farmers in places in need have to make huge efforts while not having assured if they will be rewarded fairly for them. This limitation can be addressed by creating value chains that connect smallholder farmers with buyers, establishing certification systems for sustainable agroforestry products, and promoting the processing of agroforestry products to add value. Furthermore, linking agroforestry products to international markets through certification schemes such as organic or fair-trade certification could allow farmers to access premium markets, thus improving their economic returns and incentivizing more farmers to adopt agroforestry. [Murali K. V. and C., 2015] These markets have great potential and support development and sustainability, with countries like Uganda being a prime beneficiary, showcasing the effects of improvements in the area.[Jennifer Turyatemba Tumushabe and Chavula, 2023]

Governmental bodies can get involved by leasing certification to premium markets enabling farmers to access higher-paying customers for Ugandan farmers or communities. [AllAfrica, 2025] Governments can also introduce policies that ensure secure land tenure, encouraging farmers to plant trees, as they are more likely to commit to agroforestry systems if they feel confident that they will benefit from the long-term financial returns.[Murali K. V. and C., 2015] Additional tools such as soft loans and low interest credit from the government are also critical in the path to adoption. [Pulleman et al., 2022]. Grants and subsidies can gradually improve as the adoption of agroforestry increases. Carbon schemes, tax exemptions, and premium markets must be made easily available to poorer farmers, in order to limit the impact financial barriers have on adoption. To ensure long-term sustainability and economic viability,

governments, financial institutions, and development organizations need to foster an environment that encourages farmers to adopt agroforestry.

Category	Incentives	Details/Examples
Financial Incentives	Access to Credit	Microloans for smallholder farmers to invest in agroforestry.
	Subsidies & Grants	Government or NGO funding for tree planting.
	Tax Reductions	Tax breaks for sustainable land use.
	Market Access	Fair trade certification support.
	Risk Mitigation	Agricultural insurance for financial stability.
Policy Incentives	Land Tenure Security	Legal frameworks for farmers' ownership rights.
	Training Programs	Government workshops and knowledge transfer.
	Regulatory Support	Certification schemes for market access.
	Public-Private Partnerships	Government-business-NGO collaborations.

Table 1: Financial and Policy Incentives for Agroforestry

2.4 Knowledge transfer

The adoption of agroforestry techniques in Uganda is largely dependent on training and knowledge propagation. This fact is supported by the dataset, which shows that a great deal of people who do not use agroforestry are in fact unaware of these methods and their advantages. Creating local champions — skilled and reliable farmers who are frequently the community's social centre — is a crucial strategy for promoting knowledge transfer and it's being used more and more in Africa [Selener et al., 1997]. These local champions demonstrate and serve as role models for the adoption of new technologies and techniques, giving other farmers concrete proof of their effectiveness. [Taylor and Bhasme, 2018]

Model farmers, act as intermediaries between agricultural extension services and smallholder farmers. Themselves given proper training and expertise on the optimisation of land use and the market of crops, they distribute their knowledge accordingly, step by step, made easy for different individuals with different scenarios – role known as Gatekeeper [Taylor and Bhasme, 2018]. Beyond that, they are often the ones leading communities sharing knowledge in their networks, with an emphasis on problems like as low and unstable crop prices, erratic rainfall patterns, and soil fertility depletion. Local champions are essential in assisting smallholder farmers in connecting with larger markets, international carbon markets, VCM, certifiers and validators. In international markets, a variety of crops that are undervalued in local markets have substantial value, but farmers frequently lack the connections needed to take advantage of these opportunities [Ijaiya et al., 2016]. Local champions could act as a bridge, connecting farmers with exporters, traders, or other businesses that can help sell high-value goods outside

of their local communities. They also bridge the connection between governments and their various assistance, notably, support programs, subsidies or policy-driven initiatives [Kilelu, 2013].

Training programs for coffee farmers are further explored in a farmer-to-farmer (F2F) extension model research that explores the effectiveness of volunteer farmer trainers (VFTs), in enhancing knowledge transfer. [Kiptot and Franzel, 2015]. The study employs a mixed-methods approach, combining surveys and interviews with VFTs, farmers, and extension officers, to identify factors influencing VFT performance. The paper emphasizes the role of social networks and local knowledge in knowledge sharing.

One innovative approach to motivate agroforestry adoption is through the use of gamification. The farmers would get points for participating and encouraging knowledge propagation of agriculture [Llorens et al., 2016], an example of a detailed point system is shown in [Nuritha et al., 2017]. To make sure that help reaches the most committed people, these points might be used as a criterion to choose the most engaged participants for specialised training programs. Making use of leaderboards , where top-performing farmers are acknowledged and given access to opportunities for additional education, is one efficient gamification technique. Farmers are encouraged to compete and be more motivated by this merit-based strategy, which increases their ability to learn and use latest information, at the same time tackling the problem of gender opportunity

Aside from leaderboards, behaviour and cognition games - such as popular simulations like trust game and coordination games - provide insight on how farming communities make decisions and work together. [Ismael and al., 2024] For example, coordination games can mimic real-life agricultural difficulties by simulating situations in which farmers must work together to manage common resources. On the other hand, farmers can learn about market dynamics and practice risk management through market games and simulations, which gives them the tools they need to manage price swings and input distribution. [Ismael and al., 2024]. These types of stories-based games are a practical way of education and researched proved as more effective than normal games in the agriculture sector. [Fernández Galeote, 2021]

The benefit of such gamification is wide since it not only propagates awareness of new techniques like agroforestry and their benefits, it increases engagement of farmers, improved knowledge retention and enhanced community participation. However, its drawbacks should be acknowledge, it could alienate farmers who have digital illiteracy or access to technology. Additionally, competition can be a motivating factor, but it should not by any means become harmful. In conclusion, an effective plan for enhancing agroforestry adoption in Uganda combines traditional knowledge distribution through local champions with gamification tactics. Policymakers and extension initiatives can improve information transmission and ultimately encourage more resilient and sustainable agricultural systems by exploiting social networks and digital advances. Another future research includes the feasibility of using leaderboards, or even AR and VR games in developing countries like Uganda.

