Sokoine University of Agriculture

MSc Dissertation

Tree Farming Investments and Implications to Carbon Storage in Bukoba District, Tanzania

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TREE FARMING INVESTMENTS AND IMPLICATIONS TO CARBON STORAGE IN BUKOBA DISTRICT, TANZANIA

Dissertation is Submitted to Sokoine University of Agriculture in Fulfilment of the Requirements for the Master Degree of Ecosystem Sciences and Management

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EXTENDED ABSTRACT

The current contribution of farm trees in solving wood related problems and income generation to smallholders in developing countries is unquestionable. However, the factors influencing households' decisions to invest in tree planting and the amount of carbon stored in agroforestry systems in many areas remain to be site and time specific and not clearly understood. The study aimed at assessing the factors influencing household decisions to invest in tree planting and implications to soil organic carbon storage in Bukoba district, Tanzania.

A total of 80 households (40 with and 40 without woodlots) were randomly selected in four villages and questionnaires were applied for data collection. Data were analysed through descriptive statistics and binary logit regression. In the other hand, random sampling technique was used to select 32 homegarden and 32 woodlot farms. In farm sampling plots of 5m x 5m were established and two soil samples per plot were extracted, one from a depth 0-15cm and another from 15-30cm. A total of 128 composite soil samples were collected for laboratory analysis. The Walkley – Black procedures for Soil sample analysis was applied.

The study's results showed that household land size, the age of the household head, accessibility to loan and credit services, availability of land not suitable for crop production, and education level of the household head, significantly ($P<0.05$) influenced households' decisions to invest in tree planting. Sex of the household head, market availability, land ownership and risk perception had no influence ($P<0.05$) on the decisions of the household to invest in woodlot farming. Furthermore, the results revealed that woodlots significantly ($P<0.5$) stored higher soil organic carbon content (125.2 ton/ha) compared to the homegarden agroforestry (96.8 ton/ha) in general.

The knowledge created in this study is essential for policy makers and implementers to come out with appropriate agricultural approaches, which will have multi impacts economically, socially and environmentally.

IKISIRI KUU

Ni ukweli usiopingika kuwa kilimo cha miti miongoni mwa nchi chipukia kiuchumi, kina mchango mkubwa katika kumaliza taizo la upatikanaji wa mazao ya miti na kuinua kipato cha wakulima vijijini. Hata hivyo, sababu zinazomsukuma kaya kuwekeza kwenye kilimo cha miti na kiasi cha hewa ukaa kinacho hifadhiwa katika udongo uliopo kwenye mashamba ya miti hutegemea eneo na muda. Hivyo lengo mahususi la kufanya utafiti huu ni kubaini sababu zinazosukuma kaya kujihusisha na kilimo cha miti pamoja na kiasi cha hewa ukaa kinachohifadhiwa katika udongo kwenye mashamba ya miti.

Jumla ya kaya 80 zilichaguliwa bila kuzingatia kigezo chochote na taarifa zilkusanywa kwa kutumia karatasi yenye maswali. Taarifa zilizokusanywa zilihaririwa kwa njia ya maumbo na maelezo lakini pia kwa kutumia “logit regression”. Vilevile, mashamba ya sampuli 32 ya miti na 32 ya kilimo mseto yalichaguliwa bila kigezo chochote. Sehemu ya shamba yenye ukubwa wa mita 5 x 5 ilipimwa katikati ya shamba na samupuli za udongo kuchukuliwa katika kina cha sentimita 0-15 na 15-30. Jumla ya sampuli za udongo 128 zilichukuliwa na kupelekwa maabara kwa ajili ya uchunguzi. Taarifa za udongo zilihaririwa kwa kutumia njia ya ”Walkley – Black”.

Matokeo ya utafi huu yalionesha kuwa sababu kama; ukubwa wa ardhi inayomilikiwa na kaya, umri wa mkuu wa kaya,upatikanaji wa mikopo na huduma za kifedha, kaya kumiliki ardhi isiyostawisha mazao ya chakula na biashara na kiwango cha elimu cha mkuu wa kaya zilichangia kwa kiasi kikubwa $P<0.05$ maamuzi ya kaya kuwekeza kwenye kilimo cha miti katika eneo la utafiti. Hata hivyo, Jinsia ya mkuu wa kaya, upatikanaji wa masoko, hali ya umiliki wa ardhi, na hofu ya kupata hasara pia kwa kiasi kidogo sana kisichoweza kudhibitishwa $P<0.05$ zilichangia kwenye maamuzi ya kaya kuwekeza kwenye kilimo cha miti. Aidha, matokeo pia yalionesha kuwa kiujumla, mashamba ya miti yanahifadhi kiasi

kikubwa cha kaboni 125.2 ton/ha kwenye udongo kuliko mashamba mseto 96.8 ton/ha.

Matokeo ya utafit huu yanaweza kutumiwa na watunga sera na waandaaji wa programu za ugani na misitu kuibua mikakati bora ya kukuza kilimo cha miti kwa wakulima wadogo. Pia kubuni na kuamasisha mikakati bora ya kulimo kwa kupanda na kutunza miti mashambani kwa ajili ya kukuza uchumi wa kaya na kulinda ikolojia. Zaidi ni muhimu pia kutunga sheria zitakazosimamia ulimaji na uvunaji miti bila kuleta athari hasi za kiikoloji

DECLARATION

I, **ARISTERIUS B. CHRISTIAN**, do hereby declare to the Senate of Sokoine University of Agriculture that this dissertation is my own original work done within the period of registration and that it has neither been submitted nor being concurrently submitted in any other institution.

__________________________ ____________________

Aristerius B. Christian Date
(MSc. Candidate)

The above is declaration is confirmed by;

__________________________ ____________________

Dr. Beatus J. Temu Date
(Supervisor)

__________________________ ____________________

Dr. Bernardol J. Manyanda Date
(Supervisor)

LIST OF MANUSCRIPTS

Manuscript 1: Factors Influencing Households' Decisions to Invest in Pine and Eucalyptus Woodlots in Bukoba District, Tanzania

Manuscript 2: Soil Organic Carbon in Agroforestry Technologies in Bukoba District, Tanzania.

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I would like to express sincere gratitude to my supervisors Dr Beatus J. Temu and, Dr. Bernardol J. Manyanda for their passionate support and guidance throughout the research project. They taught me the research methodology and helped me to present my work clearly. I am honored to have worked under their guidance and thank them for their friendship, compassion, and sense of humour. I appreciate their constructive feedback and comments and have learned a great deal from them.

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My deepest gratitude goes to my family and friends, especially to my wife (Jonia A. Clemence), my children and brothers for their love, prayers, encouragement and patience throughout my study. Your presence has a great value to me, you always have a special place in my heart. Thank you so much.

DEDICATION

I would like to dedicate this work to my wife Jonia A. Clemence, my sons Jackson Christian, James Christian, Jacton Christian and my only daughter Jackline Christian, may this achievement forever be your inspiration for a great future ahead, I love you.

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LIST OF ABBREVIATIONS, ACRONYMS AND SYMBOLS

CO_2	Carbon dioxide
CSIRO	Commonwealth Scientific and Research Organization
FAO	Food and Agriculture Organization
$FeSO_4$	Iron II sulphate
GHGs	Green House Gases
H_3PO_4	Phosphoric Acid
HGA	Homegarden Agroforestry
MSDG	Millennium Sustainable Development Goals
NGO	Non-Governmental Organization
SDGs	Sustainable Development Goals
SOC	Soil Organic Carbon
UN	United Nations
WLT	Woodlot

CHAPTER ONE

1.0 General introduction

1.1 Background information

The crucial role of farm trees in addressing wood-related challenges and generating income for small-scale farmers in developing nations is undeniable, with a clear preference for exotic tree species, as noted by Kiyingi *et al.* (2016). Pine and eucalyptus, among other exotic species, have demonstrated promising performance across various global regions. Chamshama's study in 2011 highlights the potential of integrating tree farming into agricultural landscapes as a means to meet the growing demand for forest resources locally, particularly through smallholder woodlots and homegarden agroforestry (Chamshama, 2011).

The degradation of forests poses a threat to the sustainable availability of both wood and non-wood products (Fanjana, 2020; Kiyingi *et al.,* 2016; Melvani *et al.*, 2020). Since the late 19th century, tree farming has emerged as a focal point for environmental activists and forestry professionals, driven by three primary objectives: climate change mitigation, income generation, and environmental conservation (Cardinael *et al.,* 2017; Kimaro *et al.,* 2011; Stockmann *et al.,* 2015). In response to these goals, agroforestry farming systems have been increasingly introduced, particularly in developing countries (Eshetu *et al.,* 2017).

Policy makers and local stakeholders alike have recognized agroforestry systems as a critical strategy to address environmental degradation and reinforce the supply of forest products while simultaneously enhancing income opportunities for small-scale farmers (Pandit *et al.,* 2014)

Agroforestry systems have emerged as the predominant farming method in numerous developing nations worldwide, owing to their manifold benefits across social, economic, and environmental dimensions (Duguma, 2013; Tsere *et al.,* 2023). This approach is particularly favored in regions across Asia, South America, and Africa due to its ability to utilize small land parcels while engaging household members as labor sources. Such systems provide households with a range of ecosystem services crucial for their sustenance (Bantihun Mehari & Abera, 2019).

Many households integrate tree farms, known as woodlots, alongside their agroforestry setups to meet household fuel needs and generate cash income through the sale of wood products (Kiyingi *et al.,* 2016). This practice aligns with the objectives outlined in the Millennium Sustainable Development Goals 1 and 2 (Waldron *et al.,* 2017). Woodlots also play a significant role in global climate change mitigation efforts through carbon sequestration.

In the Kagera region, homestead agroforestry (HAFs) is characterized by the intentional management of diverse trees and shrubs in close association with both annual and perennial agricultural crops, including food and cash crops, as well as livestock, all within the confines of individual household compounds. Within this farming system, the entire crop-tree-animal units are tended to by family labor (Fernandes and Nair, 1986; Rugalema *et al.*, 1994; Kewessa, 2020). This system is renowned for its contributions to food security, income generation, climate change mitigation and adaptation, as well as environmental conservation.

More recently, monoculture tree farming practices, particularly on privately-owned land (referred to as woodlots), have gained rapid popularity among farmers in the Kagera region. In this context, woodlots denote smallholder-initiated tree plantations primarily aimed at producing firewood, timber, or other tree-based products on relatively small landholdings (< 5 Ha). The prevalent high demand for fuel wood within households, coupled with the desire for additional income, prompts many households to establish woodlots on their farmland (Eshetu *et al.,* 2017). Apart from being integral to agriculture-based economies, forests, and other natural landscapes, woodlots play a vital role in families' subsistence and overall livelihoods. Similarly, woodlots contribute approximately 28% to rural household incomes through the sale of tree products on the market and through carbon credits (Ali *et al.,* 2020; Angelsen *et al.,* 2014), as well as other related revenue streams (Temu *et al.,* 2015; Kapp and Products), 2021; Arvola *et al.,* 2019; Kimambo *et al.,* 2020 Gebreegziabher and Van 2013).

