DETERMINANTS OF SMALL HOLDER FARMERS' DECISION TO PRACTICE AGROFORESTRY IN RULINDO DISTRICT, RWANDA

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Determinants of Small Holder Farmers` Decision to Practice Agroforestry in Rulindo District, Rwanda

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DECLARATION

This thesis is my original work and has not been presented for a degree in any other University.

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This thesis has been submitted for examination with our approval as the University Supervisors

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DEDICATION

This Thesis is dedicated my wife, **Raissa Kayitesi** for her support and encouragement. It is with this in heart that I truly appreciate her support towards attaining the Master of Science degree in Agriculture and Applied Economics

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ACRONYMS AND ABBREVIATIONS

EICV	Integrated Household Living Conditions Survey
FAO	Food and Agriculture Organization of United Nations
FONERWA	Rwanda Green Fund
GDP	Gross Domestic Product
ICRAF	World Agroforestry Centre
NGO	Non-Government Organizational
NISR	National Institute of Statistics Rwanda
PAREF	Projet d`Apuit a la Restoration
PRCA	Property Rights and Collective Action
REOSA	Regional Emergency office for southern Africa
SPSS	Statistical Package for the Social Sciences
VUP	Vision 2020 Umurenge Program
US$	United States Dollar

ABSTRACT

Agroforestry plays an important role in production of both local and global commodities. It plays a strategic role in helping many countries to meet key national development objectives, especially those related to poverty eradication, food security and environmental sustainability. The Government of Rwanda, through its Vision has committed itself to an ambitious target of increasing agroforestry area to 85% in all farm lands by 2030. Various studies have been reported from different parts of the country, but there has been no research on determinants that influence the farmers' decision on planting agroforestry trees on farms in Rulindo District. The current study addressed this knowledge gap by identifying socio-economic characteristics and factors influencing decision to plant trees on farms, limitation of the farmers and motivating factors which could increase farmers' willingness to adopt agroforestry on their farms. This study was based on data from a survey of 270 smallholder farmers randomly selected and interviewed using semi structured questionnaires. Descriptive statistics and a Probit model were applied in data analysis. Results showed socio-economic factors have effects on farmers' decision to practice agroforestry. For instance; land size, access to extension services and household size had a positive and significant effect, power in decision making to plant agroforestry trees in household was identified by respondents as an important factor affecting practice of agroforestry. More specifically, being men increased the power on decision making at household on planting of Agroforestry trees on agricultural land. Inadequate knowledge and skills on Agroforestry hindered the farmers from planting more trees on their farms. It was concluded that small land sizes and inadequate knowledge and skills on Agroforestry were limitations on the farmers' decision to practice agroforestry in Rulindo District. The results of the study implied that strengthening extension services and capacity building of local actors in agroforestry should be targeted. Additionally, policies promoting agroforestry system that is more gender equitable, productive and market oriented should be implemented.

CHAPTER ONE

INTRODUCTION

1.1 Background Information

In Rwanda, a little less than 68% of population depends on agriculture as an economic activity (EICV4, 2016). Land clearing to create room for agriculture is rampant and the rate of deforestation has been very high. The annual rate of deforestation was almost 1.84% between 1990 and 2010 which was very high compared to the average of annual deforestation rate reported for Africa at 0.5% (FAO, 2010).

This has led to environmental degradation which comes with associated problems like degradation of soil fertility, climate change, soil erosion, biodiversity depletion and poverty. This negative affect was greatest among poor households who depend on natural resources only as a source of income, energy and building materials.

Growth of population and poverty is sometime considered as the main driving force accelerating deforestation, but it is surely not the only factor. It needs to be viewed in relation to tradeoff between different land use systems, change in social-economic structure of rural societies, patterns of tree and resource exploitation, government policies, agriculture development, markets, settlement patterns and change in technology.

Babigumira et al.(2014) reported that well-planned policies like agricultural intensification and market-focused approaches can sometimes lead to more deforestation, as farmers clear land to increase its value. However, agroforestry, which involves adding trees and shrubs to farms, can be a smart solution. Trees can provide food, fodder, fuel, and timber, while also protecting and improving soil fertility.

Leakey (2017) defined agroforestry as a dynamic, ecologically based natural resource management system that, through the integration of trees in farmland and rangeland, diversifies and sustains production for increased social, economic and environmental benefits for land users at all levels. The integration may either be a spatial mixture or in temporal sequence with both ecological and economic interactions between the woody and non woody components of the system. The practice of agroforestry is usually with the intention of developing a more sustainable form of land-use that can improve farm productivity and the welfare of the rural community as a whole.

In Rwanda agroforestry system may be defined as the presence of scattered trees on farm, planted trees along contour or erosion control ditches, boundaries of farm, or set as rotational woodlots or blocks (Ndayambaje et al., 2011). These trees are maintained in combination with crops in agroforestry systems. These trees provide a number of economic and ecological functions related to the trees in forests (Catacutan et al., 2017)

Agroforestry systems offer a wide range of products and benefits to people globally. Economic growth and new technologies have increased the value of these products. Forests also provide alternative income sources and job opportunities, especially in rural areas of developing countries, helping to improve household incomes (Chomitz and Kumari, 1998).

FAO (2012) reported contribution of forest industries to more than US$450 billion to national incomes providing formal employment at 0.4% of global labor force. In Rwanda, forests provide 98.5% of primary source of energy used for cooking, lighting and heating (EICV 4, 2013-2014). Forests is supporting agriculture sector which contributes around 33% on GDP of the country through protection of downstream wetlands and watersheds.

Although adoption of trees on agricultural land provides a lot of opportunities as potential source of income, in Rwanda the main motivation for small scale farmers to plant trees on less than 1 ha for 80% of farmlands is largely unknown (NISR, 2010). Based on findings of Pattanayak et al., (2003) after a review of 120 articles on adoption of Agricultural and Forestry technology by small holder farmers, five categories of factors affecting technology adoption within economic framework are found: preferences, resource endowments, market incentives, biophysical factors and uncertainty. The results from this analysis show that preferences and resource endowments are the factors most often included in studies. However, adoption behavior is most likely to be significantly influenced by risk, biophysical, and resource factors but this needs to be studied considering site/area specificities.

The government of Rwanda promotes agroforestry as a strategy to reduce the depletion of forest resources, environmental degradation, and soil fertility degradation. Achieving these goals requires attention to farmers' attitudes and decision-making about the planting of trees.

Farmers' decision to grow trees on their farms depends on many factors including social, economic, household characteristics, behavior, and environmental factors. For agroforestry practices to be successful these factors need to be understood before interventions. Local situations are important to consider when investigating the reason why farmers grow trees in association with crops. The determinants of tree planting are region-specific, and cannot be easily generalized for all agricultural households at a national scale.

Rulindo District is located in medium altitude Region in Rwanda. None of the variables studied in previous research explained why farmers planted trees in agricultural landscapes (Ndayambaje et al., 2012). This provides an opportunity for future research aimed at a better understanding of the determinants of agroforestry practice in this region.

1.2 Statement of the Problem

Deforestation is one of the prominent problems in developing countries. Expansion of agricultural land, declining farm land productivity, demand for forest products and investments in the forested areas are some of the major underlying factors exacerbating the problem. The increasing pressure on limited land resources is a problem being faced in the rural areas of Rwanda. Environmental degradation is mainly severe when living conditions of poor households relying on natural resources as a basis for farming, building materials and source of energy are concerned (Ndayambaje et al., 2012).

In Rwanda, qualitative surveys identified the reasons why farmers planted trees on farms or adopted agroforestry technologies (NISR, 2010; Behaim and Bezzola, 1994; Biggelaar, 1996; Bigirimana, 2002; Uwiragiye, 2002; Tuyisenge, 2003). Many of these studies were conducted in different parts of the country using structured interviews or focus-group discussions. The Research on adoption of agroforestry generally focused on social, biophysical and wealth parameters, leading to the ranking of constraints and benefits by rural households as well as priority areas for research (Djimde et al., 1988; Mukuralinda et al., 1999).

Ndayambaje et al., 2012, highlighted that policy measures enhancing tree planting should be site specific, to account for biophysical conditions and specific rural household motivations to plant trees on farms. These studies focus mainly on resource endowments and farmers preferences, however attention to farmers behavior which might be significantly influenced by risk, market incentives, policies and extension services, attitude towards conservation of natural resources and commercialization is missing.