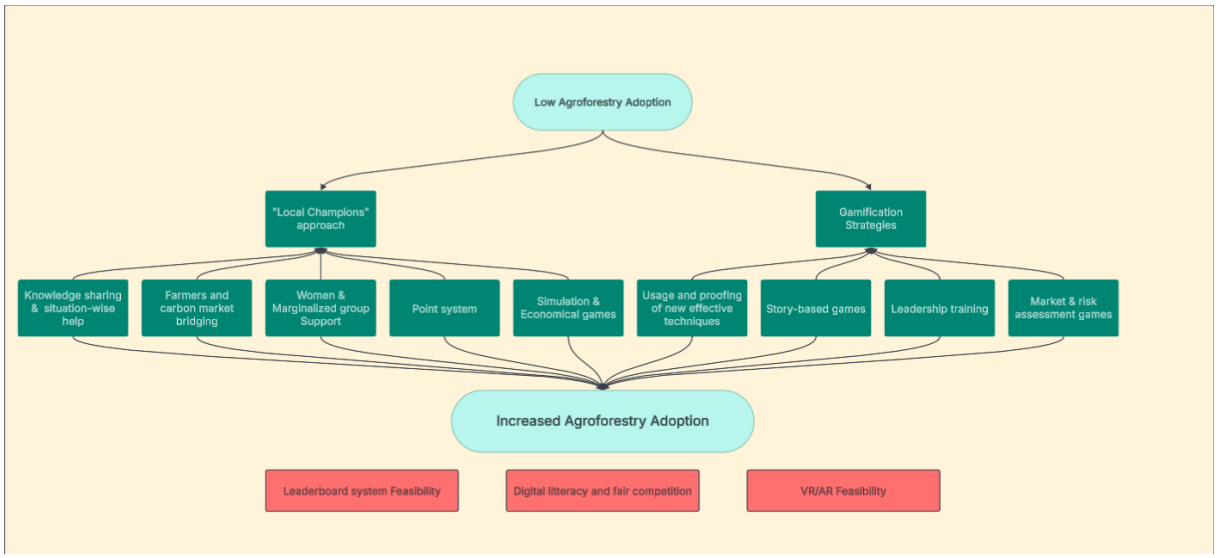

Figure 3: Knowledge Transfer Summary

3 Critical Analysis

3.1 Strengths

This literature review explores in a comprehensive manner the implications, limitations, benefits, and costs associated with the implementation of agroforestry systems in small coffee farms. The report benefits from a multi-dimension approach, which offers an in-depth understanding of the adoption process. By considering environmental, social, and economic factors, the review ensures that the proposed incentives are practical, effective, and aligned with the needs of smallholder farmers.

The review integrates and explores diverse sources and incentives, analyzing their impact on farmers' decisions and behavior. It focuses on practical approaches and potential solutions, such as financial mechanisms, market access, and risk mitigation strategies, which are critical for the successful adoption of agroforestry. The report also explores case studies and examples, such as the Dream Fund [Network, 2025] initiative in Uganda, which provides real-world context and increases the validity and application of the findings.

The focus is on the entire process offering a valuable perspective for policymakers, development organizations, and farmers to better improve their practices and adopt new policies and techniques to improve adoption.

3.2 Weaknesses and Limitations

The literature review faces several constraints due to the challenges in obtaining concrete and reliable data. This issue is particularly pronounced for small coffee plantations in Uganda, which are often located in less economically developed regions, leading to a scarcity of dependable sources. To address this limitation, the paper broadened the scope of the research to include extensive studies on various types of plantations

over a longer time period, however, this approach led to generalizing findings. To address this issue the literature compared these findings with more targeted research on coffee plantations in Uganda to ensure the validity of the conclusions. Despite the benefits of the findings of this broadened research, the evidence for causality is weak. Furthermore, many of the assumptions are either not supported by statistics or do not specify the full amount of their effectiveness.

3.3 Literature gap

The literature reviewed has certain limitations due to the numerous variables influencing motivation and initiative. Existing research has yet to fully account for regional differences, including environmental conditions, social structures, and economic circumstances, all of which shape agroforestry adoption. Furthermore, current recommendations often adopt a generalized approach, overlooking the diverse cultural backgrounds that influence implementation strategies across different areas. Addressing these gaps is essential for developing more context-specific and effective agroforestry policies. This research aims to close some of the gaps by focusing on regional differences in Uganda, and asses the incentive implication that accounts for the different local knowledge, economic environment, and training.

Existing studies provide valuable insights into the factors driving smallholder coffee farmers to adopt agroforestry, however significant gaps remain. Agroforestry systems are inherently complex and context-dependent, and available data is usually limited and inconsistent. Although studies have identified key drivers of adoption such as financial incentives, training programs, and local knowledge, the connection between these factors remains underexplored. Most research tends to examine them individually, often relying exclusively on either quantitative or qualitative methods. This fragmented approach fails to capture the context-specific nature of farmers' decision-making processes.