Pines and eucalypts are the common tree species adopted by farmers in many parts of Tanzania. The tree species are well known for their adaptability to many areas in the world but also in many parts of Tanzania including the northern, southern and western regions (Chamshama, 2011; Eshetu et al., 2017; Kimambo et al., 2020). The woodlots are widely grown mainly in farmers' land to generate cash income from poles, fuel wood, and wood-based products through selling to urban and peri-urban markets (Kimambo et al., 2020). Besides the financial benefits that farmers draw from the woodlots, they also play in part soil conservation and forest land restoration (Ndayambaje, 2013; Lusambo *et al.*, 2021; Negelle & Central, 2012; Zoysa & Inoue, 2016)

1.2 Problem Statement and Justification

In developing nations such as Tanzania, the cultivation of trees on farms has emerged as a pivotal strategy to address complex challenges while fostering economic growth among smallholder farmers. Beyond the traditional role of providing timber and fuel wood, farm trees have increasingly become essential contributors to income generation and environmental sustainability.

In many countries including Tanzania, pines and eucalypts are commonly cultivated exotic tree species (Ahimbisibwe *et al.,* 2019; Ndayambaje, 2013). This preference stems from their adaptability to local climatic conditions and the presence of fertile soil (Ahimbisibwe *et al.,* 2019). A study conducted by Kimambo *et al.,* in 2020 underscored the significant social, economic, and environmental benefits of woodlots populated with pine and eucalypts in Tanzania's southern regions, where conditions closely resemble those of tropical areas. Similarly, in Bukoba district, situated in the western part of mainland Tanzania, there exists a similar potential for widespread tree planting, which could greatly benefit farmers. Furthermore, pine and eucalyptus are commercially valuable species, and the sale of their products could substantially augment farmers' incomes and enhance rural livelihoods in the district. Consequently, the widespread adoption of tree planting by farmers in Bukoba district holds promise for addressing local poverty, safeguarding the environment, and mitigating climate change.

1.2.2 Justification

Despite the evident social, economic, and ecological benefits offered by two key tree species, farmers in Bukoba district demonstrate a lack of sufficient interest in investing in tree planting endeavors (Kulindwa, 2016). However, the dynamics influencing households' decisions to invest in tree farming and the implications for carbon sequestration remain complex and understudied. This study seeks to assess the factors shaping household decisions regarding tree farming investments and their impacts on soil organic carbon storage, focusing on the context of Bukoba district, Tanzania.

Through this exploration, we aim to provide insights into the potential of tree farming as a sustainable livelihood strategy in the context of developing economies. Additionally, the findings of this study are expected to inform policymakers in developing optimal approaches for land use planning, forestry, and extension services, thereby promoting the widespread adoption of farm tree farming practices without compromising agricultural crop production. Ultimately, such initiatives will contribute to sustainable development in impoverished rural communities, fostering food security, income generation, and environmental conservation (UN assembly, 2015)

1.3 Objectives

1.3.1 General objective

Assessment of the factors influencing household decision to invest in tree planting and implications to soil organic carbon storage.

1.3.2 Specific objectives

i. To assess factors influencing households' decision to invest in pine and eucalypts woodlots in the study area
ii. To quantify soil organic carbon in agroforestry technologies in the study area

1.4 Limitations of the Study

After assessing the factors affecting households' decision to invest in tree planting and their contribution to carbon storage, the variations among the responses of the households to the factors influencing the household to invest in or not and the amount of carbon stored in the soil in each farm type remain to be site and time specific. This is because this study was established in a single district with only one visit to the sampled households and farms, thus, assessing peoples' decisions which change from time and place and the amount of carbon stored in the soil without assessing other factors apart from farm type and tree species remain as limitations. Here, suggestions for follow-up research are presented:

- Similar studies should be conducted in other places to explore the validity and variability of the factors revealed in this study as factors influencing households' decisions to invest in tree farming.
- It is advisable to consider other factors which affect SOC such as climatic conditions, edaphic and topographic factors in estimating SOC over time and place.

1.5 Dissertation Structure

This dissertation is divided into five chapters and is structured as a series of publishable manuscripts. The first chapter provides an introduction to the study, including background information, the problem statement and study objectives. Chapter two encompasses first manuscript titled factors influencing households' decisions to invest in pine and eucalyptus woodlots in Bukoba District, Tanzania. Chapter three consists paper 2 titled estimates soil organic carbon in agroforestry technologies in Bukoba District, Tanzania. Chapter four is a general discussion of the study's findings, and Chapter five provides a summary of the key contributions, conclusions, and recommendations.

CHAPTER TWO

Manuscript One

2.0 Factors Influencing Households' Decisions to Invest in Pine and Eucalyptus Woodlots in Bukoba, Tanzania

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Abstract
Pine and eucalypts have shown good performance in terms of growth in many parts of the world including Tanzania. The financial performance of the two tree species has been described to be feasible in many parts of Tanzania. The effective adoption of pine and eucalypts farming could increase the households' income in many poor rural communities in the Kagera region. Recently there has been a surge of tree planting in the Kagera region, though inadequate, regardless of the good climatic condition and enough land to establish pines and eucalypts farms in the region. Therefore, there is a need to understand the factors influencing households' decisions to invest in tree farming, specifically pines and eucalypts in Bukoba district, Kagera-Tanzania. Multistage sampling techniques were employed. A total of 80 households (40 with and 40 without woodlots) were randomly selected in four purposively selected villages. Interviews and questionnaires were applied for data collection to village heads and household heads respectively. Data were analysed through descriptive statistics and binary logit regression analysis. The findings revealed that farm size, age of household head, land not suitable for crop production, loan and credit accessibility, and education level of household head significantly ($p<0.05$) influenced the household's decisions to invest in pines and eucalypts farming. Incorporating smallholder tree planters into social groups like cooperatives and tree grower's associations, as well as providing wood product prices and markets such as through an information platform would encourage many farmers to engage in woodlot farming.

Keywords: Agroforestry, Income, Farming, Woodlot, Household, Trees

2.1 Introduction

2.1.1 Background

The on-going depletion of natural resources especially land and forests due to over dependence of many people to these resources has become a serious problem around the world. Agroforestry is an effective land-use method for diminishing lands, that involves cultivating many tree species alongside crops Zoysa and Inoue, 2016; Taylor *et al.,* 2015). Woodlots on agricultural lands are becoming more acknowledged for the potential to mitigate climate change while providing solutions to energy associated issues and households' income generation (Ndayambaje 2013; Melvani *et al.,* 2020; Kimambo *et al.,* 2020). Small and large-scale investments in tree enterprises created many employment opportunities for skilled and unskilled communities (Eshetu *et al.,* 2017; Arvola *et al.,* 2019).
Tree farm operations such as farm preparations, planting, management, and harvesting are some of many farm activities employing several workers in forestry enterprises (Melvani *et al.,* 2020). For instance, many global initiatives (e.g., Paris Accord, Aichi Targets, New York Declaration on Forests, REDD+, IPCC) make a clear commitment to lessen deforestation in developing countries by promoting tree planting for climate change mitigation and adoption while improving the livelihood to the local people (Laestadius *et al.,* 2015: Temu *et al.,* 2015). Many programs have clearly stated goals of improving rural livelihood and environmental conservation. Governments in the tropics struggle to come up with strategies that would improve the livelihoods of the rural communities while conserving the environment through tree farming.

The study by Zoysa & Inoue (2016) in Sir Lanka on the farmer woodlot management and sustainable livelihood development found that woodlots ensure households' welfare development and widening of the sources of energy for cooking. Further, he commented that increased households' annual income promoted household ability in self-financing forest and agricultural activity and improved capabilities in formal banking transactions under financial capital development. On the other hand, in Chile, Salas *et al.* (2016) explained that farm forestry beneficiaries generating new employment within their villages and use profits to invest in other enterprises and build community assets and physical assets without assistance from the government. In Eastern-North America, Sophie *et al.* (2016) used FVS growth model to simulate three management scenarios, found that tree planting could increase timber production, supply firewood, and improve degraded ecosystems. Obiri *et al.* (2018), in their study on financial analysis of fuel wood production from woodlots in the Savannah transition zone of Ghana, showed that fuelwood production from woodlots was profitable with an NPV of GH¢1,787.00, B/C ratio of 1.17, and IRR of 40.42 percent at a market discount rate of 22 percent over 25 years. Similarly, the study by Ninson *et al.* (2022) in Ghana, using a profitability model to assess the profitability of agriculture and woodlots, found that woodlot producers with contractual relationships with the Forest Commission and other forestry companies produce the highest Net Present Value (NPV) and Benefit-Cost Ratio (BCR. Ashraf *et al.* (2015) in India explored the factors influencing farmers' decisions to plant trees on their farms. Using the binary logistic regression model, he found that factors such as the size of land holdings, overall annual income, area of irrigated land, and prior experience with tree planting correlated positively and significantly with tree planting. Many studies use a binary logistic regression model to determine the factors influencing smallholders to adopt tree farming. For instance, Ndayambaje (2013) in Rwanda assessed the determinants and the purposes that enhance the propensity to grow woodlots in low, medium, and high-altitude regions. He found that the age of the householder, number of salaried household members, farm size, travel distance to fuelwood sources, and household location influence the adoption of eucalypts planting. He further argued that many households possess eucalyptus woodlots for economic reasons and not for environmental purposes. Apeh *et al.* (2023) of Nigeria assessed the determinants of adopting urban tree planting as a climate change mitigation strategy. He found that the price of the tree, access to information on the changing climate, access to water, use and access of trees, and occupation positively influenced households' decisions to adopt urban tree planting. In Uganda, Ahimbisibwe *et al.* (2019) studied determinants influencing the decision-making process and the likelihood of woodlot establishment. He concluded that the willingness and intention of households to establish woodlots and the relative age of the household head significantly influenced the likelihood of woodlot establishment. Additionally, Tefera *et al.* (2017) in Ethiopia analyzed the determinants that influence the decisions of farmers to plant eucalypt trees in the Market District. He reported that farm size, loan and credit facility, per capita income, age, land ownership, and availability of non-agricultural land significantly affected the adoption decisions of many farmers.