In general, it is difficult and inappropriate to generalize these adoption studies because of some limitation including population sampled, time dimension considered, factors and variables included and variation in technology or policy variables (Pattanayak et al., 2003). However, this information and systematic feedback regarding farmers' decision to practice agroforestry is relatively insufficient in the context of Rulindo District. Therefore, this brings the need to unveil determinants that leads farmers to practice agroforestry and others do not.

The Rwandan government has actively promoted agroforestry through various initiatives, including the National Agroforestry Strategy (2018-2027), which integrates agroforestry into rural development policies. Programs like the Integrated Soil Fertility Management Programme and efforts by the Environmental Management Authority's Forestry Authority support the integration of trees into farming systems to enhance soil fertility and combat climate change. Local government initiatives also play a crucial role in implementing these practices, contributing to Rwanda's goal of achieving a climate-resilient, low-carbon economy by 2050.

However, no research has been done on determinants that influence the farmer's decision to plant agroforestry trees on farms in Rulindo District, which has caused a knowledge gap in agroforestry research. Rulindo maybe well-suited for agroforestry due to its mountainous terrain, cool climate, and ample rainfall, which support diverse tree and crop growth. Therefore, there was a need of conducting a study on the determinants particularly based on five categories identified for adoption; preferences, resource endowments, Market incentives, biophysical factors and risk and uncertainty, considering also behavior factors that influence adoption of agroforestry technologies in Rulindo Districts.

1.3 Justification of the Study

The study is significant in terms of its contribution to both theory and practice. Rulindo district is an agricultural area dominated mainly by the small-scale farmers practicing subsistence farming of food crops. This study investigated the determinants that lead small-scale farmers`decision to practice agroforestry. Moreover, the findings of the study were significant by providing empirical information on farmer's decision about adoption of agroforestry.

The results of this study provided baseline information and will be useful in planning and improving agroforestry programs and strengthening ongoing initiatives in Rulindo District. In addition the results of the study are significant in facilitating stakeholders to design strategies for scaling up and promoting of agroforestry technology so as to attain sustainable agriculture, land restoration and protection, increasing rural income and ultimately poverty reduction in the country.

1.4 Objectives of the Study

1.4.1 General Objectives

The main objective of this study was to evaluate the determinants of small holder farmers` decision to practice agroforestry in Rulindo District

14.2 Specific Objectives

1. To characterize the small holder farmers in Rulindo District
2. To determine the factors affecting the decision to practice agroforestry in Rulindo
3. To determine Government interventions to promote agroforestry practice in Rulindo District

1.5 Research Hypothesis

1. Ho: Smallholder farmers in Rulindo District do not exhibit diverse agricultural practices, socio-economic statuses, and levels of access to resources and support services.
2. H_0: Socio-economic factors do not influence farmers' decision to practice agroforestry system in their farms.
3. H_o: There`s no interventions to promote practice of agroforestry system in Rulindo District

CHAPTER TWO

LITERATURE REVIEW

This chapter reviews the fundamentals of agroforestry by summarizing existing literature on factors affecting farmers`decision to practice agroforestry. This review will permit to focus on further investigation on key issues that are likely to affect adoption of the proposed agroforestry technologies by resource-poor farmers in study sites.

2.1 Definition of Agroforestry

Agroforestry is defined as a dynamical and ecologically based natural resource management system that, with the integration of trees in farmland and rangeland, transforms and assists production for expanded social, economic and environmental gains for land users at all levels (Leakey, 1996). In order to address land degradation and loss of soil fertility, different practices were developed, where Agroforestry as well as conservation agriculture have emerged as the sustainable land management practices (FAO, 2010).

Different land use existed from generations to generations especially in the tropics, but it is was only in the late 1970's that Agroforestry was developed as a tropical modern practice, mostly for the improvement of the land use through scientific studies. In 1990's, complex land management systems were discovered by scientific community, that were developed by rural landowners in North America and Europe, which included forest farming, shelterbelts, silvo pastural systems and riparian buffers.

Hence an interest has emerged, particularly in temperate regions (Lassoie and Buck, 1999). Although much was achieved through science and technology from 1980 to 1990, agroforestry as a probable practice has not yet been fully accomplished (Nair, 1996). A number of agroforestry projects were unsuccessful for several reasons, one general being the low application of socioeconomics while developing systems and projects (Current et al., 1995). It was in the mid-90s that experts in agroforestry started to emphasis on agroforestry research in order to adopt its decision process (Mercer et al, 1998; Sanchez, 1995).

2.2 Impact of Agroforestry Practice at Global Scales

Research on new technologies adoption in agriculture is important to guide policymakers in management of natural resources. Fundamental societal transformations are required in order to achieve sustainable development pathways, therefore the outcomes in change of technology should be assessed in terms of their contributions to extensive targets of sustainable development (Siri et al., 2011).

Sawadogo (2011) recognized the need of conservation of soil and water on the tropical working lands and the potential of agroforestry to rehabilitate degraded land. (David et al., 2011) reported that adoption occurs when the landholders perceives that the innovation in question will enhance achievement of their personal goals including economic, social and environment. Agroforestry system is more likely to be adopted when it has a high relative advantage and when is readily trialable. Policy measures will be needed to bridge the gap between individual and societal benefits and between individual costs and societal benefits.

2.3 Agroforestry as a Land Use System in Rwanda

In Rwanda, agroforestry practice started with an integration of trees in agriculture landscapes, which is known to reduce soil erosion, as well as to increase agricultural productivity through recycling of nutrients. This practice also improve fertility of the soil, provide timber and non-timber products from trees and woodlots on farms. It is well established that the retention and management of indigenous species, are among important properties of a traditional agroforestry system, where in Rwanda some indigenous species were observed on farmalands, such as Markhamia spp., Ficus spp., Vernonia amygdalina, and Erythrina abyssinica. (Habiyambere, 1999).

Biggerlaar (1996) highlighted that shrub species and extensive number of exotic trees were dominants in Rwandan agroforestry syestem, mostly due to their appropriateness on several land use systems. It was also observed that about 150 trees and shrub species were maintained in several agroforestry systems, where they added some assets into those systems, such as wood products and ecosystem services.

In Rwanda, mostly in altitude regions, ten dominants tree species in agroforestry were identified by Ndayambaje et al.,2013. These trees had different usage such as fuelwood, building poles, medicines, stakes for climbing beans, fodder, fruits, timber. They were also known to contribute to functions like; fertility replenishment and soil conservation (ISAR and ICRAF 2001; Ndayambaje et al., 2011). Different systems were observed such as:

- Farm woodlots that included useful wood production such as fuelwood, timber as well as stakes to hold different crops like tomatoes, beans and peas. This was also useful to design the niches to deal with incompatible crop and livestock production as a result of arduous slopes and insufficient soil fertility;
- Hedgerows that involved a plantation of trees on contour lines, on ditches for erosion control as well as on balanced crop bench terraces. They also included different benefits such as green manure, stakes for climbing crops, fodder and fuelwood;
- Trees on cropping through alley cropping were also observed. This refers to us, as cases where different crops were grown between hedges of trees coppiced, often to reduce the competition for the light, and to provide the improvement of green manure for soil fertility, as well as other tree products such as fuelwood, fodder and stakes. This also was observed to be done through scattered trees on farm, which is defined as the dispersion of trees in the farm, without any particular arrangement at low density, in order provide fruits timber, stakes, and fodder.
- Home gardens which is defined as a mix of upper and under story trees that involve exotic and indigenous fruits, timber, fodder species with annual or perennial crops such as beans, coffee, maize, vegetables, banana etc. It is also includes livestock,

to fill multiple functions such as shelter, windbreaks, shade, and cultural functions in the proximity of homestead.

- Lastly the boundary planting was observed. This is defined as tree plantation for delimitation between two farms for live fencing, buffer between roads and farms, in order to provide fruits, timber, poles, fuelwood and functions like wind breaks.

Biggelaar and Gold (1996) observed that Rwandan farmers preferred both indigenous and exotic tree species, in particular those with several usage properties and immense local resilience, due to the diverse benefits. They also highlighted that for most of those trees were less competitive to crops, and had a minimal negative effects on soils, that is less allelopathic effects and efficient use of water and nutrients.

On the other hand, the competition was observed to be partly overcame by the plantation of trees in selected farm niches. Thus, that method, especially with the combination of agriculture crops, can add a great value in the production of tree species. Hence, Rwandan agroforestry systems fulfill the criteria of the tree-based ecosystem approaches definition (Willem et al., 2013), as serving multi-objectives at landscape.