Qualitative research has been effective in highlighting the social and cultural perspective of agroforestry adoption. These studies emphasize the importance of trust, social networks, and farmer experience in shaping adoption behavior. However, qualitative approaches have several limitations, they fail to quantify the relative importance of different factors. Research identifies the benefits of agroforestry in income diversification for farmers, highlighting the benefits of the practice in achieving rural development and improving farmers' quality of life [K V et al., 2025], however, these effects are not measured, leaving a massive gap in determining their effectiveness or long-term development.

Quantitative studies, employ structured surveys and statistical models to identify key determinants of agroforestry adoption. These methods offer generalizable insights and allow comparisons between different groups of farmers. However, they also present significant challenges such as the lack of context and the connection between the different aspects influencing the farmer's decision. Reviewed research identifies training programs as a significant predictor of adoption [Buyinza et al., 2020], but it does not explore whether this is due to the quality of training, the relevance of content, or the delivery methods. It does not assess the design and how it aligns with local cultural practices, and if it is supported by appropriate incentives. The lack of contextu-

alization results in a gap that limits the understanding of the cause behind the adoption, and could result in ineffective or inaccurate conclusions.

Bridging this literature gap requires the integration of all aspects into a comprehensive and complete report that can identify and quantify the intricate relationship between different aspects affecting farmers decision.

4 Data analysis

MISACI data about coffee farmers smallholders in Uganda will be used in this research; it is a survey data divided into 3 groups: the pilot group – farmers receiving training and playing the game; control group 1—receiving training but they do not play the game; and Control group 2 – they do not receive training nor play the game. The survey was done in 3 regions in Uganda to prevent bias.

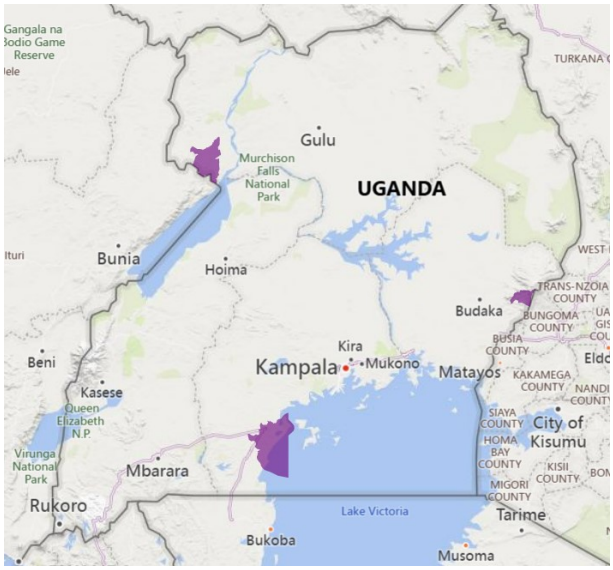

Figure 4: Agroforestry tree plantation

With 36 questions, the data contains demographics and focus on gamification, with some data on carbon payments. Some descriptive analysis and visualisations will be made to showcase the conclusions the main aims of the paper. The data, which is collected through structured and semi-structured interviews, can be systematically codified, to identify patterns and relationships across participants' experiences.

By codifying qualitative responses, the paper can approach the question with a structured analysis of key themes, allowing for a deeper understanding of the socio-economic and informational barriers to agroforestry adoption. Moreover, some data was transformed into new variables, such as Earning per acre - how much the farmers earn per acres - to standardize data and identify new relationships that could affect adoption.

Furthermore, from the Likert-type questions (Score of 1 being a negative answer to a score of 4 being very positive), it is possible to explore how positive their view is on the training or gamification. To ensure it is statistically significant a t-test was done:

One-Sample Test[a]

Test Value = 0

Group_Num		t	df	Significance One-Sided p	Significance Two-Sided p	Mean Difference	95% Confidence Interval of the Difference Lower	95% Confidence Interval of the Difference Upper
Control Group 1	How motivating was the training for you to practice agroforestry?	9.327	29	<.001	<.001	3.000	2.34	3.66
Pilot Group (game and training: 25 farmers per region)	How motivating was the training for you to practice agroforestry?	21.783	74	<.001	<.001	3.747	3.40	4.09

a. No statistics are computed for one or more split files

Figure 5: T-test for motivation of the farmers for agroforestry

P-value is less than 0.05, it is safe to proceed
This variable is statistically significant and reflective of the population

Likewise, a t-test was done for other variables namely: How many trees they planted and how many trees they plan to plan in the scope of ”climate heroes” - the agroforestry program; Earning per acres, expected earning per acre in a year and the aggregates of the perception on board games and league games.

A descriptive analysis was done to identify patterns and observe more in-depth insights about the data set.

1. The farmers’ view on climate change is mostly because of unpredictable weather since it ruins their expected timing to harvest and some produce cannot be cultivated anymore.

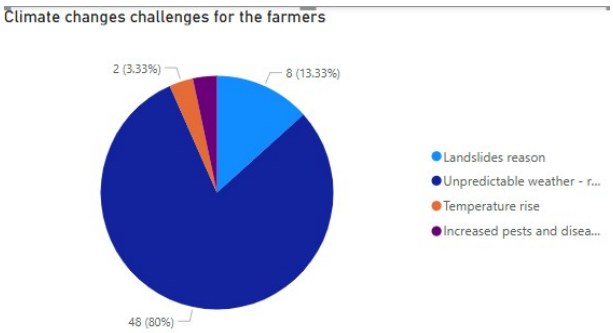

Figure 6: Agroforestry tree plantation

2. The people who didn’t go for agroforestry was mostly unaware of the program, others were unfortunately occupied on the day they got invited.