In Tanzania, few studies have assessed the factors influencing household decisions to invest in tree planting. The research by Kulindwa (2016) in the Coast and Morogoro regions is one of them. His study assessed the key factors that influenced households' tree-planting behaviors and reported that households' land sizes, households' awareness of tree-planting programs, trees for wood energy, and the age of the head of the household positively and significantly influenced the behavior of the household. However, more efforts are needed to explore the factors influencing households' decisions to or not to invest in tree farming in other regions in the country since the influencing factors are site and time-specific. These efforts should motivated by the known financial, social, and environmental benefits of the exotic species such as pines and eucalyptus. For instance, the economic report (2023) of the Ministry of Finance of Tanzania ranked the Kagera region as the third poorest region in the country. Probably following the downfall of the price of coffee as the major cash crop, low banana production, unsustainable fishing in Lake Victoria, and increasing population growth might have contributed to the prevailing poverty among the people in the region (Region, 2018). However, the region has unexploited potential in the forestry sector that supports pine and eucalypts farming, for example, good climatic conditions, good soil, and plenty of land not used for crop cultivation (Mwijage, 2015). The sales of wood products from the pines and eucalypts in the growing urban centers in the region and neighboring regions can increase smallholders' income and government revenue.

It therefore implies, the need for more studies to increase the understanding of the factors influencing household decisions to establish tree farming. For that concern, the study assessed the factors influencing households' decisions to invest in pines and eucalypts farming in Bukoba district, Tanzania. In this study factors influencing household decisions such as farm size, age of household head, market availability for tree products, Sex of the household head, Loans and credit services availability, land ownership, risk perception, availability of land not suitable for crops, and education level were assessed in this study. The results will provide an effective means for policymakers, development professionals, and extension staff to promote farm forestry to improve households' income and to meet the rising demand for fuel woods while contributing to sustainable environmental conservation in the country.

2.1.2 Analytical framework

Pines and eucalypts are the most outstanding exotic species in generating extra household income for many poor rural farmers in developing countries (Kimambo *et al.,* 2020; Kiyingi *et al.,* 2016; Lusambo *et al.,* 2021). Woodlot farming is a new agroforestry technology in many developing countries like Tanzania. The adoption of farmers to it is gradual, involving information processing and decision-making to maximize the use of household productive assets (Ashraf *et al.,* 2015). Smallholders go through steps of trial and error to gain an understanding of the advantages and disadvantages of planting pines and eucalyptus before deciding whether or not to proceed with the investment. The study by Carroll *et al.* (2011) and Ashraf *et al.* (2015) explained that institution and policy tools designed to match households' utility, which includes tree planting programs, grants and loans and credit service availability, market for wood products and income motivations influenced farmers' decisions to invest in woodlots. Ashraf *et al.* (2015) stated that the area of cropping land of the household, monthly income of the family, tree planting experience of the head of the family, and cropping land with access to irrigation were the main determinants of the adoption of tree planting at 5 % level of significance. This study adopted the approach put out by Tefera *et al*. (2017) and Ahimbisibwe *et al.* (2019) (Figure 2.1).

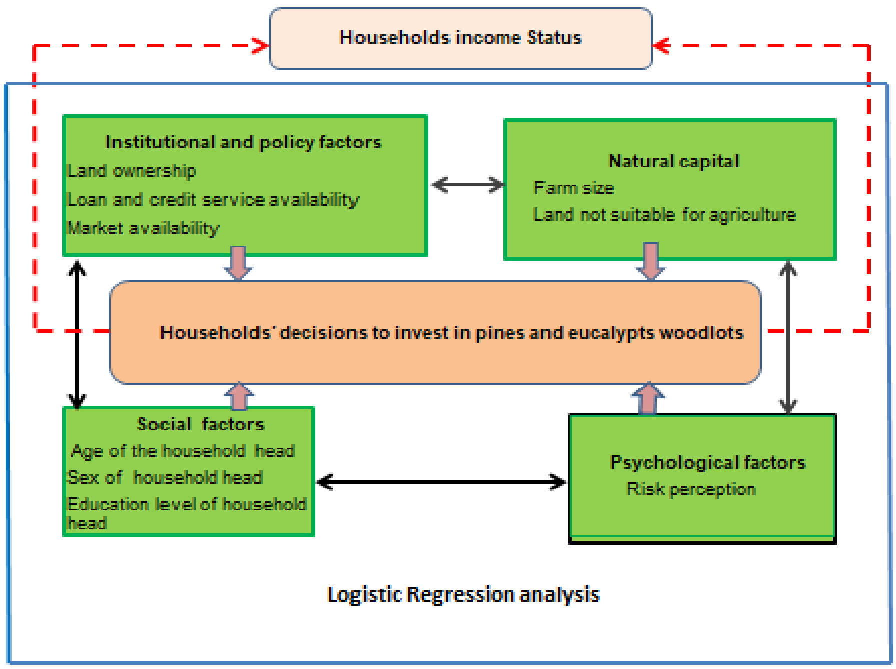

Figure 2.1: Analytical framework of the factors influencing households' decisions to invest in pines and eucalypts woodlots

Ahimbisibwe *et al.* (2019); Setiye *et al*. (2017)

Note The study focuses only on bold arrows

2.2 Methodology

2.2.1 Study area description

Bukoba District is in the Kagera region (Fig. 2.2) and covers an area of 1,618 km2 with a population of 322,448 people (NBS census of 2022). Located between latitudes 1° 00′ and 2^0 00′ S and between longitudes 31° 24′ and 31° 41′ E. Has the altitudes between 1200 and 1400 meters above sea level. It receives rainfall between 750 and 1250 mm per year, which peaks in two periods in a year, March-May and September-December, whereby June-August is a dry season. The district borders with Lake Victoria to the north, Muleba District to the south, Bukoba Municipal to the northeast, Lake Victoria to the southeast, Karagwe District to the southwest, and Missenyi District to the northwest. The climatic condition varies into savanna in the southwest and tropical rainforest in the northwest and central parts of the district. The vegetation cover varies from thickets and short grasses in the south to thick forests with a canopy of tall trees and long glasses in the north (Mwijage, 2015). The most preferred farming system is home-garden agroforestry. Bananas, cassava, and yams are the dominant food crops, and coffee and vanilla are common cash crops. Seasonally, crops such as maize and beans get mixed on the same farm (Rugalema *et al.,* 1994). The deforestation and degradation of natural forests are high in the region regardless of the tree planting campaign from the government institutions and NGOs aiming at restoring the forest land.

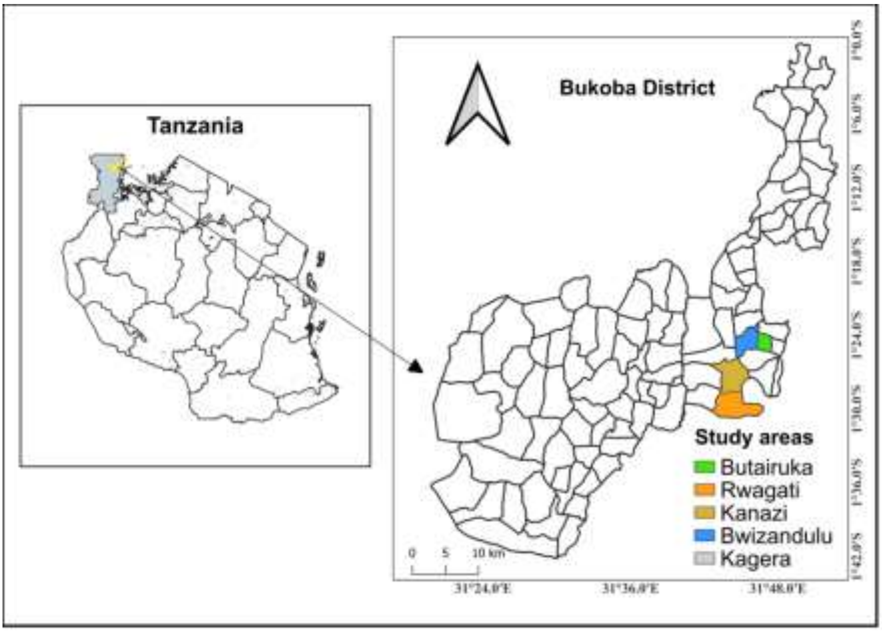

Figure 2.2: Map showing the geographic location of the study areas

2.2.2 Research design

The study used a cross-sectional research design. This research design tends to provide a snapshot of the outcome and associate the characteristics at a specific point in time (Levin, 2016). The selection of this study design considered its appropriateness and cost-effectiveness and less time-consuming. It tends to allow the collection of data from respondents at a time, and it is suitable for description purposes as well as the determination of relationships between the variables under study. The village heads prepared the lists of households with and without woodlots. The lists helped to select the sampling units in each village.

2.2.3 Sampling design and sample size determination

The study employed both purposive and random sampling techniques. Wards, villages, and sub-villages were purposively sampled based on the intensity of woodlot farming practices in these administration areas. The households with and without pine and eucalyptus woodlots (focal units of analysis) were selected randomly from the registers in the village offices.

The minimum sample size is summarized below.

$$n= N/1+Nxe^2 \qquad \text{Equation.............(1)}$$

whereby, n is the minimum sample size of households, N is the target population of households in the wards (two villages), and e is the 10% minimum level of precision accepted for statistics (Naing, 2003)

Replacing Equation (1) with actual values,

$$n=392/1+(392x(0.1)^2)=79$$

Therefore, n = 79 was the minimum sample size. In the end (as indicated in Table 2.1), 80 households (40 households with woodlots and 40 without woodlots) were sampled in all four villages, covering 20.4% of the sampling intensity of all households.

Table 2.1: Sampling proportions for household surveys

Number of Households Sampled per Village					Sample Percentage Proportion per Village		
Sampling Village	**With tree farms**	**Without tree farms**	**Total Sample**	**Total Households**	**With tree farms**	**Without Tree farms**	**Total**
Butairuka	9	10	19	96	9.4	10.4	19.8
Buizandulu	11	11	22	107	10.3	10.3	20. 6
Kanazi	9	9	18	86	10.4	10.4	20.8
Rwagati	11	10	21	102	10.7	9.8	20.5
Total	**40**	**40**	**80**	**392**	**10.2**	**10.2**	**20.4**

2.3 Data Collection

Key informant interviews: The ward administrative, extension, and forest officers were all interviewed. Additionally, interviews were conducted with the village heads since they have general background knowledge about the farming practices of the study site.

Household survey**:** A total of 80 households surveyed. Structured and semi-structured questionnaires were developed and employed to collect information from the household heads. Data on their biophysical and farming practices, including specific production costs and production per harvesting time, were gathered.

Market assessment**:** The triangulation assessment (Si 2017) method of data collection was applied in collecting the data related to prices of the marketable outputs from woodlots and home garden agroforestry farms. The information about the market prices of the farm commodities were given by village heads, household heads, and farm commodity dealers at the markets.

2.4 Data Analysis

A binary logistic regression model was the appropriate model used to determine the factors that influenced household decisions to invest in pines and eucalypt woodlots in the study site. It is the appropriate model because of the categorical independent variables and the binary response variables (yes /no). Similarly, the model does not require an independent variable to be on a meaningful scale. Analytically, a household has two choices: to establish a tree farms (1) or not to establish a tree farms (denoted as 0). Logistic regression identifies the predictor variable (X) that best associate with the dependent variable (Y) (Ahimbisibwe *et al.*, 2019). In summary, only nine factors were the most influential predictor variables during the binary logistic regression analysis. SPSS version 20 software was used

The farmer's choice to establish woodlots is the dependent variable in this scenario, and it is assigned a value of 1 and a value of 0 if otherwise.