One example is, Eucalyptus *woodlots* which are known to be among the most important assets in Rwandan agroforestry systems, due to the fact that from an estimation of around *36*-40% of farm owners, keep *Eucalyptus* on their land national-wise (Ndayambaje et al., 2013). Note that, whereas this can be taken as monoculture form, Eucalyptus woodlots in Rwanda don't only play a role in supplying timber, but also provide essential benefits such as the production of charcoal, fuelwood and stakes, where some income are gained while selling these products.

The report from World Bank also highlighted that Eucalyptus woodlots in Rwanda on agricultural land showed a positive gross margin, in particular for marginal areas with secure land tenure and rising wood fuel prices (World Bank 2012). Although *Eucalyptus* can sometimes have some negative impacts on soil water balance, these woodlots are often implemented in strategic farm niches, which are inadequate for crop production and livestock farming (Balasubramanian and Egli 1986; Mugabo 2003).

An argument was raised that woody biomass stock from these farm woodlots across Rwanda was estimated to be between 100 and 228 oven dry ton ha-1, and that is considered to be higher than that in forest plantations (50 - 97 oven dry ton ha-1). Hence, this was potentially the cause of reduction on the gap among fuelwood supply and demand, therefore this can contribute to the reduction of pressures on deforestation and degradation (Mukuralinda et al., 2013).

To date in Rwanda, most of the charcoal production are planted on private woodlots, especially in west and south of the country, where all charcoal production is legal and don't negatively affect protected natural forests (World Bank 2012, Drigo et al., 2013). This is not the same situation in other sub-Saharan Africa (SSA) countries, where most of the times the charcoal production causes degradation of natural forests particularly in dry lands (Iiyama et al. 2014).

In addtion, it was observed that contour planting of *Alnus spp.* on farming plots in steep slopes is a well-established method for agroforestry system particularly in the agricultural landscape of the highland zones. Rwandan farmers who plant Alnus *acuminata* provide several products such as fuel, fodder, and especially stakes for beans.

This plantation also helps them to derive ecosystem services, such as erosion control and soil productivity improvement through green manure, so that the capture and use of rare environmental resources can be optimized (Iiyama et al. 2014). A study from Gicumbi district showed that the majority of the surveyed farmers (68%) grew climbing beans and *Alnus* trees, in particular at contours of their own bench terraces, as their primarily source of stakes, which would be otherwise cost 5 RWF per stake.

Given the comprehensive background provided, there is a clear need to conduct research on the determinants of smallholder farmers' decisions to practice agroforestry in Rulindo District, Rwanda. The literature highlights the importance of socio-economic considerations in the adoption of agroforestry. Research in Rulindo District should focus on understanding how factors such as income levels, education, and access to resources influence farmers' decisions.

As noted, adoption occurs when farmers perceive significant benefits. Research should investigate what specific benefits (e.g., economic, environmental, social) are most valued by farmers in Rulindo and what barriers (e.g., financial, knowledge, cultural) they face. Research should explore the role of local policies, government support, and institutional frameworks in promoting agroforestry practices in Rulindo.

By addressing these areas, research can provide valuable insights into the determinants of agroforestry adoption among smallholder farmers in Rulindo District, ultimately contributing to more effective and sustainable agroforestry interventions

2.4 Theoretical Review

Using household production theory as a conceptual framework (Amacher et al.,1993; Pender and Kerr, 1998) and the five broad determinants identified, a model of farmers` decision to practice agroforestry as an investment choice was developed. Considering a representative farm household that maximizes its utility, U, which was assumed to be a concave, continuous, twice-differentiable function of agricultural commodities, Q_c, (example of banana or cassava) and household time inputs, Y_C, (example of leisure). The function was conditioned by household preferences that were proxied by socio-demographics, H. Utility maximization was subject to three constraints (time input endowment, technology, and cash income). The household time input constraint implied that the sum of own input supply of time, Y_P, (labor), and own input consumption of time,

Y_c(leisure), could not exceed the household time endowment, Y_E, which is conditioned by household characteristics, *H.*

Agricultural outputs, Q_P, were assumed to be a convex, continuous production function, *F*, of Y_P. Productivity depends on household resource endowments, *L*, such as land, tools, money, human capital, and economic incentives provided by the government, such as subsidies or inputs. The biophysical characteristics of the farm, *Z*, also mediate the production technology. A typical cash constraint requires household expenditures on agricultural commodities and inputs to be less than or equal to the sum of agricultural profits, π, which depend on market prices, P_Y, and exogenous income,*E.*

The household's budget constraint combined a typical cash income constraint with the endowment constraint such that expenditures were equal to the sum of the monetary equivalent of the household input endowment, agricultural profits, and exogenous income; this sum is the "Beckerian" full income (Strauss, 1986).

Based on findings from (Amacher et al., 1993), adoption of agroforestry requires joint investments of money, labor, and land to acquire agroforestry capital. That was labor and money collectively embodied in the amount of land dedicated to agroforestry. As described above, this joint investment was conditioned by the resource endowments and biophysical conditions faced by the household.

Agroforestry (L_{AF}) could therefore be conceived as one among many sets of coordinated investments that produce an annual rate of return, *r*, to enhance overall well-being. Since the returns to agroforestry occur in the future, households considered the expected stream of income net of consumption *(I)* or the market-based incentives, in choosing between alternate investments.

These expectations were based on the household's assessment of the relative importance of agroforestry income to total farm income, which depends on risks and uncertainty, *R*, in the short and long terms. Mathematically, the household's utility-maximization problem was expressed with the Lagrangian in equation (1).

$$MaxE\{[U(Q_C, Y_C; H) + \lambda(\pi + E - P_Y Y_P - rL_{AF}) + \mu(Q_P, Y_P; L_{AF}, Z) + \eta(Y_E - Y_C - Y_P)], R\} \quad (1)$$

The objective was to maximize expected utility by choosing levels of inputs (including land) and outputs. The first-order conditions with respect to Q_C, Y_C, Q_P, Y_P *and* L_{AF} had the standard Marshallianequi marginal interpretations when households choose the level of agroforestry technology that maximizes total utility.

Considered the choice facing household *i* when deciding whether to practice agroforestry. The utility maximizing household compared to its expected net utility with and without adoption EU_i^*.

A reduced form version of this net utility is given by equation (2):

$$EU_i^* = \alpha_L I_i + \alpha_L L_i + \alpha_R R_i + \alpha_z Z_i + \alpha_H H_i + \varepsilon_i \quad (2)$$

Where I_i ,L_i, R_i, Z_i and H_i are as defined above. Note that I_i captured market incentives because net income was a function of explicit and implicit prices of outputs and inputs of the agroforestry process. Since the true net utility function is unknown, Estimated function is treated as random by including the error termε_i^2. Although $EU_i^*$is not directly observable, the researcher could observe the owner-manager's adoption decision. Let L_{AFi} be an indicator of whether the household *I* adopts agroforestry $(L_{AFi} = 1)$ or not $(L_{AFi} = 0)$*so* that:

$$L_{AFi}^* = 0 \; if EU_i^* \leq 0 \text{ and } L_{AFi}^* = 1 \; if EU_i^* > 0 \quad (3)$$

Depending on the assumptions regarding the distribution of the error term in equation 2, this structural relationship could be estimated using a variety of methods. In most analyses of binary choice data, probit or logit models are estimated assuming either a normal or logistic distribution, respectively, for the error term (Maddala, 1983). That is;

$$Prob(L_{AFi}^{*} = 1) = \Phi(\alpha_I I + \alpha_L L + \alpha_R R + \alpha_Z Z + \alpha_H H) \quad (4)$$

where Φ was the cumulative distribution function and *Z, L, R, Z, and H were* the explanatory variables in equation 2 and α was a vector of parameters to be estimated. Although one might expect different predictions from the logit and probit models for samples with very few positive responses for the dependent variable (Y = 1), or very few non-responses Y= 0) and very wide variation in important independent variables, usually the two models produced similar results. In fact, little theoretical justification existed for choosing between the probit and logit models (Greene, 1997). To investigate the determinants of agroforestry adoption, in my case study I empirically estimated equation 4 with binary adoption data from Rulindo District.

2.5 Empirical Studies on Determinants of Smallholder Farmers` Decision to Practice Agroforestry

Various studies have investigated different determinants of Agroforestry practices. For instance, (Oluwaseun & Sibongile, 2019) studied adoption of agroforestry practices and climate change mitigation strategies in North West province of South Africa. The authors found that the awareness of climate change is not a determining factor for the adoption of agroforestry practices, however the study revealed that information source and member’s association were the significant variables that determined the adoption of agroforestry practices in the study area.