3. Next, is the solution for climate change mitigation according to farmers as shown in [Appendix figure 11]:

Agroforestry was the solution for most people. Other new techniques like mulching were also mentioned.

4. Even after joining ”Climate heroes” which specialises in agroforestry, they expect the following issues found:

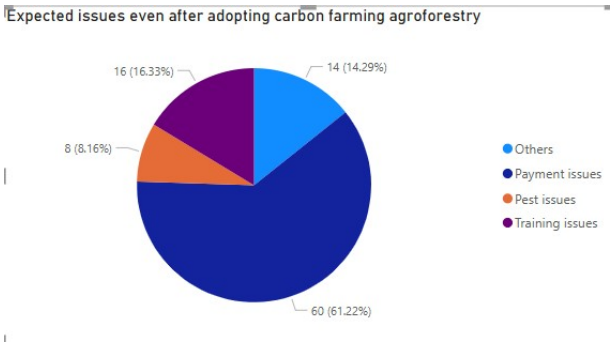

Figure 7: Agroforestry tree plantation

They mostly anticipate carbon payment issues, and prompt training issues.

5. Since payment issues were mostly anticipated, the farmers were asked if they would still engage with ”Climate Heroes” if no payments were made and the response graph found in:

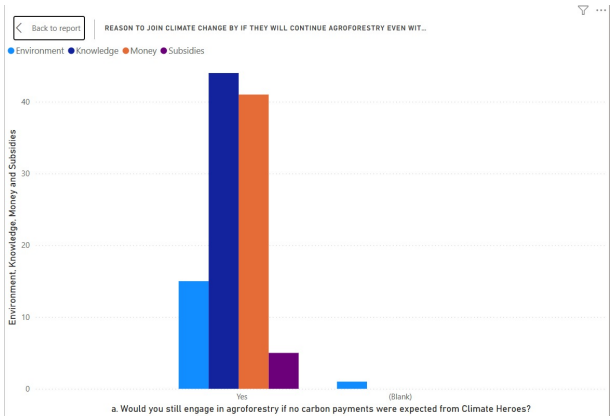

Figure 8: Agroforestry tree plantation

All except one responded ”Yes” - they will continue engaging with climate heroes, and the reason why was mainly for knowledge, money from produce from the trees, for the sake of the environment and because of subsidies they get.

To further analysis of the dataset,it is necessary to quantify the impact of the engagement and participation of local farmers from gamified training: While analysing the survey, Pilot group farmers have a slight, negligible gap of motivation aggregate compared to Control group 1 (88% and 87.5% respectively). They both seem to feel the same motivation subjectively, but data says otherwise when ask how much agroforestry trees they planted in the last 12 months and how much they plan to plant in the next 12 months, as shown in the figure below.

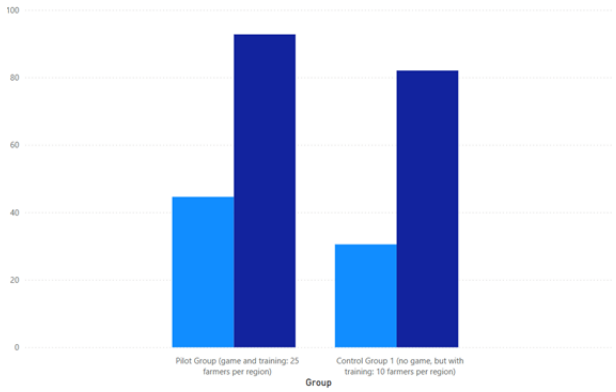

Figure 9: Agroforestry tree plantation

The figure shows that Pilot groups are more engaged in agroforestry after gamified training. Precisely, gamified trained farmers have planted 14 more trees on average in the past 12 months and plan to plant 10 more trees in the next 12 months.

The following will highlight the extent to which carbon payments contributes to household income of the control and pilot groups from the survey of coffee smallholders in Uganda:

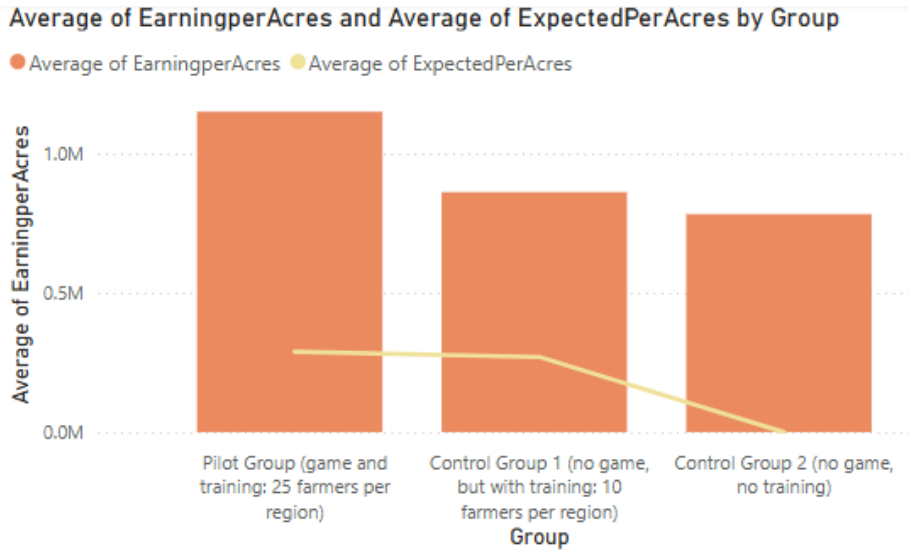

Figure 10: Agroforestry tree plantation

This diagram shows how much the different groups are earning per Acres of land. Farmers with training gets slightly better income whereas people participating in both trainings and the games in agroforestry has far better income. Numerically in Ugandan shillings, 1.15M earning per acres for Pilot groups, 0.86M earning per acres for control group 1 and 0.78M per acres for control group 2. Regarding expected carbon payments, Control group 2 obviously has no carbon payments, and both Pilot and Control group 1 expects around 0.275M ($75) per acres, making up around 23-32% additive of their normal income.

