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Original Article

Smallholder Farmers' Local Practices Underpinning the Use of Agroforestry Technologies in Uganda's Mt. Elgon Region

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ABSTRACT

Mt. Elgon is a unique cross-border afro-montane ecosystem that has always provided vital essential goods and services for human livelihoods. However, with the increasing population density, forest degradation has become a significant issue, resulting in a rise in landslides, mudslides, pest and disease outbreaks, and reduced land productivity. Recently, it has been realized that many smallholder farmers have incorporated trees into their farming systems using indigenous knowledge. This indicates that smallholder farmers' profound knowledge regarding tree use and management has reminded us that farmers have always been privy to much information regarding tree use and management accumulated over the years. This study aims to investigate how smallholder farmers' local practices enhance the use of agroforestry technologies in the eastern highlands of Uganda. This information will help develop and promote agroforestry practices that are acceptable to farmers. The study employed a case study approach, collecting data from 12 smallholder farmers over four months. The results indicate that smallholder farmers use local practices to enhance tree seedling survival, optimize space, and shorten the waiting time for tree-related benefits. Although some of their practices may not align with the desired outcome of farm productivity, further validation is needed to understand how they can be integrated into mainstream agroforestry research and development.

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INTRODUCTION

As the population increases significantly in Sub-Saharan Africa, large farms have previously been reduced to small landholdings due to cultural land-sharing practices. The role of smallholder farmers in the global value chain is becoming more prominent. Smallholder farmers face increasing pressures from land degradation, soil erosion, over-cultivation, and climate change, which threaten millions of people's food and income security (Gomez et al., 2020). To make smallholder production systems sustainable, agroforestry has been proposed and promoted to replenish land productivity and enhance food security.

It is worth noting that agroforestry is not a novel concept, as many farmers have been cultivating trees in agricultural landscapes for a long time (Nair, 1993). However, there has been a recent push by promoters such as researchers and extensionists to disseminate agroforestry technologies to smallholder farmers. While these technologies are seen as a blueprint for enhancing agricultural productivity (Nair & Latt, 2011), many smallholder farmers do not implement them as designed by agroforestry experts. This raises concerns that the technologies' intended benefits may not be fully realized. Moreover, there has been a disconnect between agroforestry researchers, development agents, and smallholder farmer practices for many years. Some researchers have even dismissed these practices as mistakes in implementation, which could lead to unpleasant outcomes and disincentivize others from adopting agroforestry (Appiah et al., 2020). Smallholder farmers continue to refer to their indigenous knowledge to shape how they utilize new technologies (Bruchac, 2014; Kalanzi et al., 2022).

In this study, local agroforestry practices are defined as on-farm tree farming practices that are not scientifically proven but are used by smallholder farmers to enhance the relevance of trees to their contexts (Kalanzi et al., 2022; Tega & Bojago, 2023). Local practices are based on a knowledge-building process that farmers have identified as crucial for survival. They are developed by smallholder farmers and influenced by external factors such as climate, geographical location, and culture.

Much attention has been given to adopting agroforestry technologies, with various studies exploring their potential benefits (Dagar et al., 2020; Kalanzi et al., 2021). However, some experts argue that we should also encourage and recognize the value of smallholder farmers' traditional practices, as these practices are often vital to ensuring food security and reducing poverty in rural communities (Altieri et al., 2017). Despite this, there is still a lack of understanding of how local practices can be integrated with modern agroforestry techniques. To address this gap, this study investigated the local agroforestry practices of smallholder farmers and how they affect the integration of trees in different contexts. By understanding the rationale behind smallholder farmers' local agroforestry practices, researchers and development workers can develop appropriate agroforestry technologies that are better suited to local realities and can help support sustainable agriculture and rural development.

MATERIALS AND METHODS

Study Area

The study was conducted in the Mt. Elgon region, also known as the eastern highlands of Uganda. The Mt. Elgon region is famous for producing Arabica coffee, which is more valued than the other coffee types in Uganda. To enhance the yield and quality of cherries, Arabica coffee is often interplanted with suitable shade trees (Rahn et al., 2018), a practice widely adopted by smallholder farmers in this region (Kalanzi et al., 2021). The study was explicitly conducted in the Manafwa and Namisindwa districts in the Bugisu

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sub-region. Selection of the two districts was mainly based on the high uptake of agroforestry technologies, as supported by actors such as the National Agricultural Research Organization (NARO), World Agroforestry Centre (ICRAF), and Mt. Elgon Tree Growers Enterprises (METGE), who have long engaged with the district local governments in promoting agroforestry in region (Kalanzi et al., 2021). One sub-county was purposively selected in each district based on the high concentration of smallholder farmers using agroforestry technologies. Butta and Namabya sub-counties were selected for Manafwa and Namisindwa, respectively.