Abebe et al., 2019, analysed household level determinants of Agroforestry practices adoption in rural Ethiopia, the authors estimated Heckman selection model using household level data collected in different rural areas of Ethiopia. The results of their study showed that land size, household head, insecurity on land tenure and proximity to towns had a significant effect on probability of adopting agroforestry.

Mulatu et al., 2014, analysed determinants of agroforestry technology adoption in Tambo district in the Eastern Cape Province of South Africa. The study found that level of education of the household head, experience in farming activities, a proxy variables for household wealth status including land size owned, number of livestock owned, adoption of other agricultural technologies, the slope of farm land and level of degraded of farm land affected the adoption of Agroforestry in the study areas.

Sanou et al. (2017) analysed drivers of farmers` decisions to adopt agroforestry in Burkina Faso. The authors found that farmers' decisions to incorporate trees into their farmland were mainly influenced by knowledge and skills on silviculture, participation in farmers' groups or other social organizations with an interest in tree conservation, the social value of biodiversity in the rural landscape, and the perceived economic benefits of trees on farmland.

Roberto et al., 2020, Studied factors affecting the adoption of Agroforestry Practices: insights from silvopastoral systems of Colombia, the authors found that different factors influenced the decision of adopting agroforestry practices including access and use of credit, location and livestock farming. Participation in development projects on tree planting had a positive influence on the adoption and intensity of agroforestry practices, on another hand access to water springs was boosting the intensification of adoption.

Srijna et al., 2021, Studied factors influencing the adoption of agroforestry by smallholder farmer households in Tanzania, the results indicated that only 10.19 % farmers in studied areas of Morogoro and Dodoma reported planting new trees and actively practicing agroforestry. Farmers who were part of a project, were able to rent land and have a source of seedlings were more likely to adopt agroforestry. While farmers who perceived changes in rainfall patterns, their land rights to be only moderately secured, and their right to plant trees to be dependent on obtaining permission from the landowner or family members, were less likely to adopt agroforestry.

Thus, the determinants of farmers’ decision to practice agroforestry greatly exhibit differences based on the location of study. Therefore, there was a need to conduct a study on the determinants of farmers`decision to practice agroforestry in Rulindo District, Rwanda. Particularly we categorize the factors as follows; preferences (education, age, gender, marital status, size of household), resource endowments (income/occupation, livestock, credit/savings), Market incentives and institutional factors (potential source of income, distance to market, Government Policies), biophysical factors (location of the farmland, size of the farmland) and risk and uncertainty (tenure, extension, membership).The next chapter describes the methodology applied in the study.

The literature on determinants of agroforestry adoption reveals significant variability across different regions and contexts, highlighting the complexity of factors influencing farmers’ decisions. Studies from South Africa, Ethiopia, Burkina Faso, Colombia, and Tanzania identify diverse determinants such as information sources, land tenure security, education, household wealth, and participation in social organizations.

However, gaps and inconsistencies arise due to the lack of a unified framework that comprehensively addresses these factors across different settings. Additionally, many studies focus on specific regions without considering broader socio-economic and environmental contexts. This underscores the need for targeted research in Rulindo District, Rwanda, to understand local determinants such as preferences, resource endowments, market incentives, biophysical factors, and risk and uncertainty.

Such research can provide tailored insights to enhance agroforestry adoption among smallholder farmers in this specific locale.

CHAPTER THREE

METHODOLOGY

This part describes the research methodology used for this study. It provides description of conceptual framework used in the study, the study area, outlines the study population, sampling procedure including sampling design and sample size, data collection procedure and data analysis procedure.

3.1 Description of Study Area

Rulindo district is located in the Northern Province with 17 sectors, 71 cells, 494 villages; the estimate terrain elevation above sea level is 1874 meters. The Integrated Household Living Conditions Survey 3 results showed that the total population of Rulindo district in 2010–11 was 294,000. This represented 16% of the total population of Northern Province and 2.7% of the total population of Rwanda.

Women comprised 52.7% of the population of Rulindo district. The majority were young, with 82% of the population aged under 40 years old. The average household size was 4.7 for Rulindo district, which was slightly lower than the national average of 4.8. Rulindo had the second lowest figure among other districts in Northern Province (the averages for the other districts are: Gakenke 4.5; Musanze 4.8; Burera 5; and Gicumbi; 5.1).

Rulindo district was ranked 10th from bottom (42.9%) of all districts by percentage of extremely poor and poor population categories. In Rulindo district, 57.1% of the population was identified as non-poor, 23.2% as poor and only 19.7% as extremely poor. Compared with other districts in Northern Province, Rulindo district had the highest percentage of extreme-poor.

Most people aged 16 and above in Rulindo were classified as independent farmers as their main job (61.9%). The second most frequent main job was wage non-farm with 16%. Agriculture was shown as the main industry for 77% of the population aged 16 and above, followed by Trade (5.6%), Mining and Quarrying (5.3%), and Construction (4.1%). Household income was driven by agriculture (52.4%), followed by wage income (23.5%) and business income (8.8%).

Rulindo district, the mean size of land cultivated per household was 0.7 ha, which was above the national average (0.59), rural average (0.6) and urban average (0.46). Rulindo district also had 84.1% of cultivating households that cultivated under 0.9 ha of land, 10 as compared to Gakenke (80.5%), Gicumbi (85.6%), Musanze (87%) and Burera (91.3%). Commercialisation of crop production overall, as measured by the share of harvest sold (including households selling zero crops), was17.7% in Rulindo district. It was 20.9% at national level.

Rulindo district is mostly characterized by hills, which include Tare, Tumba and the Cyungo Hills with their altitude rising to 2,438 m. These hills are interspersed by valleys and swamps that also border rivers such as Nyabarongo, Muyanza and Nyabugogo. The valleys and swamps, such as Rugezi, feed lake Burera and in turn supply the fall of Ntaruka in Burera District which is a source of hydroelectric energy to the country. This interweaving of hills and valleys with rivers provides a beautiful and eye catching scenery to both citizens and visitors.

Rulindo has a tropical climate, characterized by a succession of rainy seasons and droughts. The dry season usually extends from June to August and January to February while the rainy season normally stretches from September to December and March to May. Rulindo District has significant water reservoirs from local sources including rivers that have a steady flow into valleys that enables the district to have water even during the dry seasons.

Natural forest in the district have taken a decreasing toll due to many factors, key among them being human settlement and its related impact such as use of wood for cooking. It also harbors ferns and eragrostis grass (inchinge), the latter being a sign of soil degradation. While hardly any wildlife existed, the district was never the less blessed with numerous and diverse breeds of birds ranging from crowned crane, ravens, waders, wagtails, doves, hawks, humming birds, sparrows, and any others.

Figure 3.1: Administrative Map of Rulindo District

Figure 3.2: Rulindo District Administrative Map

Source: Rwanda 4th Population and Housing Census, 2012 (NISR)

3.2 Conceptual Framework

Farmers`decision to practice agroforestry system on small scale was based on different factors and vary from one region to another, one farmer to another. Figure 3 postulated the factors considered for assessing the determinants of small holder farmer`s decision to practice agroforestry in Rulindo District. From an extensive literature on agriculture and forestry technology, five groups of determinants are categorized used for agroforestry adoption. (Pattanayak et al., 2003):

a. **Preferences** were placeholders for the majority of farmers that were influenced by risk tolerance, conservation attitude and intra-household homogeneity. Since farmers preference were challenging to measure, therefore socio-demographic proxies such as age, gender, education, and marital status are used in this study. For example, the education level could be used to measure the opportunity cost of labor investments in agroforestry technology. Also, gender could reflect the resource capacity of the household.
b. **Resource endowments** measured the resources available to the technology adopter for implementing the new technology. Some examples included land, labor, livestock and savings. In general resource endowments were associated with the decision to practice agroforestry. However, different endowments would encourage different types of agroforestry practices.
c. **Market incentives** Consisted of factors related to explicitly lower costs and/or higher benefits from technology adoption. Their determinants included availability of markets, transportation, and potential income losses or gains.
d. **Bio-physical factors** related to influences on the physical production process associated with farming and/or forestry. Some examples included location of farmland and plot size. In general low biophysical production conditions such as greater slope or potential for high erosion, created a positive incentive to adopt technologies that will alleviate these situations. However, it was also possible that some farms were of a quality that is below the threshold of useful investment.
e. **Risk and uncertainty** referred to the unknowns in the market and institutional environment from which decisions weremade. For example, a short-term risk and uncertainty would be fluctuations in commodity prices, projected output and rainfall. To some extent, the uncertainties of the new technologies were reduced

by public inputs like extension and training as well as their household familiarity or even related experience. An example of a long-term risk and uncertainty would be tenure insecurity.

f. Due to the long gestation period of investments in farming and forestry, lower risk and uncertainty would generally advance technological adoption. Different agroforestry characters such as multiple-output, multiple-input or multi-seasonal were known as potential mechanism to reduce risk and uncertainty by expanding farmer's portfolio and therefore a good candidate for adoption by smallholders (Scherr S. , 2000) (Frenzel and Scherr, 2002).