$y = \{^{1}_{0}\beta 0 + \beta 1x1 + \varepsilon > 0\}$ Equation ……(2)

Whereby ε is the distribution error by the standard logistic distribution, and the logistic function takes the real input value t, whereas the output always takes values between 1 and 0, making it a probability/likelihood function. Therefore, the logistic function σ (t) is defined as

$\sigma(t) = 1/1 + exp^{-t}$ Equation ……(3)

Expressing t as a linear function of a single predictor x

$t = \beta 0 + \beta 1x$ Equation …(4)

Hence, the logistic function becomes

$y_1 = \mathbf{1}/1 + exp^{-(\beta 0 + \beta 1x)}$ Equation….(5)

This can be linked to the linear predictor function

$Li = ln\left[\frac{Pi}{1-Pi}\right] = Zi = \beta 0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_4 x_4 + \ldots\ldots\beta_n x_n$ …………….Equation…………………………………………………..(6)

$\beta 0$ = An intercept

$\beta_1 + \beta_2 + \beta_3 + \beta_4 + \ldots\ldots\beta_n$ = Slopes of the equation model

Li = is the log of the odds ratios

Zi = is the vector of relevant farmer characteristics

If the error term '**ε**' is introduced, the equation becomes:

$Zi = \beta 0 + \beta_1$ Farm size+ β_2* Age of household head + β_3* Loan and Credit service accessibility + B_4* Land not suitable for crop growth + B_5*Education level of household head + B_6*Market availability + B_7*Sex of household head + B_8*Risk perception*

Nine factors; household farm size, age of household head, availability of land not suitable for crop cultivation, loans, and credit service accessibility, education level of a household head, market availability, sex of household head, and risk perception were finally computed in the logit regression model above to assess their likelihood influence on the household decisions to invest or not invest in pine and eucalypt woodlots.

2.5 Results

Table 2.2: Characteristics of households with and without woodlots (Standard deviations of means are in parentheses)

Variables	Household		Statistical tests		
	With tree farms	**Without tree farms**	**t Test (t-Ratio)**	**Pearson's Chi-Square (χ2)**	**p-Values**
Natural Capital					
Land ownership (%)					
Household owned	100	96		1.3	0.62
Rent	0	4			
Natural forest availability (%)					
Good	3	4			
Poor	12.5	8		1.5	0.51
Average	84.5	88			
HH Land not under crop Production (%)					
Yes	72	21			
No	28	79		7.16	0.042**
Mean Land size holding	1.1(0.65)	0.89(0.32)			0.031**
Financial Capital					
Mean number of livestock	4.3(1.2)	5.4(0.8)	0.49		0.072
Nonfarm income (%)					
Yes	42	12		1.6	0.53
No	58	88			
Loan and Credit service Availability **(%)**					
Accessing	31	8			
Not accessing	69	92			
Human Capital					
Household Education level (%)					
Adult education	3	8			
Primary education	63	84			
Secondary education	13	4		7.8	0.041**
Collage/university	21	4			
Mean household head Age	40	55	2.72		0.007***
Mean household size	5.4(2.3)	3(0.8)	1.3		0.08
Mean available household labor (no.people)	2(1.3)	3(2.01)	0.7		0.66
Mean external labor hired labor per season (no.people)	3.3(0.31)	2.2(0.51)	1.04		0.34
Mean number of household dependents	2.5(3.1)	3.6(2.33)	0.5		0.97
Social Capital					
House hold head gender (%)					
Male	81	75			
Female	19	25		1.7	0.532
Risk perception (%)					
Low	69	33			
Average	31	67		1.5	0.66
Source of fuel (%)					
Firewood	99	100			
Gas	1	0		1.9	0.43
Electricity	0	0			
Source of firewood (%)					
Natural forestland	6	98		1.2	0.78
Woodlot	94	2			

Note: Pearson's Chi-squared test of association (2) for categorical variables and t-test of differences in means for continuous variables. Standard deviations in parenthesis are provided only for continuous variables. Asterisks represent level of significances, **: $p < 0.05$.

2.5.1 Households with tree farms and tree species types

In contrast to eucalypts, the results indicate a comparatively high number of households in all four villages engaged in pine farming. The study divided woodlots into pine farms, pine with eucalypt farms, and eucalypts farms. According to this classification, the proportion of households with pine farms was (65.5%), followed by both pine and eucalypts farms (19%) and eucalypts farms (15.5%) Table 2.3.

Table 2.3: Type of tree farms in the study area

Villages	Sampled Households (%)	Type of trees Pine only (%)	Eucalypts (%)	Both pine and Eucalypts (%)
Butairuka	28	78	11	11
Buizandulu	25	63	13	25
Kanazi	25	50	25	25
Rwagati	22	71	14	14
Total	100	65.5	15.5	19

2.5.2 Factors influencing household's decisions to invest in tree farming

The analysis shows that the household farm size holding, age of the household head, loan and credit service availability, land that is not suitable for crop cultivation, and education level of the household head significantly ($P<0.05$) influence households' decision to establish woodlots in the study as shown in Table 2.4. The sex of the household head, market availability, land ownership, and risk perception seemed not to have any significant ($p<0.05$) influence on the decisions of the household to invest in tree farming.

Table 2.4: Factors influencing household's decisions to invest in both pine and eucalyptus woodlots

Parameters	B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I.for EXP(B) Lower	Upper
Farm Size	.371	.805	.212	1	.014**	1.449	.299	7.019
Age of household head	-1.651	.573	8.291	1	.004***	.192	.062	.590
Sex of household head	.275	1.391	.039	1	.843 NS	1.317	.086	20.105
Market availability	.857	1.947	.194	1	.660 NS	.425	.009	19.287
Loan and credit service accessibility	20.514	10120.475	.000	1	.021**	.000	.000	.
Land not suitable for crop production	.364	.966	.142	1	.047**	1.439	.217	9.554
Land ownership	.483	54592.550	.000	1	1.00 NS	1.622	.000	.
Risk perception	-1.288	1.487	.749	1	.387 NS	.276	.015	5.091
Level of education	20.072	12666.731	.000	1	.008 ***	521451349.	.000	.
Constant	-16.574	12666.731	.000	1	.999 NS	.000		

Note: *, **, and *** indicate statistical significance at the 0.1, 0.05, and 0.001 level, NS=not significant

Table 2.5: Factors influencing the households' decisions to invest in only Pine woodlots

Parameters	β	S.E.	df	Sig.	Exp(B)
Farm size	.724	.573	1	.026**	2.062
Household head Age	-1.625	.549	1	.003***	.197
Household head Sex	.897	1.297	1	.489 NS	2.452
Market availability	.592	1.504	1	.694 NS	1.808
Loan and credit services accessibity	1.879	12203.380	1	.018 **	.000
Land not Suitable for crop production	.611	.982	1	.053**	.543
Land ownership	1.628	8629.134	1	.998 NS	8.7
Risk perception	-.336	1.323	1	.800 NS	
Household education level	0.589	12605.947	1	.009 ***	.715
Constant	-1.584	12605.947	1	.999 NS	.000

Table 2.6: Factors influencing the households' decisions to invest in only Eucalyptus woodlots

Parameters	β	S.E.	Sig.	Exp(B)
Farm size	.322	.695	.023 **	.739
Age of household head	.197	.671	.009**	1.217
Sex of household head	.243	1.577	.878 NS	1.275
Market availability	0.316	8742.340	.998 NS	48.7
Loan and credit accessibility	-1.781	9190.476	.999 NS	.000
Land not Suitable for crop production	.599	6649.652	.018 **	11.799
Land ownership	.328	25845.542	.999 NS	.000
Risk perception	-.039	7744.318	.998 NS	.000
Household education level	.448	13342.158	.011**	17.8
Constant	-38.442	14377.414	.998 NS	.000

2.6 Discussion

2.6.1 Households with tree farms and the common tree species

Household participation in tree farming reflects smallholders' need for forest products and explains the challenge of obtaining them from natural forests. In the Bukoba district, farmers prefer pines to eucalypts because of their great adaptation to various landscapes, low labor, establishment costs, and low management requirements (Lusambo *et al.,* 2021). Additionally, pine is a commercial species whereby its products are sold within the district and to the adjacent towns in the Shinyanga, Geita, and Mwanza regions for construction activities. Farmers regard pines as household assets, generating income for smallholders (Eshetu *et al.,* 2017; Lusambo *et al.,* 2021. According to Tefera *et al.* (2017), many households decide on eucalyptus farming to solve to fuel woods problems, build animal shades, and generate cash for the owners. The households in the Bukoba district had different agricultural preferences for pines and eucalypt farming due to projected profit margins, with pines creating more money at time than eucalypts.

2.6.2 Characteristics of households with and without tree farms

The non-significance of factors such as the sex of household heads, market availability, land ownership, and risk perception in the surveyed households with and without woodlots suggests the close similarity of the interviewed households in the two wards in terms of decision environments. However, households with and without woodlots had similar land ownership statuses (100%) and (96%) of the land being household property, respectively. Land ownership status allows the household to utilize untapped land for woodlot farming. The results concede with the study by Kulindwa (2016) from the tropics, he explained that farmers with land tenure and more land resources carry out tree-planting projects. He argued that land ownership status (tenure), the household dependency ratio, and the high dependence of households to fuel wood indicate the potential of households without woodlots to establish woodlots. Factors other than the above listed influence the behaviors and decisions to allocate the intact input resources towards tree planting within the study area, such as the age of household head, household farm size holding, availability of land not suitable for agricultural crop farming, accessibility of loan or credit services and education level of the household's head as pointed out by the theory of bounded rationality (Ahimbisibwe *et al.,* 2019).

2.6.3 The factors influencing households' decisions to invest in tree farming

Age of household head

The household head is an influential decision-maker at the family level. Age is an integral part of the cognitive ability for decision-making. The findings reveal that the decisions to invest in woodlots generally decrease with an increase in the age of the household head. It shows that a unit increase in the age of the household head significantly ($p<0.05$) decreases the chances of a household establishing pine and eucalyptus farming. Probably, younger farmers are less risk-averse and have longer planning horizons (lower discount rates). They are physically more capable of managing woodlots, especially in terms of labor (Nigussie *et al.,* 2017). However, tree rotation requires a significantly longer time, roughly 15 to 20 years for pine species less than eucalypts (Lusambo *et al.,* 2021). Younger farmers are more likely to benefit from the project than older farmers.