Research Design

A case study approach was the most appropriate to understand the nature of smallholder farmers' practices and how they enhance the usability of trees in their prevailing situation. A case study focuses on conducting an in-depth investigation of a phenomenon in its real-life context involving thematic analysis (Creswell, 2009; Crowe et al., 2011; Yin, 2018). In this case, the phenomenon that needed to be unearthed was the smallholder farmer practices, the rationale behind their use, and their outcomes or benefits. Understanding these local practices and relevance required frequent and regular interactions with the selected smallholder farmers for four months.

Sampling Procedure for Selection of Cases

In this study, 12 smallholder farmers were purposively selected based on the following four parameters: (1) The smallholder farmer had ever attended agroforestry training sessions; the assumption was that these had acquired knowledge to transform from their conventional agroforestry practices (2) The smallholder farmer had integrated at least one of the three popular agroforestry technologies in the region (boundary planting, intercropping, and woodlot), (3) The smallholder farmer owned land on which they were practicing agroforestry; hence the flexibility in implementing agroforestry technologies and modifying them for any intended purpose, and (4) The smallholder farmer had integrated local practices in the agroforestry system. A smallholder farmer who ticked the above parameters was presumed to be knowledgeable and experienced enough – aspects necessary in decision-making during the implementation of agroforestry (Hockett & Richardson, 2018; Oyana et al., 2015). Priority was given to smallholder farmers who were interested, willing, and had time to participate in the study.

Based on the above criteria, a stratified purposeful sampling procedure was used (Omona, 2013), with the two sub-counties (Manafwa and Namisindwa) forming the strata. The smallholder farmers in each sub-county were selected while ensuring that the predominant agroforestry technologies in the areas (boundary planting, intercropping, and woodlot) and slope categories were represented (Kalanzi et al., 2021). For a smallholder farmer with more than one agroforestry technology, the selection was based on the most predominant one as assessed by the local government extension worker. Due to the topography of the eastern highlands, efforts were made to select cases from the three slope categories up-slope (>1,625 m asl); mid-slope (1,164-1,625 m asl), and down-slope (398-1,164 m asl) (UNDP, 2013). The essence of taking care of the different categories was ensuring the identified practices represented the various contexts, interests, and expectations. For example, a given slope category could influence the nature of local practices needed to make agroforestry more useful. Under each stratum, the selection of the cases was also informed by age and sex. The age categorization used by the East African Community where youth is looked at as the person falling in the age category 15-35 (Tayebwa, 2013) was used in this study's context because children in the study area who were predominantly Gisu start seeking independence earlier than elsewhere in the country. The age categories created were 15-35 years and 36-64 years, which are youths and adults, respectively. Under each age category, a female and male smallholder farmer was selected.

Data Collection

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Data were collected over four months of frequent and regular interaction with the cases using various formal and informal methods, including in-depth interviews, conversations, discussions, and direct observations of the practices on the farm. These methods complemented each other and enhanced the data's robustness and the study's validity. One of the major strengths of a case study is the different evidence sources (Crowe et al., 2011; Yin, 2018). Informal conversations are a great way of relaxing the respondent and enhancing rapport (Fritzen-Pedicini et al., 2019; Swain & Spire, 2020). Open-ended questions guided the individual in-depth interviews, while an observation checklist guided what to look for in the field. Interviews were conducted in local languages, mostly Lugisu, but often mixed with Luganda to ensure that both sides (interviewer and respondent) understood each other. The two languages are related and share many words in common. An audio recorder was used to keep the conversation uninterrupted and capture all the conversation details. Before using the recorder, each case was briefed on the reason, and permission was sought for comfort. Field notes were made too during each interaction interview/discussion with a trained research assistant (note taker). Direct observations were made to see and confirm the practices highlighted by the smallholder farmer in the in-depth interviews and understand their rationale.