Generally, preferences described the objectives and motivations of the economic agents when choosing technologies. Resource inheritance enabled their technology choices while market incentives and biophysical factors helped the timing and the nature of the technology choices. Finally, risk and uncertainty could sabotage the payment of investments to dividends in long run.

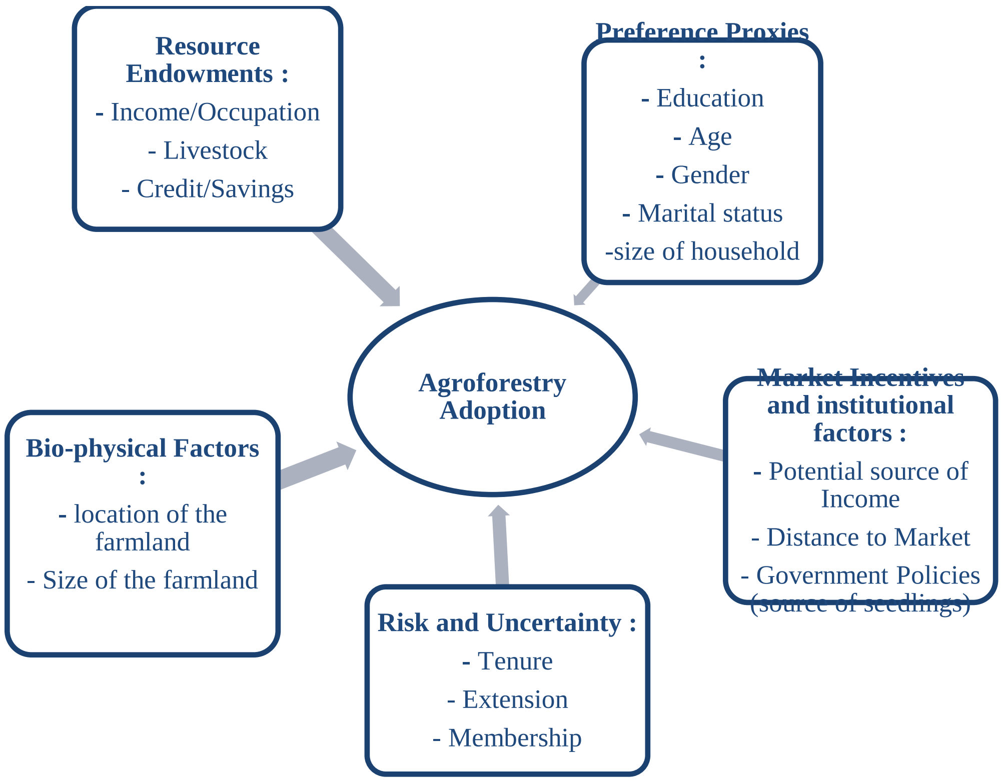

Figure 3.3: Conceptual Framework for Examining Determinants of Smallholder Farmers` Decision to Practice Agroforestry in Rulindo District

Source: Adapted from Pattanayak et al. (2003)

3.3 Analytical Framework

The decision of a farmer to practice agroforestry could be modelled as a choice between two alternatives; whereby a farmer could make the choice of practicing agroforestry or not. The random variable declaration was a binary choice that takes the value of 1 = practice agroforestry and 0 = otherwise. Logit and probit models were preferred when there are two outcome choices. The current study used a probit model. The decision of the i^{th} farmer to plant agroforestry trees or not depended on the unobserved utility index $I_{i.}$ which was determined by explanatory variables.

The probit model of the decision to practice agroforestry was derived from a latent variable model, which is specified as:

$DEC_i* = \beta_0 + \beta_{ij}Landsze_{ij} + \beta_{ij}Creditacc_{ij} + \beta_{ij}Subs_{ij} + \beta_{ij}dairy_{ij} + \beta_{ij}Gender_{ij} + \beta_{ij}Age_{ij} + \beta_{ij}Hholdsze_{ij} + \beta_{ij}Groupmbr_{ij} + \beta_{ij}Accext_{ij} + \beta_{ij}Occup_{ij} + \beta_{ij}Mktdist_{ij} + \beta_{ij}Educ_{ij} + \beta_{ij}Maritatulstat_{ij} + \beta_{ij}Landtnre_{ij} + e_i$

Where DEC_i* is the underlying index showing the utility difference among those who were practicing agroforestry and those who did not; β0 is the constant, βij is the vector of parameters to be estimated, $Landsze_{ij}$ is the total land size owned by the household, $Creditacc_i$ is the variable showing if the household had access to credit, $Subs_{ij}$ captures the information if subsistence production satisfies own household consumption, $dairy_{ij}$ shows if a household practiced dairy farming, $Gender_{ij}$ is whether the respondent was men or women, Age_{ij} represents the average number of years of the respondent, $Hholdsze_{ij}$ shows the number of people who depend on the household, $Groupmbr_{ij}$ is an indicator for group membership, $Accext_{ij}$ represents a respondent's access to extension services, $Occup_{ij}$ is the main occupation of the respondent, $Mktdist_{ij}$ shows the distance from the farm to the market, $Educ_{ij}$ represents the level of education, $Maritatulstat_{ij}$ indicates if a respondent is married or not, $Landtnre_{ij}$ is the tenure status of the land owned, and e_i is the error term.

From the model above, the decision of the household to grow trees was derived as:

$$P(DEC_i* = 1|x) = F(\beta_0 + \beta_{ij}X_{ij})$$

Where F was the likelihood function of the decision to practice agroforestry and it was restricted between 0 and 1. Therefore a farmer practices agroforestry if $DEC_i* = 1$, and otherwise if $DEC_i* = 0$.

3.4 Research Design

Quantitative data were collected using a semi-structured questionnaire to capture farmers' information on socio-economic factors, market and institutional factors, bio-physical factors and resource endowment factors. This study also reviewed literature to collect secondary data.

3.4.1 Sampling Procedure

The study used primary data collected from randomly sampled farmers who grow agroforestry trees in Rulindo District. A two-stage sampling procedure was applied to select the respondents.

In the first stage, i used systematic selection which involved selecting sectors at regular intervals from an ordered list. Six sectors namely Base, Bushoki, Tumba, Ngoma, Rusiga and Ntarabana were selected systematically from all sectors of Rulindo District. This method ensures that the selected sectors are spread out across the district, reducing the risk of clustering and ensuring a more representative sample.

In the second stage, individual farmers were randomly selected. This method was suitable as it guarantees representativeness of the population of interest and is cost-saving (Anderson et al., 2011).

Semi-structured questionnaires were administered to a total of 270 farmers in six sectors by equal allocation. Face-to-face interviews were conducted as they enable real-time clarification of questions (Doyle, 2014).

The sample size was determined following Anderson et al. (2007) as:

$$n = \frac{p(1-p)Z^2}{E^2}$$

Where;

n was the sample size, ***p*** was the proportion of population having the major interest, ***Z*** was the confidence interval and ***E*** was the margin of error. Since the proportion of the population in the study site was unknown, $p = 0.5$ (assumed to be 0.50, as this would yield the maximum sample size), $Z = 1.96$ and $E = 0.06$.

Thus, the sample size was determined as:

$$\text{Sample size: } \frac{0.5(1-0.5)1.96^2}{0.06^2} = 266.77$$

The 266.77 was rounded off to 270 respondents to enable the distribution of the sample in the four districts.

3.4.2 Data Needs and Data Collection Methods

Both primary and secondary data were used in this study. Reconnaissance survey is carried out before conducting the detailed data collection. The aim of the reconnaissance survey was to get familiar with the sector administration and to gain initial information on the nature of the district, farming systems including agroforestry systems and techniques. A pre-test of the questionnaire was done to check for clarity and improve reliability before the actual data collection. A sample of 10 farmers were used for pre-testing the questionnaire. These farmers are picked at random from the list of farmers in the respective cells.

After this reconnaissance survey, face-to-face household interviews were conducted to obtain primary data on farmers' socio-economic characteristics including gender, education level, and source of income, land ownership, extension services and size of the household. Other data captured in the questionnaire included main motivation to practice agroforestry and major constraints.