They also have lower switching costs than older farmers, especially in the event of a food shortage, and may more readily turn to alternative sources of income, such as looking for work off the farm (Ashraf *et al.,* 2015; Nigussie *et al.,* 2017). In contrast, the study by (Abiyu et al., 2016; Ahimbisibwe *et al.,* 2019; Tefera *et al.,* 2017) showed the opposite trend in the proportion of age of the household head and woodlot establishment. They proposed that an increase in the age of the household head favors and is linked to higher chances of woodlot establishment

Household farm size

The farm size is an important aspect that farmers consider most before deciding on the type and size of a farming project to establish. General logistic regression results indicate that the farm size significantly (p=0.014) influenced the households' decisions to invest in tree farming. Households with larger farms diversify farm income and food sources by including woodlots, cash crops, food crops, fruit trees, and vegetables in one farm. The results of this study concur with the study by Ahimbisibwe *et al.* (2019), who explained the likelihood of a farmer using land to plant woodlots increases with farm size, unlike farmers with relatively small farm sizes. Farmers with small pieces of land prefer to adopt food crops to sustain their families rather than invest in woodlots (Ndayambaje 2013; Nigussie *et al.,* 2017; Etongo *et al.,* 2015).

Availability of Household land not under agricultural crop farming

The term "land not suitable for agricultural crop farming" refers to land with soil that is not fertile enough to support the proper growth of food and cash crops. The findings show a statistically significant (p=0.04) between the availability of land claimed as not under crop cultivation and the decisions of the household to engage in woodlot farming. Thus, many farmers are more likely to invest in tree farming when they possess unsuitable agricultural land. The results concur with Ahimbisibwe *et al.* (2019) and Boateng (1994), which showed a favorable relationship between farmers with land suitable and unsuitable for agriculture. They explained that the farmers with land unsuitable for agriculture had monoculture tree farming (woodlots) alongside crop cultivation compared to farmers with land suitable for agriculture crops who cultivated crops only. Tefera *et al.* (2017) explained that trees have an extensive root system that enables them to flourish in soil unsuitable for other crops and is the only way the household can benefit from this kind of land.

Accessibility of loan or credit services

The study showed that households with access to loan and credit services had a higher chance of investing in woodlot farming (*p=0.021*) than those without access to loan and credit services although was not the case to adoption of eucalyptus only. The results concedes with the study by Tefera *et al.* (2017), who found that tree farming projects involve a series of activities that require monetary transactions, such as preparation of farms, purchasing of seedlings, and planting processes. He argued that properly managed woodlots are accepted by many financial institutions as collateral for loan processing. Additionally, these findings are consistent with the findings by Atube *et al.* (2021) in Northern Uganda, who explained that the availability of credit services influenced farmers to invest in more costly but better rewarding farming practices such as woodlots.

The education level of the household head

The education level of a household head significantly (p=*0*.008) influenced the household decisions to invest in pine and eucalypt woodlots farming. It showed that as the household education level increases, the likelihood of a household investing in tree farming increases (Ashraf *et al.,* 2015). Education increases one's ability to integrate issues in broader perspectives and decide wisely by comparing the advantages and disadvantages of the practice in existing situations and precisely predict the future, unlike less educated persons. Ahimbisibwe *et al.* (2019) obtained similar results, portraying that educated household heads are more curious about forest and land laws and policies, spacing of trees, and management practices of woodlots, which are also influential to woodlot establishment.

2.7 Conclusions

The study analysed the households with tree farms based on the tree species preferences, whereby, many households seemed to prefer adopting pine farming to eucalypts. About 66% of households were involved in pine farming, 16% in eucalypts, and 18% preferred farming pines and eucalypts on one farm. Factors such as the household farm size, age of the household head, availability of land not suitable for the agricultural crop, availability of loan and credit services, and the education level of the household heads were the factors influencing household decisions to invest in pines and eucalypt woodlots. However, household land ownership, sex of the households, risk perception, and market availability had no significant ($p<0.05$) influence on household decisions to invest in pines and eucalypts farming. The study revealed that land being the means of production, an increase in households' farm size holdings influenced households' decisions to grow trees alongside food crops farming. Tree farming enterprises of pine and eucalypts increase the income of smallholders and rural communities. We advise that, in light of these competing demands for land, land policy should be flexible enough to accommodate successively the socio-economic and ecological activities that need land for their accomplishment.

2.8 Recommendations

It is necessary to encourage management strategies that boost the sustainable use of woodlots. It is imperative to connect socio-economic rewards from woodlots with ecological benefits. Additionally, incorporating smallholder tree planters into social groups like cooperatives and tree grower's associations, providing wood product prices and markets through an information platform would promote the development, production, and value addition to woodlot products. Consequently, supporting the on-going regional, national, and international programs like the Intergovernmental Panel on Climate Change (IPCC) and the African Forest Landscape Restoration Initiative (AFR100), which seek to minimize pressure on natural forests, restore degraded forest landscapes, and improve rural livelihood. Moreover, further studies may explore options for incorporating woodlot farming with crop production to enhance social, economic, and environmental contributions by farm forestry.

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Conflict of Interest

The Authors declare no conflict of interest

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CHAPTER THREE

Manuscript Two

3.0 Soil Organic Carbon in Agroforestry Technologies in Bukoba District, Tanzania.

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Abstract
The increase in CO_2 concentration in the atmosphere is associated with increase in global atmospheric temperature, which is lethal to the ecosystems. Assessment of the contribution of tree farming as a climate change mitigation and adaptation measure through carbon sequestration in relation to other agricultural practices such as homegarden agroforestry for the effective regulation of carbon cycle. This study assessed the amount of soil organic carbon present in farms with no trees and homegarden agroforestry technologies in Bukoba district, Tanzania. Four villages, two from Kemondo and two from Maruku wards were purposefully chosen. A total of 64 farms were randomly sampled. In each village eight farms with trees and eight without trees were surveyed. A 5m x 5m plots were set in each farm. Two soil samples from each plot were taken at depths of 0-15 cm and 15-30 cm. For laboratory analysis, a total of 128 composite soil samples were gathered. The Walkley – Black procedures for Soil sample analysis was applied. The results showed that the SOC stock in the agroforestry systems were higher (125.2 tons/ha) than in the farms without trees (96.8 tons/ha) at $p<0.05$. The comparatively lack of and frequent tillage practices in farms without trees, as opposed to agroforestry, may have contributed to the difference in SOC content between the two farming technologies. In order to ensure effective climate change mitigation and flow of ecosystem services from the soil, it is important for extension services to concentrate on extending innovations in agroforestry technologies than in tree less farming.

Keywords: Carbon sequestration, Land use, Intercropping, Annual crops, Agroforestry,

3.1 Introduction

The impacts of climate change on tropical ecosystems have been more apparent globally and have raised a great deal of international debate and negotiation(Sheldon, 2019). Many people nowadays suspect that the increasing levels of greenhouse gases (GHGs) have been responsible for recent climate shifts(Hertzberg and Schreuder, 2016). Carbon dioxide (CO2) in the atmosphere is one of the main greenhouse gases (GHGs) that contributes to the man-made greenhouse effect (Picano *et al.*, 2023). The increase in CO_2 concentration in the atmosphere is associated with increase in atmospheric temperature which is lethal to the sustainability of ecosystems (Lim *et al*., 2018). The mitigation, lowering the sources, and improving the sinks of greenhouse gases is increasingly becoming important (Ehrenbergerová *et al*., 2016; Deb *et al*., 2018). Due to the fact that trees are essential for absorbing and storing atmospheric CO2 in vegetation, soil, and biomass products(Graham *et al*., 2018; Mbow *et al*., 2014), agroforestry practices have the great potential to sequester carbon dioxide while guaranteeing livelihoods to may local communities (Ehrenbergerová *et al*., 2016). The contribution of agroforestry technologies such as woodlots and home garden to carbon sequestration particularly in Soil is important (Wiesmeier *et al*., 2018), not only to climate change mitigation but also to the soil health. It is already known that SOC maintains soil nutrients, microbial activities, and soil structure, essential for water filtration (Franzluebbers, 2021; Osei *et al.,* 2018; Zake *et al., 2015*).

Agroforestry is a land-use system that involves the deliberate retention, introduction or mixture of trees or other woody perennials with agricultural crops, pastures, and livestock in agricultural land to exploit the ecological and economic interactions of various components. Many literatures have explained the contributions of trees in improving Carbon sequestration and its subsequent amount fixed in the soil under different farming technologies.

A study by Singwane and Malinga (2012) in Swaziland used an interpretational analysis to quantify and assess the impact of pines and eucalypts' soil organic content. He concluded that both pines (3.7%) and eucalypts (2.9%) increase the amount of SOC than the agricultural land (2.24%). Kimaro *et al*. (2011), in western regions of Tanzania, studied the soil carbon stocks and revealed that woodlots expressed 21.6–25.6 Mg C ha^{-1} SOC stock in the topsoil against 13 Mg C ha^{-1} in continuous cropped areas of 5-year intervals. Similarly, the study by Osei *et al*. (2018) in rural Shinyanga, Tanzania, found that SOC stocks in planted woodlots and reserved Ngitili had higher SOC (61.38 Mg C ha^{-1}) and (58.83 Mg C ha^{-1}) than farmlands (34.33 Mg C ha-1) in Rural Shinyanga. In forest ecosystems of eastern Usambara mountains, Kirsten et al. (2016) quantified the SOC stock in undisturbed and disturbed (degraded) forests, came out with SOC stocks to 100-cm depth ranging between 16.9 and 22.4 kg C m^{-2} in undisturbed to 20.2 kg C m^{-2} in disturbed forestry. Similarly, in Wolayitta Zone, Ethiopia, Bajigo *et al*. (2015) compared the amount of SOC of agroforestry (home garden, parkland, and woodlot). The result showed a slight difference in the amount of SOC an order of home garden (1.65%) > parkland (1.44%) > woodlot (1.39%). Tumwebaze and Byakagaba (2016), in their study in Uganda, quantified SOC stocks under coffee agroforestry systems and coffee monocultures and found that farms integrating coffee with fruit trees had higher SOC stock (56.3 tCh^{-1}) than farms with coffee monoculture (51.4 tCh^{-1}).

From 2000s to date, many parts of Kagera region have faced a surge pines and eucalypts farming purposely for income generation and environmental conservation (Mwanukuzi, 2009). Even though, the contribution of pines and eucalypts to SOC stock is higher than tree species in agroforestry technologies as shown in many literatures above. The large amount of SOC in farms with trees informs the ability of the trees to ensure soil fertility, water quality and ecosystem conservation but less on food security. and biodiversity conservation in the region (Mwijage, 2015).

However, in Tanzania, few studies have devoted efforts to assess the amount of SOC stored in farms without trees and homegarden agroforestry. Therefore the current study aimed at quantifying the amount SOC in farms without trees (WT) and homegarden agroforestry technologies. The information obtained could be fundamental to farmers, environmental activists and policy makers to assess the advantages and disadvantages of homegarden agroforestry to farms without trees come with the solution that would insure food security, income and ecosystem conservation.