Data Analysis

Audio-recorded data were transcribed verbatim (from voice to text) in English with a research assistant who understood the three languages: English, Lugisu, and Luganda. No interpretation was made yet at the transcription level; the focus was on the data collected first. Field notes and transcribed data collected from conversations and discussions were aligned before reducing the data. Data reduction is vital in sorting and organizing the data for easier generation of conclusions (Namey et al., 2008). Thematic coding (question-based) enhanced the reduction process by identifying patterns or themes within the data and categorizing them into meaningful groups. Emerging themes and patterns were identified from the comprehensively reduced data. As Ryan and Bernard (2000) explained, the keywords (e.g., context, modification, practice) guided the generation of themes and patterns. Respondents' direct quotes were used to emphasize the reasons for the modifications.

RESULTS AND DISCUSSIONS

Socio-Demographic Characteristics of the Cases

Table 1 provides a detailed description of the socio-demographic characteristics of the cases. The cases were a diverse group of five males and seven females. The majority fell into the youth age categories. Most cases were married and had at least nine years of schooling. The average household size was seven persons, indicating that these farmers were likely supporting large families. Furthermore, the cases cultivated small pieces of land, averaging 2.3 acres. These findings suggest that the cases represented a typical rural farming community with limited resources and a strong need for support.

Table 1: Description of case characteristics

Case characteristics		Frequency	Mean
Sex	Male	5	-
	Female	7	-
Age (Years)	Male Youth	2	28
	Female Youth	4	29
	Male Adult	3	44
	Female Adult	3	42
Marital status	Married	10	
	Separated	2	-
Education (Years)			9
Household size (Count)			7

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Total Land Size Owned (Acres)	2.3

Agroforestry Technologies and Tree Species Integrated on Farms

The smallholder farmers grew crops for food and income security on small land, averaging 2.3 acres. The tree species grown under the three predominant agroforestry technologies are presented in *Table 2*.

Table 2: Common tree Species in the different agroforestry (AF) technologies

AF Technology	Tree species	Description	Major use
Boundary	*Neolamarckia cadamba* Roxb, *Grevillea robusta* A.Cunn. ex R.Br, *Maesopsis eminii* Engl, *Markhamia lutea* (Benth.) K.Schum *Cordia africana* Lam, *Albizia coriaria* Welw, *Melia volkensii* Mukau	Trees systematically planted on the edge of the cropped plot	Fuel Wood Windbreaks Medicinal
Wood Lot	*Eucalyptus spp, Grevillea robusta Neolamarckia cadamba*	Single or multiple tree species established on their own plots	Fuel Wood Timber Poles
Intercropping	*Albizzia coriaria, Cordia africana Persea americana* Mill. *Mangifera indica* L.	Trees planted on the same plot with other crops, e.g. coffee and banana	Fuel Wood Fruits Medicinal Soil Fertility Shade

The primary purpose of the technologies was to enhance food productivity and provide other ecosystem goods and services, including fuel wood, medicine, shade, and soil fertility enhancement. There are several ways agroforestry technologies can enhance food productivity and sustainability on small farms (Nair, 2007). For instance, the tree species planted in agroforestry systems can serve as windbreaks, which protect crops from strong winds and reduce soil erosion. Additionally, the trees can provide shade, which helps regulate soil temperature and moisture, thus improving crop growth and yield. A study by Duffy et al. (2021) found that agroforestry systems can provide additional sources of income for farmers. Some tree species, such as *Persea americana*. and *Mangifera indica* produce fruits, while others like *Grevillea robusta* and *Neolamarckia cadamba* produce timber that can provide additional income for smallholder farmers. Moreover, trees can fix nitrogen and other nutrients in the soil, improving soil fertility and reducing the need for synthetic fertilizers, consequently increasing crop productivity (Cyamweshi et al., 2023). Though important, agroforestry is never a quick "fix" because trees, unlike crops, take a long time to mature before they can fulfil their purpose.

Smallholder Farmers' Practices

Smallholder farmers devised diverse practices to make the different agroforestry technologies relevant to their contexts (*Table 3*). The practices encountered have been categorized into seedling survival-enhancing, space-optimizing, and waiting-time shortening. The intended purpose and positive and negative impacts of the practices are also discussed.

Seedling Survival-Enhancing Practices

When tree seedling survival was the main obstacle, smallholder farmers devised techniques to aid the survival of tree seedlings during the dry spell, as discussed below.