To ensure the accuracy and reliability of the survey data, the study incorporated secondary data from a variety of reputable sources. This included information from District Agriculture Officers and District Livestock Officers, who provided authoritative and up-to-date data on agricultural practices, and local farming conditions. These officials' insights were crucial in cross-verifying the primary data collected from farmers, ensuring that the study's findings were grounded in the most current and comprehensive information available.

In addition to official reports, the study also utilized a range of other secondary sources to enrich the analysis. Geographic maps were consulted to understand the spatial distribution of agroforestry practices and environmental factors across the Rulindo District. Academic journals and publications offered peer-reviewed research that provided scientific context and supported the study's theoretical framework. Both published and unpublished reports from government agencies, non-governmental organizations, and research institutions were reviewed to gather detailed studies and surveys relevant to the study's focus. This extensive literature review helped to identify trends, gaps, and corroborate the primary data findings.

Furthermore, the study leveraged online resources and databases to access the latest statistics, policy updates, and research findings. Relevant websites, including those of agricultural departments and international organizations, were invaluable for obtaining current data and insights. By comparing and contrasting this secondary data with the primary data collected from the field, the study was able to validate its findings, ensuring a robust and credible analysis. This comprehensive approach not only supplemented the primary data but also provided a richer, more nuanced understanding of the factors influencing agroforestry practices in the Rulindo District.

3.4.3 Data Analysis

The data were entered and cleaned using the Statistical Package for Social Sciences (SPSS) version 17. Descriptive statistics were computed to characterize smallholder farmers in

Rulindo district as first objective of the study, for- the second objective to determine the factors affecting the decision to practice agroforestry, Probit model was estimated using STATA 14 software and presented using Table. Limitation of the farmers and perceived Government interventions to promote agroforestry practice were presented in tables, pie charts and bar graphs.

Table belo provides a detailed overview of the variables used in the study, including their definitions and the expected signs of their effects.

Table 3.1: Variable Definition and Expected Signs

Variable	Description	Expected sign
Land size	Average size of land in Ha	+/-
Access to credit	=1 if household accessed credit	+/-
Crop enough subsistence	=1 if household produce enough food for family use	-
Dairy farmer	=1 if the respondent is a dairy farmer	+
Man	=1 if man	+
Age	Age of the respondent	+
Household size	Number of people living in the household	+
Group membership	=1 if household belong to any developmental group	+/-
Access to extension services	=1 if household had access to extension services in the last 12 months	+
occupation	=1 if main occupaion s farmer	+/-
Distance to the market	Average distance from farm to the market	-
Level of education	=1 if respondent has ever attended school	+
Land tenure	=1 if land is owned or purchased	+
Farm location	=1 if land is on a level platform	-

3.5 Diagnostic Tests

3.5.1 Multicollinearity

Multicollinearity is mostly found in cross-sectional data, whereby variables in the model are highly correlated. If it is not corrected for, the coefficient estimates generated from the regression are not valid. Further, it causes ordinary least square (OLS) estimates to be sensitive to small changes. In this study we used variance inflation factor (VIF) to test for the presence of multicollinearity. The rule of the thumb is that a VIF of less than five is an indicator of the absence of multicollinearity in the data. The results showed that all the variables had a VIF that was less than 5, indicating the absence of multicollinearity among the explanatory variables used in the model.

3.5.2 Heteroscedasticity

Heteroskedasticity is a situation where by the error term does not have a constant variance conditional on the chosen levels of the independent variables. We test for heteroscedasticity using the Breusch-pagan test. The chi-square value was 20.01 (p=0.0001). Therefore, reject the null hypothesis of a constant variance in the error term, indicating that heteroscedasticity was present in the data. To correct for this we use robust standard errors.

3.5.3 Justification for Pseudo R2 and Log Likelihood

Probit uses Maximum Likelihood estimation given the value of independent variables, what value of Beta will maximise the likelihood of observing the given value of the dependent variable. The usual null hypothesis is this case is all the beta values are zero. (Parameters of all the explanatory variables is zero) meaning that none of the independent variables have any role in determining dependent variable. The Alternative Hypothesis is that at least one of the parameter values is not zero. So, if the chi square is significant, it indicates at least one independent variable is significant. In other words, the model can be used for interpretation. In our model we find the chi-square to be significant at 1%.

Pseudo R2

Further, the McFadden's pseudo R-squared value for the probit model was 0.22, which is within the range of 0.2 to 0.4 that indicates an excellent fit.

CHAPTER FOUR

RESULTS

4.1 Characterization of the Farmers in Rulindo District

4.1.1 Socio-Economic Characteristics of Respondents

Table 4.1: The Socio-Economic and Household Characteristics among the Respondents in Rulindo District

1	2	3	4	5	6
	Pooled		**Agroforestry adoption status**		
Variable	**Mean (n=273)**	**Std. Dev.**	**Non- adopters (n = 90)**	**Adopters (n= 183)**	**Mean differences (5 – 6)**
Adopters of agroforestry (% yes)	67				
Land size	0.49	0.63	0.33	0.57	-0.24***
Access to credit (% yes)	44		0.33	0.50	-0.16**
Crop enough subsistence (% yes)	49		0.41	0.54	-0.12*
Dairy farmer (% yes)	74		0.58	0.82	-0.24***
Men (% yes)	56		0.42	0.63	-0.21***
Age	45.15	14.81	43.21	46.10	-2.89
Household size	4.49	2.04	3.72	4.87	-1.15***
Group membership (% yes)	69		0.57	0.76	-0.20***
Access to extension services (% yes)	41		0.27	0.48	-0.21***
Farmer (% yes)	86		0.83	0.87	-0.04
Distance to the market	5.00	5.30	4.51	5.24	-0.73
Above primary school (% yes)	72		0.68	0.74	-0.06
Owned / Purchased (% yes)	77		0.74	0.78	-0.04
Level ground (%)	30		0.28	0.31	-0.03

The statistical analysis of the data reveals several significant differences between adopters and non-adopters of agroforestry. Adopters tend to have larger land sizes, better access to credit, and are more likely to have enough crops for subsistence. Additionally, a higher percentage of adopters are dairy farmers and male. They also tend to have larger household sizes, are more likely to be members of groups, and have better access to extension services. These differences are statistically significant, indicating that these factors may play a crucial role in the decision to adopt agroforestry practices.

On the other hand, some variables did not show significant differences between adopters and non-adopters. These include age, farmer status, distance to the market, education level, ownership status, and the percentage of level ground. This suggests that these factors may not be as influential in the adoption of agroforestry. Overall, the analysis highlights the importance of certain socio-economic and demographic factors in influencing agroforestry adoption, while other factors appear to have less impact.

4.1.2 Household Decision-Making on Agroforestry

Power in decision making to plant agroforestry trees in household was identified by respondents as an important factor affecting adoption of agroforestry. The results showed that the share in decision making regarding planting of agroforestry trees between men and women is respectively 38% and 19%. While Join decision represented 43% (Figure 4). Specifically, we find that the decision making pattern is more biased towards men, which can be supported by the patrilineal nature of land ownership in Rwanda.

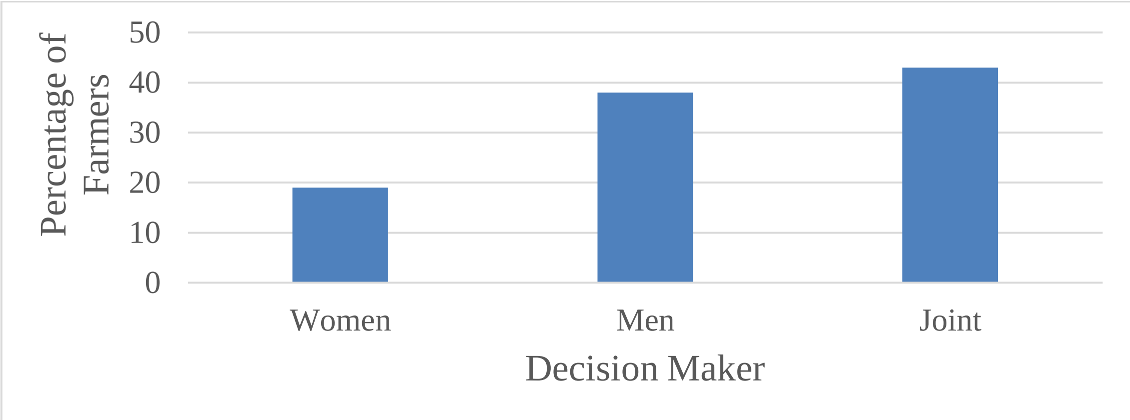

Figure 4.1: Household Decision Making in Practicing Agroforestry System

4.1.3 Source of Seedlings for Agroforestry in Rulindo District

Source of agroforestry inputs is considered as an important aspect and this study has shown that the government provided 33 percent of seedlings and 22 percent were provided by development partners as shown in Figure 5. Access to inputs motivated farmers to grow more trees on their land because available inputs reduced investment cost needed to plant trees. In addition, 22 percent of surveyed farmers were also getting seedlings from their own farms (Figure 5). This reduced the revenue spent by households in purchasing seedlings and thus motivated Rulindo farmers to grow more trees**.** It is also worth to mention that farmers have the propensity to invest in purchase of seedling, with about 6 percent purchasing seedlings from private nursery.