3.2 Materials and Methodology

3.2.1 Description of study area

Bukoba District is in Kagera region, it covers an area of 1,618 km^2 with a population of 322,448 people (NBS census of 2022). It is located between latitudes 1° 00′ and 3° 00′ S between longitudes 30° 45′ and 31° 00′ E with altitude between 1200 -1400 meters above sea level. It receives rainfall between 750 - 1250 mm per year which peaks in two periods in a year, March-May and September-December whereby from June-August is a dry season. The district is bordered with Lake Victoria to the north, Muleba district to the south, Bukoba Municipal to the north-east and Lake Victoria to the south-east, Karagwe district to the south-west and Missenyi district to the north-west. The climatic condition is divided into Savanna in the south-west and tropical rain forest in the north-west and central part of the district. Vegetation cover varies from thickets and short grasses in the south to thick forests with canopy tall trees and long glasses in the north (Mwijage, 2015). The common farming system is homegarden agroforestry whereby Bananas, cassava and yams form the major food crops, coffee and vanilla are common cash crops, *Maesopsis eminii*, pines and eucalypts being the common shed and timber production trees in many farms. Moreover, seasonal crops such as and beans in most cases are included in the same farm plot (Rugalema *et al.,* 1994). In some cases farmers prefer integration of agricultural crops without any tree species in their farms. Crops such as bananas, cassava, yarms, sweet potatoes and seasonal crops such as maize and beans system is new farming system mainly consisting of eucalypts and pine tree species.

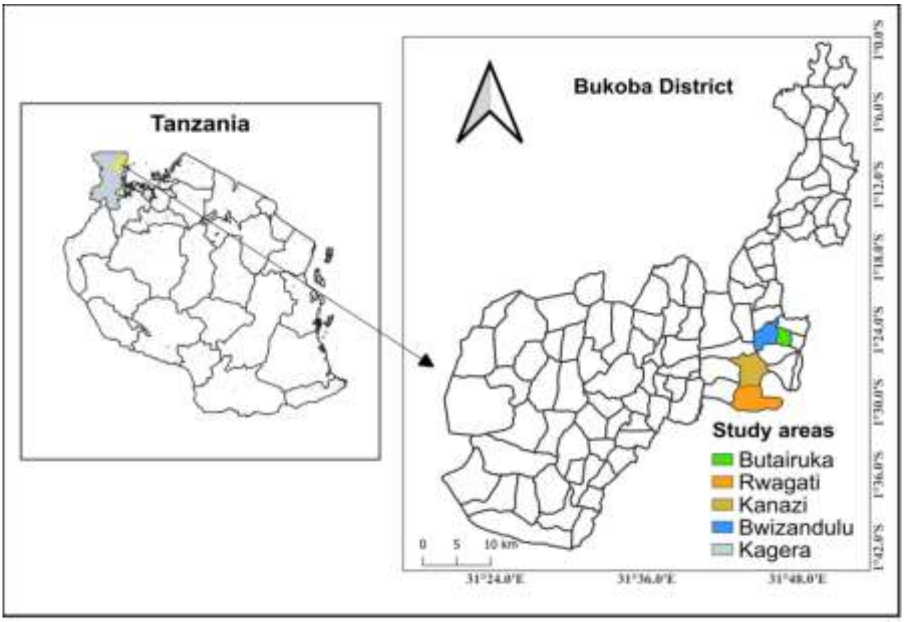

Figure 3.1: Map showing the geographic location of the study area

3.2.2 Descriptions of the farming practices in the study area

Homegarden agroforestry is a complex ecosystem made up of many plant species ranging from simple herbaceous to complex woody perennial plants. HGA are composed of food crops such as bananas (*Musa sp*.), cassava (*Manihot esculenta*), yams (*Dioscerea sp.)* and perennial cash crops such as coffee (*Coffea Arabica*) and Vanilla (*Vanilla planifolia*). The farms also contain fruit trees such as mango (*Mangifera sp*.), citrus and avocado (*Parsea sp*.). On the other hand, HGA contain shade and timber trees such as *M. eminii*, and in recent years, *pinus sp and eucalyptus sp*. Farms experience low tillage, because mulching with dry banana leaves and grasses is commonly applied to reduce weeds (Rugalema *et al.,* 1994; Reetsch, 2022). These farms are also seasonally intercropped with annual crops such as maize (*Zea mays*) and beans (*Phaseolus sp*.). Alternatively, some farmers decide to establish farms with only agricultural crops. These farms integrate crops without perennial tree such as bananas (*Musa sp*.), cassava (*Manihot esculenta*), yams (*Dioscerea sp.)* and seasonal crops such as maize (*Zea mays*) and beans (*Phaseolus sp*.).

3.2.3 Sampling design

The Wards and Villages were purposively selected based on tree farming intensity (the households' involvement in tree farming). The list of households with both homegarden agroforestry and farms without trees were prepared by the village leaders. Then random sampling technique was employed to obtain HGA farms and farms without trees. Eight (8) farms for each farming practice were selected from each of the four sampled villages, resulting in a total of 64 farms (32 HGA and 32 WT and). The WLT farms considered in this study were monoculture Pinus sp., Eucalyptus sp., *M. eminii* and in farms whereby the pinus sp. and eucalyptus sp. were intercropped. In addition, HGA farms with similar management but different tree combinations were also considered. In which, HGA were categorized into; HGA without fruit/shade trees (with crops only), HGA with fruit trees (Mango and avocado trees), HGA with shade trees (*M. eminii* with or without pines) and HGA with fruit trees and shade trees. One plot of 5 x 5 m was established at the center of in each farm for both WT and HGA farms and the location was marked and recorded by using the GPS coordinates. The size of the plots was selected based on the relative small average land size holdings of the households.

3.2.4 Data collection

The plot was placed at the center of each farm and the soil sample from four corners and the center of the plot was extracted by using Dutch soil auger (Graham *et al*., 2018) which was then mixed to make one composite soil sample for each soil depth (0-15 and 15-30 cm) per farm. In each village eight (8) soil samples at each depth for both WT and HGA was collected giving a total of 16 soil samples for WT and 16 for HGA per village. In total, 128 soil samples (64 soil WT and 64 for HGA) per all four villages were collected and taken for laboratory analysis. For bulk density, soil sample near to the center of the plot was taken using 4.3 cm length and 3 cm diameter core sampler.

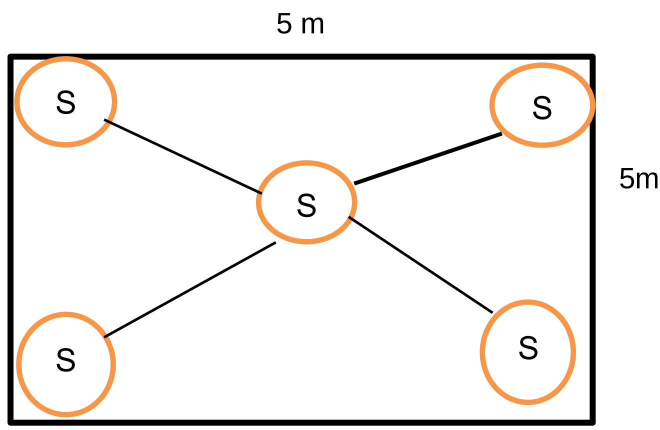

Figure 3.2: A diagram showing Soil sampling plots as laid on the farms S - Stands for the point where the soil sample was extracted in a plot

3.2.5 Data analysis

Soil Moisture Content

A soil core sampler with a diameter of 5.7 cm was used to calculate the bulk density of the soil (AL-SHAMMARY *et al*., 2018). The core soil sample was weighed fresh, oven-dried at 105 °C for 48 hours, and left to cool before reweighing. Soil Moisture Content for

adjusting chemical parameters was calculated as:
$MC = (\mathrm{Wf} - \mathrm{Wd}|\mathrm{Wd})100$…………………………………… Equation (1)
Where
MC = Moisture content in the soil
Wf = Weighed fresh (soil)
Wd = Reweighed soil after oven dried

Soil Bulk density

$\mathrm{BD} = We/_{Vt}$ … … … … … … … … … … … … … … … Equation(2)

Where
BD = Bulk density
We = Oven dry weight
Vt = volume

Soil organic carbon

The 128 soil samples taken from 32 HGA and 32 WT agroforestry farms were air dried for five days in the soil laboratory. The air-dried soil samples were passed through a 2-mm sieve whereby leaf and root litters and gravel were discarded. To determine soil organic carbon the Walkley – Black procedure was adopted. One-gram (g) of each sample was transferred into a conical flask and a solution mixture of 10 ml of 0.1667M K_2Cr_2O7 and 10ml concentrated H_2SO_4 was added. After 30 minutes 200 ml water, 10 ml of H_3PO_4s, 0.2MNaF and 8-10 drops diphenylamine indicator were added. The residual dichromate contents were back titrated with ferrous sulphated to bright green colour endpoint.

The difference in added FeSO4 is compared with a black titration was used to determines the amount of easily oxidizable OC. The percentage of WB carbon (WBC) is given by the formula (Olson, 2014):

$$WCB = \mathrm{M} \times \frac{(\mathrm{V1}-\mathrm{V2}) \times 0.3 \times \mathrm{CF} \times 100}{\mathrm{W}} \quad \text{Equation……….(3)}$$

Where

M is the molarity of the FeSO4 solution (from black titration), V1 is the volume (ml) of FeSO4 required in black titration**,** V2 is the volume (ml) of FeSO4 required in sample titration and W is the mass (g) of the oven-dried soil sample. The value obtained in percentage was used in formulae 4 below to calculate the SOC amount (kg ha^{-1}) for that soil sample. Additionally, bulk density is used to standardize the SOC (%) data and report results on a mass basis per area.

SOC (kg/ha) = SOC (%) × BD (g/cm^3) × SD (cm) x 1000   Equation…(4)

Where, BD is soil bulky density and SD is the soil depth.

Influence of farming type to SOC

Logistic regression model was applied to determine the influence of the independent variables (HGA and WT farming technologies and soil depths) to dependent variable (SOC)

$y = \{^1_0 \beta 0 + \beta 1 x 1 + \varepsilon > 0\}$ Equation ……(5)

Whereby, ε is the distribution error by the standard logistic distribution, and the logistic function takes the real input value t, whereas the output always takes values between 1 and 0, making it a probability/likelihood function. Therefore, the logistic function σ (t) is defined as

$\sigma(t) = 1/1 + exp^{-t}$ Equation ...…(6)

Expressing t as a linear function of a single predictor x

$t = \beta 0 + \beta 1 x$ Equation …(7)

Hence, the logistic function becomes

$y_1 = \mathbf{1}/1 + exp^{-(\beta 0 + \beta 1 x)}$ Equation….(8)

This can be linked to the linear predictor function

$Li = ln\left[\frac{Pi}{1-Pi}\right] = Zi = \beta 0 + \beta_1 x_1 + \beta_2 x_2 + \ldots . \beta_n x_n$ Equation.……..(9)

$\beta 0$ = An intercept

$\beta_1 + \beta_2 + \beta_3 + \beta_4 + \ldots\ldots\ldots \beta_n$ = Slopes of the equation model

Li = is the log of the odds ratios

Zi = is the vector of relevant farmer characteristics

If the error term ‘**ε**’ is introduced, the equation becomes:

$$Zi = \beta 0 + \beta_1 * HGA + \beta_2 * WT + \beta_3 * DPT1 + B_4 * DPT2$$

Whereas, HGA- Homegarden agroforestry, WT-farm without trees, DPT1- Depth 0-15cm and DPT2-Depth 15-30cm

3.3 Results

Homegarden agroforestry farms with shade trees had the highest concentration of SOC (2.9%), than farms with both fruit trees and shade trees (2.6%), with fruit trees only (2.4%) and

In farms without trees of bananas mixed with cassava, beans and maize recorded the highest SOC concentration (2.3%) than farms bananas with cassava (2.0%) and bananas with maize and beans (1.9%).