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Table 3: Diversity of practices undertaken by smallholder farmers to increase the usability of agroforestry technologies

Case	Agroforestry System	Description	Practice Undertaken						
			Planting trees adjacent to the banana stool	Spot Mulching	Trees to support climbing plants	Integrating cocoa yams	Relayed planting	Injury to fruit tree	No thinning
1	Boundary	Married Young Male	√	√					
2	Boundary	Married Adult Male			√				
3	Boundary	Married Young Female		√					
4	Boundary	Single Adult Female				√			
5	Intercropping	Married Young Female			√				
6	Intercropping	Single Adult Female	√	√				√	
7	Intercropping	Married Adult Male				√		√	
8	Intercropping	Married Young Female	√						
9	Woodlot	Married Adult Female			√				√
10	Woodlot	Married Young Male					√		
11	Woodlot	Married Adult Male				√			
12	Woodlot	Married Adult Female							√

Planting Tree Seedlings Adjacent to Banana Stool During the Dry Season

Planting tree seedlings during the dry season (January - March and June - July) in Namabya and Butta can be challenging due to high temperatures that threaten the survival of the young plants. However, some smallholder farmers have found a way to increase the chances of survival of young plants by planting them adjacent to the banana stools, as explained below. The banana plants provide a conducive microclimate for the young trees, shielding them from direct scorching sun rays during prolonged droughts. In addition, the trees also tap into the moist soils around the banana plants. This local practice has been observed to significantly improve the survival and establishment of tree seedlings in the field, as explained by one of the smallholder farmers below.

> *"From my experience, the avocado tree seedling I once planted adjacent to an established banana stool grew very well and vigorously with dark green good-looking leaves."*.

The farmer has since applied the same technique to other tree seedlings to enhance their chances of survival. This corroborates the findings of Jassogne et al. (2013), which showed that bananas provided adequate shade for the young coffee trees in the East African highland region. However, it's important to note that seedlings could outcompete the banana plants underneath as they grow into trees. Therefore, the integration of trees in banana plantations should be planned to minimize direct competition for water, light, and soil nutrients (Burgess et al., 2022; Muhammed, 2019). When suitable tree species are planted at the proper spacing, the integration of trees can increase the productivity of the bananas. On the other hand, if the integration of trees is not well planned, the banana plantation could reduce vigor and productivity, which may discourage other smallholder farmers from planting trees in their banana plantations.

Spot-Mulching of the Tree Seedling

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Spot-mulching of tree seedlings is a traditional practice where the banana pseudo-stems are cross-cut into pieces of about 1ft, which are split using a panga and laid around the tree seedlings that have been planted. The succulent sheaths of the banana pseudo-stem are placed while facing downwards. This practice has proven effective in reducing the impact of high temperatures during drought by releasing moisture around the seedlings' root zone as the cut pseudo stem's succulent sheaths decompose. It also helps suppress weeds, minimizing tillage that could damage the fragile roots. The pseudo-stems are readily available in the study area since banana is one of the main crops grown. However, this practice is labor-intensive, involving collecting and splitting the pseudo-stems. Additionally, a dump environment can promote the emergence of pests and diseases, such as moulds and fungi, which may affect the seedlings (Alves & Nunes, 2017; Lamichhane et al., 2017; Zhang, et al., 2018).

Space Optimization

The smallholder farmers who faced space limitations for tree growing used innovative techniques to maximize the number of trees and their usefulness in supporting food security.

Using Planted Trees as Support for Climbing Crops

In the Mt. Elgon region, where land is a limiting factor for agricultural production, smallholder farmers planted climbing crops next to the planted trees for support. For instance, one of the cases planted *Neolamarkhia cadamba* in their coffee garden for firewood and shade. Still, they also used the same trees to support climbing yams (*Dioscorea* spp), locally known as 'balugu'. This practice helped them grow more food on limited land and supplemented their income as they sold some of the yams in the market. One of the cases explains:

> *"My aunt used to plant these yams on every tree in her garden. We used to feed on them, especially for breakfast. But now they are marketable when you visit Manafwa town in the evening; the women prepare and sell them as food. I have decided to plant yams on each of my trees".*

The climbing yams perform well in any soil if they have a stake or support, making them an excellent companion crop to increase the relevance of trees in enhancing food security and supporting income for smallholder farmers. This practice can also buffer failure in the leading crop enterprises, making it a sustainable and practical solution for smallholder farmers (Gwynn-Jones et al., 2018; Kebede et al., 2018; Khan et al., 2014).