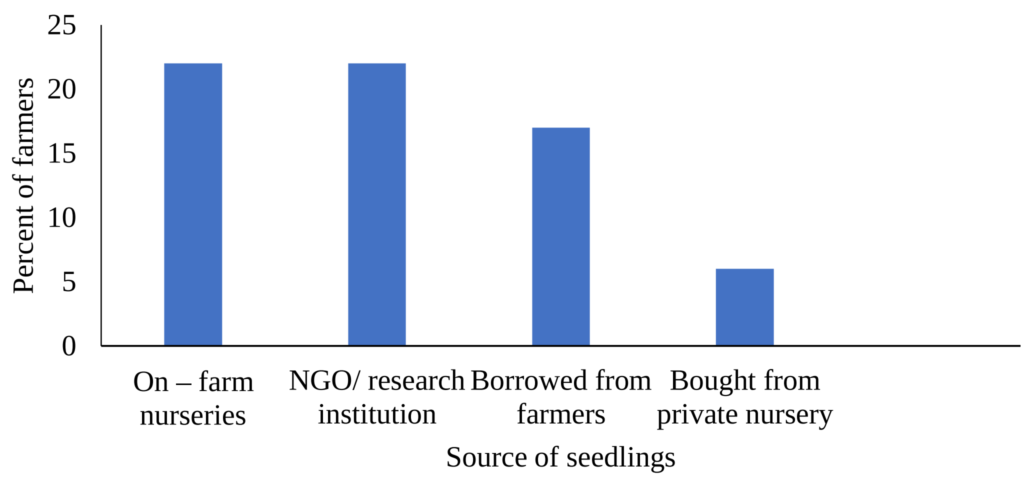

Figure 4.2: Source of Seedlings for Use in Agroforestry

4.1.4 Access to Credit

Forty four percent of surveyed farmers in Rulindo District had access to credit and thirty percent of the loan received was used on purchasing agricultural inputs including tree seedlings. The figure below depicts the use of credit.

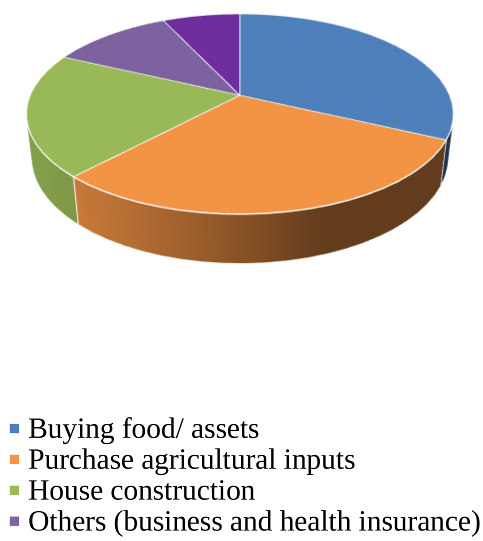

Figure 4.3: Use of Credit by Smallholder Farmers

4.1.5 Farmers' Membership in Development Groups

At the farmer level, studies have shown factors have that influence decision to practice agroforestry including strong social capital which increase the rate of technology adoption and improve management of environment (Woolcock & Sweetser, 2007). Low income communities may benefit from social capital to leverage their limited resources. To observe the impact of social capita on the decision to practice agroforestry in Rulindo, household's membership in development groups was analyzed. Most of the respondents are members of Savings and Credit Co-operatives (77%) (See figure 7) and farmer cooperatives (15%).

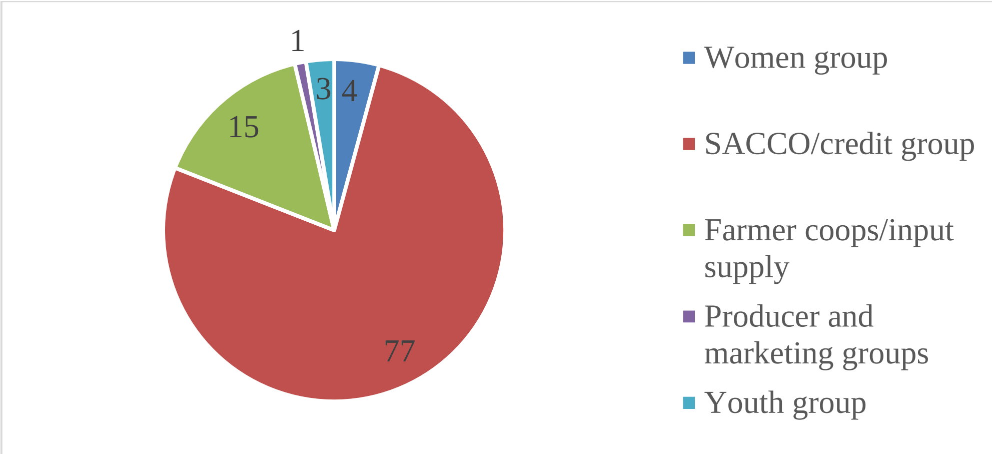

Figure 4.4: Category of Farmer Groups Present in Rulindo District

4.1.6 Annual Income from the Farm Produce

Table 4.2: Annual Income from Farm Produce of Respondents in Rulindo District

	Non-adopters		Adopters	
Income Levels (RwF)	**Frequency**	**Percentage**	**Frequency**	**Percentage**
< 12,000 Rwf	24	26.67	44	24.04
Between 12,000 and 50,000 Rwf	14	15.56	52	28.42
Between 50,000 and 120,000 Rwf	2	2.22	23	12.57
Between 120,000 and 360,000 Rwf	4	4.44	7	3.83
More than 360,000 Rwf	0	0	1	0.55
	90	**100**	**183**	**100**

Annual income from farm produce between adopters and non-adopters of agroforestry in Rulindo was measured to understand economic benefits of agroforestry practice. Larger share of adopters 28.42 percent are earning between 12,000 and 50,000 Rwf Compared to 14 percent of non-adopters. Further, majority of adopters were found to have higher proportions of annual income than non-adopters.

4.2 Factors Affecting the Decision to Practice Agroforestry in Rulindo District

Table 4.3: Estimates from a Probit Model Highlighting the Determinants of Decision to Participate in Agroforestry among Farmers

	Coeff	Robust Std. Err.	P value	Marginal effects	Robust Std. Err.	P value
Land size	1.78*	0.72	0.01	0.51	0.2	0.01
Credit access	-0.02	0.22	0.94	0.00	0.06	0.94
Crop enough subsistence	0.25	0.20	0.22	0.07	0.06	0.22
Dairy farmer	0.35	0.23	0.13	0.10	0.07	0.13
Men	0.59***	0.21	0.01	0.17	0.06	0.00
Age	0.01	0.01	0.11	0.00	0.00	0.10
Household size	0.17***	0.05	0.00	0.05	0.01	0.00
Group membership	0.34	0.24	0.15	0.1	0.07	0.15
Access to extension	0.51*	0.22	0.02	0.15	0.06	0.02
Occupation						
Casual workers	0.31	0.38	0.42	0.08	0.10	0.40
Public or private Servant	-0.63	0.48	0.19	-0.19	0.14	0.18
Business Man/Woman	0.57	0.59	0.33	0.15	0.13	0.27
Level of education	0.17	0.22	0.44	0.05	0.06	0.43
Land tenure	0.07	0.21	0.73	0.02	0.06	0.73
Married	-0.15	0.25	0.57	-0.04	0.07	0.56
Sector						
Bushoki	-0.13	0.27	0.65	-0.03	0.08	0.65
Buyoga	0.12	0.26	0.66	0.03	0.07	0.66
Ngoma	-0.71**	0.28	0.01	-0.21	0.08	0.01
Constant	-2.21	0.57	0.00			

Notes: Wald chi^2 (18) = 71.02; Prob > chi2=0.0000; Pseudo R^2 =0.23

4.3 Reasons Why Farmers Practice Agroforestry

Farmers adopted agro-forestry in the study area for various reasons mainly for food, land conservation, source of income, fodder, government policy, fuelwood, stakes for climbing beans and cultural belief. Approximately one third of farmers planted agroforestry trees for food (fruits trees) and for control against soil erosion. Notably, 15% of these farmers practiced agroforestry for income purposes while another 8% did it to use them for staking beans (Figure 8). This results show the holistic importance of agroforestry on livelihoods.