5 Methodology

Existing literature review shows a variety of approaches and methodologies are used. When considering which method fits the topic best, a comprehensive analysis of the strengths and limitations of each approach is needed, and compare the findings with available data and the context of the research. The following table provides an overview of methodologies used by explored literature, identifying the limitations and strengths of each specific paper to better contextualize the implication of each method.

Method	Strengths	Limitations
Quantitative	Enables large-scale trend analysis using econometric models [Liu and Chuang, 2023]. Provides objective, replicable results and supports evidence-based policy.	Lacks farmer-specific behavioural insights. Simplifies socio-cultural factors into numerical variables.
Mixed-Methods	Integrates statistical analysis with participatory approaches [Kiptot and Franzel, 2015] Validates findings through triangulation and identifies financial and non-financial drivers.	Requires significant time and resources. Challenges in aligning qualitative insights with quantitative models.
Qualitative	Provides deep contextual insights on farmer motivations and local barriers [K V et al., 2025]. Captures informal knowledge-sharing and cultural influences.	Findings lack quantitative validation, limiting transition into policy.

Table 2: Comparison of Research Methods in Agroforestry Adoption

Taking into account the complex nature of the topic, which requires an understanding of the local knowledge, training, and financial concepts to fully comprehend the factors that influence farmers' decisions, a mixed methodology is most suitable for the report. The available data also more to this approach as it is flexible and can be modelled to fit different analysis techniques, providing a broad perspective. The choice of

methodology was also influenced by the contradictory top-down and bottom-up perspectives. Top-down approaches emphasize policy frameworks and financial incentives [K V et al., 2025], while bottom-up approaches focus on farmers experiences and local dynamics [Kiptot and Franzel, 2015]. Top-down approaches often overlook the cultural and social factors that shape farmers' decisions, while bottom-up approaches provide deeper insights into local dynamics but lack scalability. Given the dataset in this report has a more focused view of farmers' local knowledge, training, and individual perspectives, a bottom-up approach is more suitable. This method allows for a more in-depth understanding of farmers' perspectives and contextualizes the analysis. In addition, it ensures that the findings are actionable for designing effective interventions in the specific regions in Uganda explored in the dataset.

Among the quantitative techniques reviewed the most successful techniques are Structural Equation Modeling and Multiple Regression. The Structural Equation Modeling (SEM) methodology has proven to be an effective method, as demonstrated by [Buyinza et al., 2020]. in their study on smallholder farmers' motivations to adopt agroforestry. The Multiple regression methodology is a reliable and effective way to identify incentive effects as demonstrated in [Liu and Chuang, 2023].

Both approaches have distinct strengths and limitations. Multiple Regression is useful for analyzing direct relationships between observed variables, however, it struggles to capture the complexity and behavioural aspects explored in agroforestry adoption for small farmers. The model cannot analyze latent variables, such as motivation, perceptions, or training, which are critical to understanding the decision-making processes of farmers. Additionally, Multiple Regression is more suited to top-down approaches, and may not fully account for the context-specific dynamics of local farming communities. Papers [Liu and Chuang, 2023] using this method focus more on the policy aspect of incentives as it takes advantage of the model's strengths.

SEM allows for the analysis of complex relationships between latent variables such as attitudes, and motivation, and observed variables such as years of training, and income levels, providing a solid framework for understanding the interplay of multiple factors influencing adoption decisions. However, the model assumes linear relationships and normally distributed data, which may not always hold true. SEM can also overlook qualitative aspects, such as cultural or contextual dynamics. Research [Buyinza et al., 2020] using this method focuses on latent variables such as intent and subjective norms to analyze intent. This provides an effective way to quantify behavioural aspects.

Considering the nature of the data SEM is more suitable for this research because it enables the quantification of key drivers such as economic incentives, training, and local knowledge. To address SEM limitation complementary qualitative insights from semi-structured interviews capture the cultural and social dynamics that SEM alone may overlook.

The implementation of the model was done considering agroforestry adoption as the dependent latent variable, while training, knowledge, and financial incentives acted as independent latent constructs. The observable variables were obtained from standardized codified semi-interview data and each independent latent variable was based on at least 3 indicators. The model was built considering the following hypotheses: Training has a direct positive effect on agroforestry adoption, financial factors have

a positive effect on agroforestry adoption, local knowledge has a positive effect on agroforestry adoption The model demonstrates a good fit to the data, chi-square test ($p > 0.180$), a CFI of ($0.915 > 0.9$), and an RMSEA of ($0.048 < 0.08$). This suggests that the SEM findings are reliable and significant. The results of the model are presented in Table 4.