The top soil (0-15 cm) showed higher SOC concentration in both farming system management practices compared to sub soil (15-30 cm). Table 3.1

Table 3.1: SOC concentrations in surveyed HGA and WT Management practices

Type of Farming	Land management practice	SOC(%) at 0-15 cm	SOC(%) at 15-30 cm	Mean SOC (%)
HGA	HGA with fruit trees	3.62	2.12	2.9±0.012
	HGA with Shade trees	3.31	1.95	2.6±0.039
	HGA with Shade and fruits trees	3.20	1.50	2.4±0.25
WT	Bananas,Cassava, Maize, Beans	2.9	1.56	2.3±0.03
	Bananas,Cassava,	2.73	1.20	2.0±0.062
	Bananas, Maize, Beans	2.63	1.30	1.9±0.012

SOC (ton/ha) in Homegarden and Woodlot agroforestry practices

The woodlot farming system significantly had higher SOC stock (125.2 ton/ha) compared to the homegarden agroforestry (96.8 ton/ha) Table 3.2. Additionally, SOC stocks in the top soil (0-15cm) was higher in both WLT and HGA that is 82.1 and 58.3 ton/ha compared to sub soil (15-30) 43.09 and 38.5 ton/ha respectively. Table 3.2

Table 3.2: Distribution of SOC stock (ton/ha) at 0–15 cm and 15–30 cm in HGA and WLT farming systems

Farming system	Soil depth (cm)	Bulk density (g/cm3)	SOC (%)	SOC (ton/ha)	SOC_{Tot} (ton/ha) 0 to 30 cm
HGA	0 – 15	1.45 ± 0.06	3.6 ± 0.072	82.1	125.2
	15 – 30	1.81 ± 0.01	1.89 ± 0.08	43.09	
WT	0 -15	1.30 ± 0.04	2.99 ± 0.012	58.3	96.8
	15 – 30	1.52±0.09	1.69±0.078	38.5	

Note; ‘Tot’ = total, ton = tons, ha = hector

***Table 3.3:* The influence of the farming and soil depths to soil organic carbon**

Parameters	**B**	**S.E.**	**Sig.**
Farm	0.222	.671	0.000
Depth	-0.212	1.577	0.000

3.4 Discussions

The results showed that the amount of SOC in HGA farms where, banana trees mixed with pine and eucalyptus tree species showed the highest amount of SOC compared the rest HGA farms. The results concur with Tumwebaze and Byakagaba, (2016) in Uganda who compared the amount of SOC in monoculture coffee tree farms with farms integrating coffee and other tree crops. They found that farms with coffee and other trees had higher SOC stock (56.3 tCh^{-1}) than monoculture farms (51.4 tCh^{-1}).

High litter turnover and variations in the rates of decomposition of the different tree species could be the cause of the variation in the amount SOC in HGA has the highest rate of litter decomposition, which may account for its lower SOC (Mbow et al., 2014). The difference was brought about by the difference is due decomposition rate. Pine litters have the lowest decomposition rate than the eucalyptus and M.eminii. Singwane and Malinga, 2012 showed similar, they found that pine plantation had the SOC concentration of 3.7% compared to 2.9% of the eucalyptus have balanced litter turnover and decomposition rates which produce relatively large amount of organic matter which further form the SOC unlike the farms with non-tree species (Sánchez *et al.,* 2018).

Studies conducted on carbon sequestration potential in agroforestry system reveal that the linear simultaneous agroforestry systems have a significant potential to store more soil organic carbon compared to plots with no trees or crop only These results concede with Islam *et al.,* (2014) who explained that the content of SOC varied with tree density whereas, HGA with highest tree density (26 trees/100 m2) had the highest SOC while Homegarden with lowest tree density (3 trees 100/m2) had the lowest SOC. Further insists that HGA with high species richness had relatively higher SOC storage and those with low species richness had lower SOC.

Furthermore, the WT had lower SOC stock than HGA. The variation in SOC between WT and HGA is caused by the extensive root system of tree species unlike food crops which upon their death increases SOC. The same results were portrayed by Osei *et al.* (2018) in his study. He explained that HGA had higher amount of the SOC compared to that of the farmland and Ngitili systems. Similarly, Kimaro *et al.* (2014) in his study on Carbon stocks in tree farms, forest reserves and farmland, showed that tree farms stored SOC equal to levels in the native forests unlike farm lands.

3.4 Conclusions

The difference in SOC between the HGA and WT and indicates that HGA systems are more effective to carbon sequestration than farms without trees in sequestering carbon. This was evidenced in HGA containing a variety of perennial shade and fruit trees in farms with low tillage practices. Therefore, the integration of diverse and dense tree species in the agroforestry farming systems provides a potential opportunity to climate change adaptation, mitigation, ecosystem conservation and ensures households' food security. The results of this study, however, support a tentative conclusion, further researches are needed to explore in the difference of carbon in above and below ground biomasses in the two farming systems

3.5 Recommendations

Agricultural and Environmental Policy makers, planners and implementers should execute programs, which promote adoption of homegarden and other forms of agroforestry as the best agricultural practices, since they enhance food security and support global climate change adoption and mitigation initiatives. However, adding trees to crop land and/or animal grazing land requires learning of advanced farming methods and some technological support to ensure smooth adoption. In that regard, the extension services in both developed and developing countries should focus on extending innovations in agroforestry technologies to build resilience in socio-economic and environmental crises

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Conflict of Interest
The Authors declare no conflict of interest

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CHAPTER FOUR

4.0 General Discussion

The findings reveal that the decisions to invest in pine and eucalypt woodlots in general are influenced by number factors. Which include the age of the household head, household farm size, land not suitable for agriculture, loan and credit accessibility, and education level of a household head. It shows that a unit increase in age of the household head significantly ($P<0.05$) decreases the chances of a household to establish woodlot. These results may be explained by the fact that younger farmers are less risk-averse and have longer planning horizons (lower discount rates), making them physically more capable of managing woodlots, especially in terms of labour. On the other hand, tree rotation takes a relatively longer time, approximately 15 to 20 years, especially for pine species (Lusambo *et al.,* 2021), in this regard, younger farmers are more likely to benefit from the project than older farmers. Furthermore, young famers have lower switching costs than older farmers, especially in the event of a food shortage, and may more readily turn to alternative sources of income, such as looking for work off the farm. A similar trend of results was reflected in other studies, e.g. (Ashraf *et al.,* 2015; Nigussie *et al.,* 2017) in which younger farmers were increasingly involved in woodlot farming compared with older ones. In contrast, the study by (Abiyu *et al., 2016;* Ahimbisibwe *et al.,* 2019; District, 2017) showed the opposite trend in the proportion of age of the household head and woodlot establishment. It was found that, household's farm size is a key factor that farmers consider before deciding on the type and size of a farming project to establish. Household farm size positively and significantly ($p<0.05$) influences the farmers' decision to invest in tree farming projects. Households with larger land holdings use their have the freedom of choice to diversify their sources of income by farming on woodlots in addition to cash crops, fruit trees and vegetables. Farmers with small pieces of land prefer to plant food crops to sustain their families rather than investing in tree farming (Ahimbisibwe *et al.,* 2019; Ndayambaje, 2013; Nigussie *et al.,* 2017; District, 2017; Etongo *et al.*, 2015). Furthermore, the regression results showed a statistically significant link (*p=0.047*) between the availability of land claimed unsuitable for agriculture and the choice to engage in woodlot farming. It is possible that trees have extensive root systems that can navigate nutrients and water far enough from their point when compared with crops. Ahimbisibwe *et al.* (2019) and Boateng (1994) both revealed similar results. This is because the household's only best option for using such land to its advantage is to plant trees (District, 2017).

Similarly, results showed a positive relationship between the general willingness of the household to invest in woodlots and loan and credit accessibility. The loan and credit accessibility significantly (*p=0.021*) influenced household decisions to invest in pine and eucalypt woodlots. The availability of loan and credit services influenced pine and eucalypt woodlots establishment because establishment involves a series of activities that require monetary transactions, such as the preparation of farms, purchasing of seedlings and planting processes, where the availability of loan and credit services makes the establishment processes easier (District, 2017). In addition, properly managed woodlots are accepted by many financial institutions to be used as collateral for loan processing, which also influences households' involvement in woodlot farming (District, 2017). On the other hand, education level of a household head significantly (*p=0.021*) and positively influenced the household decisions to invest in woodlot farming particularly in pinus and eucalyptus species. It shows that as the household head education level increases the likelihood of investing in tree farming also increases. This is because education increases one's ability to integrate issues in broader perspectives and decide wisely by comparing the advantages and disadvantages of the practice in existing situations and precisely predict for the future, unlike less educated persons (Ashraf *et al.,* 2015) . Educated household heads are more curious about woodlot profits, credit services, markets, risk assessment, spacing of trees and management practices of woodlots, which are also influential to woodlot establishment (Ahimbisibwe *et al.,* 2019).

The amount organic carbon stored in the soil under WT and HGA was examined. The findings showed that WT had higher SOC stock than HGA. The results concur with the study by (Kimaro *et al.,* 2011) which explains that tree based systems contribute to reductions in atmospheric CO_2 and offset CO_2 emissions through three main mechanisms, namely: C sequestration, C conservation, and C substitution (Osei *et al.,* 2018) insisted the presence of a relatively higher amount of the SOC in tree farms compared to those in the farmland and Ngitili systems. In the same way, Kimaro *et al.* (2014) on C stocks in tree farms, forest reserves and farmland to determine their ability to sequester soil C and offsetting CO_2 emissions, showed that woodlots stored SOC which was similar to levels in the native forests unlike farm lands. This improvement was attributed to litter and root turnover amongst other factors. More than usual, higher SOC in tree farms is attributed by the extensive roots which upon their death increases SOC. Management practices causes disturbance of upper soil layers, hence, increase in mineralization rates and emissions of CO_2 from soils (Zhang *et al.,* 2022).