Integrating Cocoa Yams in the Woodlot

Smallholder farmers have devised an innovative solution to integrate cocoa yams in their woodlots, similar to the widely practiced tangy system employed in plantation forestry (Appiah et al., 2020). The woodlots are mainly established in areas prone to seasonal waterlogging, which is conducive to yam growing. According to one of the smallholder farmers, he first learned about this practice when he visited a friend's farm in Mbale, as narrated:

> *"I noticed that the cocoa yams he had planted under his eucalyptus trees were flourishing. This inspired me to plant cocoa yams under eucalyptus trees".*

From field observations, it was evident that the woodlots where cocoa yams were integrated performed better than those without. This is probably because smallholder farmers prioritize allocating household labour to food crop production before labour for maintaining woodlots, whose returns are not immediate (Ndayambaje et al., 2013). Integrating cocoa yams in the woodlot meant that when weeding the cocoa yams, the trees in the woodlot were also weeded, which helped to maintain the overall health of the woodlot.

Relayed Planting of Eucalyptus Trees in the Woodlot

The practice of relay planting, which involves smallholder farmers planting seedlings at different times in the same plot, creates an

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uneven-aged stand. This allows for continuous harvesting of trees for income generation, as affirmed by one case who stated:

> *"When I harvest older trees for firewood and poles, I create space for the young ones to grow".*

However, it's important to note that harvesting mature trees opens up the canopy for the young trees, but if these younger trees are stunted, they may fail to regain vigour. Direct observations showed that even after harvesting the mature trees, the remaining ones are often overcrowded with varying sizes and ages, leaving little space for young trees to grow and resulting in etiolation and stuntedness. Studies have also shown that when trees are stunted early due to competition, they hardly regain vigour (Bassil et al., 2019; Sharma et al., 2016), which can significantly impact the quality and quantity of firewood and poles harvested. While it's associated with the benefit of continuously harvesting trees for home use and income, relay planting can negatively impact tree vigour and the quality of tree products.

Inducing Early Harvest

Smallholder farmers often use various practices to induce early harvests of tree products, enhancing their households' food and income security.

Injuring of Fruit Trees to Induce Early and High-Yield

As trees take a long time to deliver the desired products and services, smallholder farmers induce early fruiting and high-yielding in fruit trees by injuring them. This practice can be performed in different ways. For instance, one of the smallholder farmers wounded the avocado trees by making several cuts on the bark using a panga, while another drove a nail through the heartwood of each avocado tree. However, it is essential to note that the practice of injuring works by stressing the tree, which triggers it to flower and produce fruits (Devi et al., 2019; Malik et al., 2015; Pastore et al., 2013). While this may seem like a good practice, it can also result in injuries becoming entry points for pests and diseases (Alves & Nunes, 2017; Zhang et al., 2018). Therefore, further studies are needed to ensure this practice does not become a source of pests and diseases on the avocado trees. Nonetheless, monitoring and understanding the potential consequences of this practice is crucial to ensure that it is safe and sustainable for the farmers and their crops.

No Thinning in the Woodlot

Smallholder farmers have discovered that they can earn more from their woodlots if they leave them to grow unthinned. According to their observation, regular harvesting of poles or firewood would serve to thin the remaining trees in the woodlot. One of the smallholder farmers shared her experience:

> *"I was trained to thin my eucalyptus woodlot at two years but chose to leave it unthinned and harvest whenever I have buyers for poles or firewood. When I harvest, enough space is automatically left for the remaining trees to grow".*

For this smallholder farmer, it was not necessary to thin the woodlot at two years as recommended, and she kept harvesting the poles depending on the sizes required by the customers. This practice is suitable for the woodlots established for poles and firewood. Still, it may not work optimally for timber-managed woodlots, where competition between trees can hinder them from attaining optimal timber sizes (Vigulu et al., 2019).

CONCLUSION

This study has highlighted several innovative practices that smallholder farmers in the Mt. Elgon region use to overcome challenges they face in tree growing. Some of these practices include planting tree seedlings adjacent to banana stools, spot-mulching of tree seedlings, using planted trees as support for climbing crops, integrating cocoa yams in woodlots, relay planting, injuring the fruit trees, and avoiding thinning in the woodlot. These practices have proven effective in enhancing tree survival, maximizing the use of limited land, and enhancing food security and income for smallholder farmers. The study recommends that agroforestry

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researchers and development agents recognize and integrate traditional practices with modern techniques to develop appropriate agroforestry technologies that can support sustainable agriculture and rural development. Although the sample was small, the study provided a rich and holistic account of smallholder farmers' practices, enabling them to make agroforestry technologies more applicable to their contexts. Further research is needed to evaluate smallholder farmers' practices for wide-scale agroforestry uptake.

Disclosure Statement

The authors reported no potential conflict of interest.

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