	Estimate	Std. Err	z-value	P-value ($p < 0.05$)	Std. lv	Std. all
Local Knowledge	-0.040	0.047	-0.840	0.401	l-0.089	-0.089
Training	0.189	0.094	2.013	0.044	l0.250	0.250
Financial Incentives	0.205	0.072	2.848	0.004	l0.421	0.421

Table 3: Regression Results for Agroforestry Adoption

Training and Financial Incentives are significant ($p < 0.05$) The model identifies the positive impact of these variables on the adoption rate. No significant relationship between Local knowledge and adoption was identified. Observable variables such as training and gamification of training had a positive and significant impact on training, and variables such as carbon payment received and expected amount had a significant impact on financial incentives, suggesting that the implementation of such incentives is effective. There were no significant relationships between any of the independent latent variables.

While the SEM model provided valuable quantitative insights, qualitative data from semi-structured interviews revealed additional challenges that were not fully captured by the model. Two recurring themes emerged: delayed payments and untimely training. These challenges were not fully captured by the SEM model but emerged as recurring challenges in the qualitative data. Due to the confidential data set, no quotes will be provided.

- **Financial Factors** – Farmers participating in the program expressed their challenges, with the most pressing issue being delays in receiving carbon payments. This aligns with the findings of [Tumushabe et al., 2023], which emphasize that delayed payments affect farmers who cannot afford the initial upfront cost. The implementation of agroforestry can put a burden on farmers' finances. Delayed payments could slow the plantation of trees due to limited capital availability.
- **Training & Knowledge Factors** – Farmers also highlighted the challenges of training schedules. This issue was not explicitly captured in the SEM model but is critical for understanding the adoption process. The farmer's schedule is based on the plantation cycle, which cannot be delayed [Tumushabe et al., 2023]. Farmers might not be able to attend training sessions, or the training might end up being too late to be implemented in the current stage of the plantation. This misalignment between training and agricultural cycles reduces the effectiveness of knowledge transfer and delays adoption.

The SEM model also doesn't account for how these aspects work together to influence adoption. Farmers mention that challenges include financial limitations and a lack of knowledge as key limitations. However fully understanding the decision-making of farmers needs to consider these factors together, limited knowledge might slow adoption even with enough capital and a highly trained farmer cannot implement a system without enough capital. Individual incentive implementation might be affected by other choke points for farmers, suggesting that any efforts to incentivize adoption must consider all aspects to have successful results.

6 Discussion

The results of this study emphasize the diverse aspects that need to be considered when addressing agroforestry adoption. The results are in line with findings from [Buyinza et al., 2020], who also identified financial incentives and training as critical drivers of agroforestry adoption among smallholder farmers. The model was significant and indicates a positive relationship between adoption and financial incentives and training. Additionally, underexplored areas such as gamification implementation in training programs have shown significant impacts on training [Nuritha et al., 2017] further research could develop this more by exploring the feasibility of gamification, and identifying limitation or context-specific aspects of gamification. The inclusion of qualitative data complemented the SEM results by exploring farmers' challenges that were missed by the model, such as delayed payments and misaligned training schedules, findings that are confirmed by [Tumushabe et al., 2023], who highlights that adoption of climate-smart practices slows when adequate financial support or incentives are not in place. The bottom-up approach, supported by qualitative data, ensured that the findings were based on the experiences of smallholder farmers in Uganda.

The study also had some limitations. The SEM model did not find a significant relationship between local knowledge and agroforestry adoption. This could be caused by the method and variable used in determining local knowledge. The codified interview data could have missed important aspects by oversimplifying the complex nature of the answer in a numerical format. Future research could improve this by incorporating more insightful indicators of local knowledge, such as farmers' experience with agroforestry practices, their understanding of ecological benefits or more culturally distinct aspects such as religion and belives. One critical limitation is that SEM assumes linear relationships and normally distributed data, which may not always hold true. Future research could explore alternative modeling approaches, such as machine learning algorithms, that can capture nonlinear relationships and complex interactions. The findings are limited by the specific context of smallholder coffee farmers in Uganda and may not be generalizable to other regions or crops. While the inclusion of qualitative data adds depth, it also limits the scalability of the findings. Future studies could expand the geographical scope and include a wider range of agricultural systems. This report only covered a small portion of the vast amount of variables that influence farmer behaviour, and the current results are insufficient to fully understand how farmers' decision is made. Promising avenues for further exploration include more in-depth studies that can observe aspects such as motivation, perceived benefits, understanding, and

training quality. The data used in this report still allows for more exploration, especially for the qualitative part, however for better results external data should be incorporated to improve the model's accuracy. Quantitative data such as land quality and infrastructure can provide much-needed consistency and quantifiable variables in the model. Future research should also incorporate new ideas and perspectives, that could benefit farmers. Different methodologies such as a top-down approach or Multi-regression algorithm can be used to provide a new perspective. Explored methodology such as SEM could benefit from the inclusion of additional constructs such as environmental concerns by farmers (e.g. willingness to protect existing trees, plant new trees on bare landscapes) as mentioned by [Buyinza et al., 2020]. Promising topics such as blockchain, AI implementation, and machine learning have yet to be fully explored in the context of smallholder farmers by current literature, providing an opportunity to discover new solutions, such as blockchain carbon markets. Future research that will be approached by the authors of this paper are mentioned in the following section

7 Individual research

7.1 Jorge Garcia

How do temperature and rainfall variations impact on coffee yield among smallholder farmers in Uganda?
In order to understand how weather and rainfall changes affect and motivate farmers to implement different practices, the techniques of Multiple Linear Regression and ANN will test influence of variables, alongside MSE and RMSE to test vericity of model.