CHAPTER FIVE

5.0 Key Contributions, Conclusions and Recommendations

5.1 Key Contributions of the study

- The study extends limited researches identifying the factors influencing household decisions to invest in tree farming. Importantly, the information will be useful to policy makers in reversing the existing forestry related policies..
- Moreover, the study estimated and compared the content of SOC in WTs and HGAs. The knowledge obtained will be essential to environmentalists, policy makers and extension programs that boost the best agricultural practices to improve peoples' livelihood and ecosystem conservation.

5.3 Conclusions

The study showed that woodlot farming is influenced by a set of interrelated socio-economic and ecological factors that vary with household. The variations are primarily brought about by variations in the household choice environment, which is composed of spatial, social, economic traits of the families and to the lesser extent, environmental knowledge. Based on the study's findings, it is acceptable to conclude that, it is essential for interventions to be spatial, population, and forest resource-specific to promote sustainable farm forestry. Along with initiatives to lessen excessive reliance on natural forests for fuel wood, spatial and ecological based approaches should be addressed. Additionally, integration of different tree species showed extra ability of the tree farming system to store more SOC than farms without trees. This is important not only to carbon sequestration but also to forests products diversification that ensures natural forest land restoration and biodiversity conservation. Farm forestry is contributing to the country's total forest cover and provides farmers with a variety of benefits in terms of household livelihood, climate change mitigation and adaptation. Unsustainable utilization by farm owners for fuel wood and timber could lead to ecological degradation such as loss of carbon sinks, acceleration of soil erosion, GHG emissions and global warming. Establishing and managing woodlots with consideration for age, and educational attainment is an extra benefit. Incorporating smallholder tree planters into social groups like cooperatives and tree grower's associations, as well as providing wood product prices and markets such as through an information platform would promote the development, production, and value addition of woodlots. Additionally, the integration of diverse and dense tree species in the agroforestry farming systems provides a potential opportunity to climate change adaptation, mitigation, ecosystem conservation and ensures households' sustainable development.

5.4 Recommendations

Based on the results and conclusions of this study, it is recommended that:

a) WLT and HGA farming technologies should be adopted in many areas of the world because of their multipurpose roles they play in terms food security, soil conservation, climate change mitigation through carbon sequestration and households income generation.

b) Global, regional and national efforts are needed to invest in modern agricultural technologies and expansion of expertise in areas of extension and forest services which in turn will promote profitable HGA farming for sustainable development

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APPENDICES

Appendix 1: Questionnaire for Household Survey

Introduction: This part of the study is aiming at assessing the influence of various factors as listed in this proposal to the household's decision making on tree investment, analyzing the profitability of the HGAs and woodlot farming systems and determining the optimum land size combination for the two farming systems among the farmers in Bukoba district.

Sub village…………………………………………………….
Village……………………………………………………….
Ward……………………………..
District……………………………………………………….
Region……………………………………………………….
Date of an interview

1.0 Household ID …………..
1.1 Head of the household
1.1.1. Sex

Gender	**Tick**
Male	
Female	

1.1.2. Age

Age range	**Tick**
18-34	
35-45	
45- 60	
60 and above	

1.1.3. Level of Education

Level of Education	**Tick**
Informal	
Adult education	
Primary education	
Secondary education	
College/University	
Other	

1.1.4. Household age and size

Member's age	Number of members
0-14	
15-60	
60 above	

1.1.5. Occupation (tick)

i. Employed
ii. Farmer
iii. Business
iv. Others (specify)………………………………………………………………………………...

1.2.0 Biophysical status and land

1.2.1. Availability and accessibility of natural forest

a) Good
b) medium
c) Poor

1.2.2. What is your main source of fuel energy?

Fuel wood ☐ Electricity ☐ Biogas ☐ Natural gas ☐

If is fuel wood where do you obtain it from?

natural forests ☐ woodlots ☐ agroforestry ☐

1.2.3. Land size owned by the household ……………….

1.2.4. Does the land belong to the household? Yes ☐ or No ☐

1.2.5. Land size is taken by rent Yes ☐ or No ☐

If the household farm is on the rented land, how much is the rent…………………………, which payment method does the household pay for land rent?

a) Share
b) cash
c) Others: mention……………………………..

1.2.6. Which type of farming system are you involved to?

Farm system	Land size allocated to a farming system (ha)
Home garden Agroforestry only	
Woodlot only	
Both	HGA…………….. WDL…………….

1.2.7. What are the assets of the household?

Assets	Number	Price per item (Tsh)	Total
Cattle Goat Sheep Poultry Pig Rabbit Duck	………………. ………………. ………………. ………………. ………………. ……………… ……………….		
Cash deposit …...	Yes ☐	No ☐	

1.2.8. In which land type did you/ planning to plant trees(woodlot)?

(a) Land suitable to agriculture……………...

(b) land not suitable for agriculture …………

1.2.9. Which tree species often planted in woodlot?

a) ………………………….

b) ………………………….

1.3.0 What is the reason for the household to decide upon the current land use system?

No.	Factor	Tick
1	Farm size	
2	Loan and credit facility and availability	
5	Availability of land not suitable for agriculture	
6	Market factors (price, demand and market availability)	
7	Land ownership	
8	Risk perception	
9	Gender and Education level	
10	Other?	……………… ………………. ………………. ………………..

1.3.1 For what purpose does the household use the woodlot?
a) Sale for poles
b) Sale for firewood
c) Sale split wood
d) House construction
e) Household firewood
f) Sale for Timber

2.0 Production factors

2.1 Production factors (input) for woodlot

Production factors (Input)	Cost per production season (Tsh)	Cost per year (Tsh)
Fertilizer		
Pesticide		
Seedling		
Hired labor		

2.2 Production factors (input) for HAFs

Production factors (Input)	Cost per production season (Tsh)	Cost per year (Tsh)
Fertilizer/Manure		
Pesticide		
Seedling		
Hired labor		

3.0 Labor

3.1. Number of family member engaged in farming

a) Bellow 8

b) 8-12

c) Above 12

3.2. How long does the family spend working on the farm per day? excluding church and other social activity days

a) Bellow 6 hours

b) 6-8 hours

c) Flexible? Mention

3.3. Household labor distribution

Month	**Required labor hour/day**			**Remarks**
	Banana	**Coffee/Vanilla**	**Annual crops**	
September				
October				
November				
January				
February				
March				
April				
May				
June				
July				
August				

3.4 What are the tasks most performed by family labor?

a) Seeding

b) Tending

c) Harvesting

d) Sale
e) Other?

3.5. Is there any hired laborer for the production?
a) Yes
b) No

3.6. If the answer for the above question is yes, how many laborers per production season?

3.7. What is the labor cost per day or per production year?

3.8. Which one is more labor intensive (rank 1-4 from more intensive to less)?
a) Woodlot
b) Homestead Agroforestry practice
c) Annual crop
d) All are the same

4.0 Cost

4.1 Woodlots

Woodlots Species	Establishment cost Hoeing, planting, weeding (Tsh)	Management cost Pruning, thinning, fire belt Harvest cost (Tsh)	Harvest cost (Tsh)	Remarks

4.2.0 Homestead agroforestry system

4.2.1 Perennial crops

Species	Establishment cost (Tsh) Hoeing, seeding,	Management cost (Tsh) weeding, pruning, thinning,	Harvest cost (Tsh)	Remark
Coffee				
Avocado				
Mango				
Banana				
Vanilla				
Cassava				
Sweet potatoes				
Yarms				

4.2.2 Annual crops

Annual crop	Cost (Tsh)			
	Seed	Fertilizer	Pesticide	Remark
Beans				
Maize				
Bambara beans (Groundnuts)				

5.0 Production

5.1 What is the mount produced from each farm practices?

Woodlot

Woodlot Species	Production per year	Price (Tsh)	Remark

HAFs Homestead agroforestry practice Species

HGAs species	Production per year (Kg)	Price (Tsh)	Remark
Coffee			
Avocado			
Mango			
Banana			
Vanilla			
Cassava			
Sweet potatoes			
Yarms			

Annual crops

Annual crops species	Production per year (Kg)	Price (Tsh)	Remark
Beans			
Maize			
Bambara beans (Groundnuts)			

6.0. Market

7.1. Where is the market the household sale the products?

a) On farm edge
b) Town market
c) Big cities
d) Other? Mention

6.1. What is the distance of nearest market from the production farm land or store house?

Market	**Distance from the production**	**Products**	**Price**	**Means of transport**	**Cost of transport**	**Remarks**

Appendix 2: Questions for Key Informants

1. What are the main land use practices in the area?
   i) ……………………………………………
   ii) ……………………………………………
   iii) …………………………………………….
2. Is there any government or non-governmental organizations to train about farming systems and farm products? Yes ☐ or No ☐
3. What are major constraints the farmers face in the farming practice they follow?
   i) ……………………………………………………
   ii) …………………………………………………..
   iv) ………………………………………………….
   v) ………………………………………………….
4. Is there food insecurity in the village?.......Yes ☐ or No ☐
   i) If yes, rank it from 1-3 depending on intensity
   a) Less b) medium c) Severe
5. When did the farmers started practicing woodlot on their own farm lands in this area?
   ………………
6. What are the main species of woodlot in the study area?
   i) …………………….
   ii) ……………………..
   iii) ……………………..
7. What are the advantages and disadvantages of the woodlots to the community?
8. What are the main species/ components in HGAs?
   ……………………………………………………………………………
   …………………………
9. What is the main commercial crop in this area currently?......................
10. Where is the nearest market located and how do farmers transport their commodities?
11. What are woodlot and HGAs major products and their prices?
    Woodlot
    i) …………………..
    ii) …………………
    Homegarden agroforestry
    i) ……………………
    ii) ……………………
    iii) ……………………

Kuhusu Tasnifu Hii

Utafiti ulifanyika kata mbili za Maruku na Kemondo katika wilaya ya Bukoba – Kagera, Tanzania. Utafiti huu ulilenga kubaini sababu zinazochochea maamuzi ya kaya kuwekeza katika kilimo cha miti. Pia ulilenga kubaini kiasi cha kaboni kinachohifadhiwa kwenye udongo chini ya mashamba ya miti na mashamba ya kilimo mseto. Utafiti ulibaini kuwa sababu kama umri, elimu, ukubwa wa ardhi inayomilikiwa na kaya, upatikanaji wa mikopo na huduma za kifedha, umiliki wa ardhi isiyofaa kwa kilimo cha mazao ya chakula na biashara zilichochea maamuzi ya kaya kuwekeza katika kilimo cha miti. Aidha, Udongo chini ya mashamba ya miti ulionesha kuwa na kiasi kikubwa cha kaboni kuliko kwenye udongo chini ya mashamba ya kilimo mseto. Napendekeza taasisi za umma na zisizo za umma zinazohusika na utunzaji wa misitu na mazingira kuongeza jitihada katika uhamasishaji na uwezeshaji kwenye kilimo cha miti ili kuwaongezea wakulima kipato na uhifadhi wa mazingira kwa ajili ya kujihakikishia maendeleo endelevu.