7.2 Mate Balogh

"The Effect of Carbon Farming Incentives on the Use of Agroforestry by Smallholder Coffee Farms in Uganda"

For my individual research idea I would like to focus on the financial incentives that push the coffee farmers in Uganda in the direction of implementing agroforestry. Carbon incentives are the most relevant one, as they can receive subsidies from carbon farming, and the additional growth of trees provide multiple benefits to the farm itself.

7.3 Akshat Sungkur

Uncertain Prospects: Adapting Emerging Carbon Farming Practices from Global North to Global South countries

I will be identifying success factors of practices from Global North and scale the level of feasibility it would have on Global South countries comparing those success factors identified through SEM/linear regression algorithms.

7.4 Antonio

- To what extent do carbon payments contribute to financial stability and income for Ugandan coffee farmers?

In my study, I will aim to find out if carbon payments boost household income, foster income diversification, and motivate involvement in sustainable farming practices. Statistical and financial analyses will be employed by the study to evaluate how effective they are in enhancing farmers' economic well-being.

7.5 Ioneanu Andrei

Understanding Productivity Variations Among smallholder coffee farmers Communities/regions in Uganda

The research will use a mixed-methods approach, combining quantitative analysis to measure productivity variations with case study-based qualitative insights.

Variables such as income levels, education, agricultural yields, household number, access to infrastructure across different communities, and gender will be used to identify key indicators of productivity, and critically examine the causality effect.

8 Conclusion

Agroforestry has the potential to increase the livelihood of farmers and prevent climate change.

As discussed during the literature review, agroforestry-based carbon farming practices combat climate change and help the livelihood of farmers, but implementations of the practice are challenging. Therefore, incentives must be considered in the relationship with each order, including financial, training, and local knowledge. Current governmental incentives and financial incentives try to cut down on costs for smallholder farmers to implement the practice. The Dream Fund of the Dutch Lottery which has invested €12.7 million to help farmers, as well as financial aid to purchase necessary agricultural tools are both an incentive to reduce costs for farmers[Network, 2025]. Tax incentives and exemptions were also made on machineries and equipment further reducing costs for farmers [Authority, 2016]. Services and schemes such as UAIS and PES were also introduced to cover for risks and to provide payment credits for carbon sequestration. However, these efforts are not enough, and more incentives that consider the context-specific aspects should be implemented.

The report identifies incentives such as training and financial incentives as having a positive impact on adoption, with gamification efforts proving to be significant in improving training quality. The report also identifies multiple challenges that need to be addressed for improving future adoption. The report recommends a more significant involvement from governmental bodies as well as ONG in providing smallholder farmers the tools necessary to start agroforestry on their farms. Access to capital and

proper training is necessary for adoption, and incentives aiming to solve these challenges should consider the farmers' perspective, by ensuring the payments are done in a timely manner, with short-term loans as a possible method to bridge the gap between the initial investment and the first carbon payment.

Finally considering the farmer's response when asked if they are willing to participate without getting carbon payments, all except one out of 102 respondents claimed that they would still engage with them, suggesting that farmers are willing and ready to adopt new sustainable practices such as agroforestry. The main barriers to adoption can as such be addressed with proper incentives and policies, and their implementation will decide the future of sustainable coffee farming in Uganda.

References

[Abdulkadir, 2024] Abdulkadir, K. (2024). The benefits of agroforestry coffee production systems: A review. *World Journal of Food Science and Technology*, 8:86–105.

[AllAfrica, 2025] AllAfrica (2025). Uganda: Unbs seeks global gap certification to lower costs for ugandan farmers.

[Authority, 2016] Authority, U. I. (2016). Tax incentives in the agriculture sector.

[Authority, 2024] Authority, U. I. (2024). You can profitably invest in agriculture with insurance.

[Buyinza et al., 2020] Buyinza, J., Nuberg, I., Muthuri, C., and Denton, M. (2020). Assessing smallholder farmers' motivation to adopt agroforestry using a multi-group structural equation modeling approach. *Agroforestry Systems*, 94.

[Castro et al., 2013] Castro, L. M., Calvas, B., Hildebrandt, P., and Knoke, T. (2013). Avoiding the loss of shade coffee plantations: how to derive conservation payments for risk-averse land-users. *Agroforestry Systems*, 87:331–347.

[Fernández Galeote, 2021] Fernández Galeote, D. (2021). Gamification and climate change engagement. Accessed: 2025-02-22.

[Greenland et al., 1997] Greenland, D. J., Gregory, P. J., Nye, P. H., Sanchez, P. A., Buresh, R. J., and Leakey, R. R. B. (1997). Trees, soils, and food security. *Philosophical Transactions of the Royal Society of London. Series B: Biological Sciences*.

[Ijaiya et al., 2016] Ijaiya, F. A. A., Ajayi, T. O., and Akinmoladun, O. O. (2016). Agricultural market access and rural development in sub-saharan africa: The role of intermediaries. *Research Gate*.

[Ismael and al., 2024] Ismael and al. (2024). Serious video games for agricultural learning: Scoping review. Accessed: 2025-02-22.

[Jennifer Turyatemba Tumushabe and Chavula, 2023] Jennifer Turyatemba Tumushabe, B. T. and Chavula, P. (2023). The sustainability of carbon markets for climate-smart agriculture among smallholder farmers in uganda. *Asian Journal of Research in Agriculture and Forestry*.

[K V et al., 2025] K V, M., Rathod, C., and K C, K. (2025). *POLICY AND FINANCIAL SUPPORT FOR AGROFORESTRY DEVELOPMENT: INCENTIVES, PROGRAMS, AND MARKET OPPORTUNITIES*, pages 152–166.

[Kilelu, 2013] Kilelu, C. W. (2013). *Unravelling the Role of Innovation Intermediaries in Smallholder Agricultural Development: Case Studies from Kenya*. Wageningen University and Research.

[Kiptot and Franzel, 2015] Kiptot, E. and Franzel, S. (2015). Farmer-to-farmer extension: opportunities for enhancing performance of volunteer farmer trainers in kenya. *Development in Practice*, 25(4):503–517.

[Liu and Chuang, 2023] Liu, W.-Y. and Chuang, Y.-L. (2023). Assessing the incentives and financial compensation of agroforestry considering the uncertainty of price and yield. *Ecological Indicators*, 146:109753.

[Llorens et al., 2016] Llorens, F., Durán, F. J., Villagrá, C., Rosique, P., Satorre-Cuerda, R., and Molina-Carmona, R. (2016). Gamification of the learning process: Lessons learned. *IEEE Revista Iberoamericana de Tecnologias del Aprendizaje*, 11:1–1.

[Murali K. V. and C., 2015] Murali K. V., C. B. R. and C., K. K. (2015). Policy and financial support for agroforestry development: Incentives, programs, and market opportunities. *Researchfloor*.

[Network, 2025] Network, S. (2025). Dutch dream fund invests in farmers to connect with carbon markets. Accessed: 2025-02-22.

[Nuritha et al., 2017] Nuritha, I., Widartha, V. P., and Bukhori, S. (2017). Designing gamification on social agriculture (sociag) application to increase end-user engagement. In *2017 4th International Conference on Computer Applications and Information Processing Technology (CAIPT)*, pages 1–5.

[Pulleman et al., 2022] Pulleman, M., Smit, E., and Wintraecken, E. (2022). Agroforestry models and business cases: international experiences. Technical report, Netherlands Enterprise Agency.

[Selener et al., 1997] Selener, D., Chenier, J., and Zelaya, R. (1997). *Farmer-to-farmer extension: Lessons from the field.* CABI digital library.

[Sollen-Norrlin et al., 2020] Sollen-Norrlin, M., Ghaley, B. B., and Rintoul, N. L. J. (2020). Agroforestry benefits and challenges for adoption in europe and beyond. *Sustainability*, 12(17):7001.

[Taylor and Bhasme, 2018] Taylor, M. and Bhasme, S. (2018). Model farmers, extension networks and the politics of agricultural knowledge transfer. *Journal of Rural Studies*, 64.

[Thorn et al., 2020] Thorn, S., Seibold, S., Leverkus, A. B., Michler, T., Müller, J., Noss, R. F., Stork, N., Vogel, S., and Lindenmayer, D. B. (2020). The living dead: acknowledging life after tree death to stop forest degradation. *Frontiers in Ecology and the Environment*, 18(9):505–512.

[Tranchina et al., 2024] Tranchina, M., Reubens, B., Frey, M., Mele, M., and Mantino, A. (2024). What challenges impede the adoption of agroforestry practices? a global perspective through a systematic literature review. *Agroforestry Systems*, 98(6):1817–1837.

[Tumushabe et al., 2023] Tumushabe, J. T., Turyasingura, B., and Chavula, P. (2023). The sustainability of carbon markets for climate-smart agriculture among smallholder farmers in uganda. *Asian Journal of Research in Agriculture and Forestry*, 9(4):337–345.

[(UNEP), 2014] (UNEP), U. N. E. P. (2014). The role of agroforestry in achieving the sustainable development goals.

9 Appendix

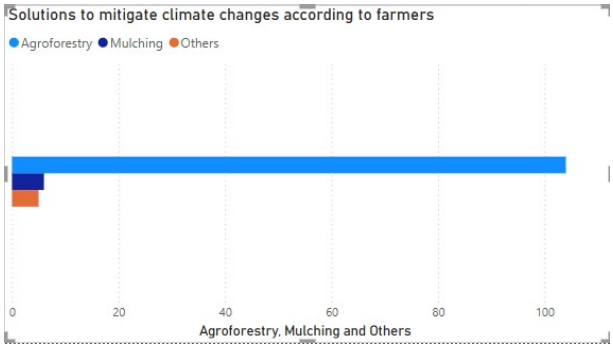

Figure 11: Agroforestry tree plantation

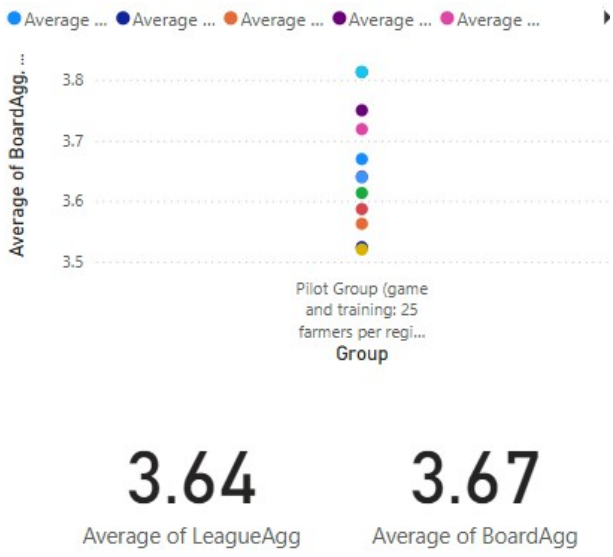

Figure 12: Agroforestry tree plantation