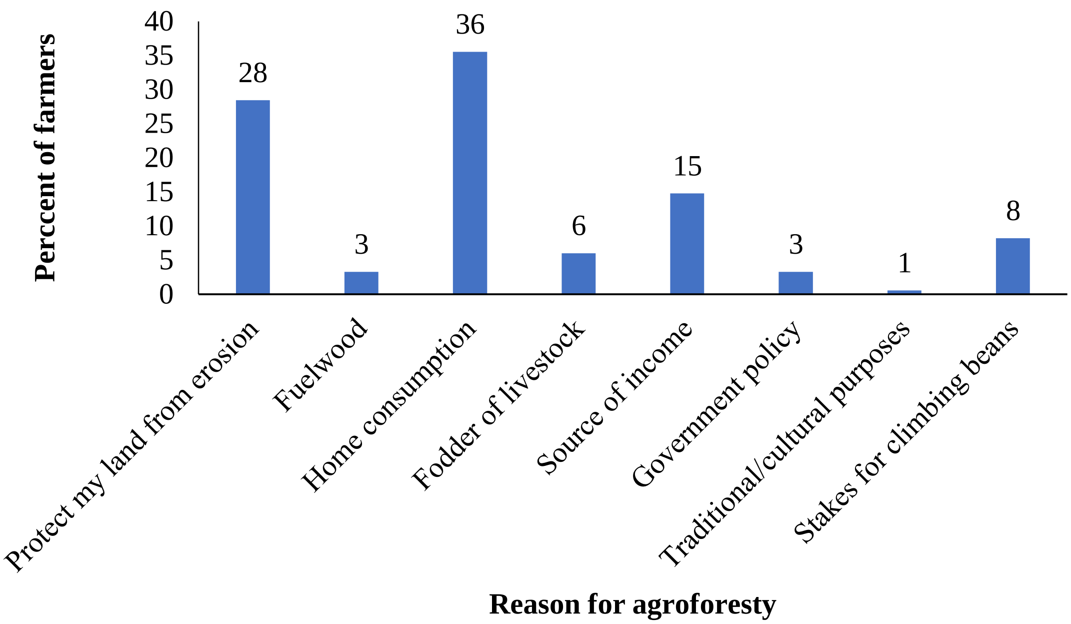

Figure 4.4: Reason for Adopting Agroforestry Trees

4.4 Limitation of Farmers to Practice Agroforestry in Rulindo District

A number of possible reasons for not practicing agroforestry are analyzed ranked as shown in figure 9 below. Results indicated that lack of knowledge and skills was ranked highest in rank one and three. Consequently, lack of seedlings was ranked highest in rank two. It is however important to note that land shortage is ranked second most inhibiting factor in all ranks.

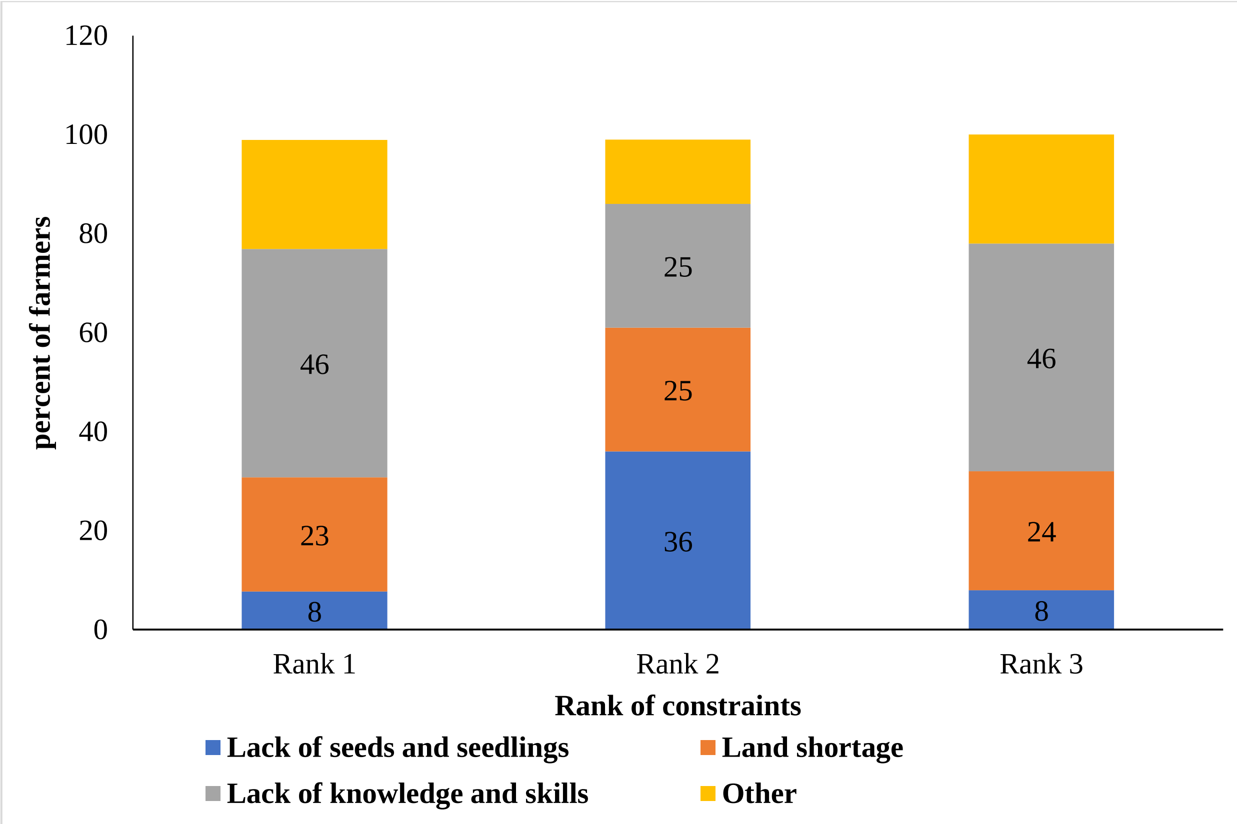

Figure 4.5: Ranking of Constraints to Adopt Agroforestry System in Rulindo District

4.5 Government Interventions to Promote Agroforestry Practice in Rulindo District

4.5.1 Status of Government and Partners Interventions in Agroforestry

Table 4.4: Estimated Area for Agroforestry Expansion in Rwanda

Land Husbandry Practices	Area (ha)
Agroforestry on cutoff drains and horizontal trenches	419,251
Agroforestry for progressive terraces	417,077
Agroforestry on radical terraces, gullies and degraded lands	741,565
Total agriculture land (with and without agroforestry)	1,577,893
Potential area for agroforestry	**1,483,218**

Source: A. Mukuralinda et al., 2016

Almost all-agricultural land in Rwanda is suitable for some kind of agroforestry system. Table 8 show how agroforestry systems would be combined with soil protection practices, based on the local slope conditions. In addition, the law of Rwanda consider land-having slopes greater than 55 percent as unsuitable for terraced farming and is to be managed in woodlots and tree plantations.

Table 4.5: NGO and Other Institutions Influence on Agroforestry Practice

Organization	Type of support	% of respondents
TUBURA	Supply of AF seedlings	7.10
PAREF	Supply and planting of AF seedlings	42.90
FONERWA	Supply and planting of AF seedlings	71.40
	Establishment of radical terraces	42.90
DUHAMIC-ADRI	Trenching on contour lines for erosion control	7.10
	Supply and planting of agroforestry seedlings	28.60
	Training and study tours on agroforestry practices	7.10
VUP	Establishment of radical terraces	14.30

Source: Damascene, 2017

In Rwanda, the lack of coordination among institutions, government agencies, and NGOs involved in agroforestry research and development has created significant challenges. For instance, different organizations often implement overlapping projects without consulting each other, leading to duplication of efforts and inefficient use of resources. This fragmentation means that farmers receive mixed messages and inconsistent support, which hampers the overall effectiveness of agroforestry initiatives. For example, one NGO might promote a particular tree species for soil conservation, while another focuses on a different species for economic benefits, confusing farmers about which practices to adopt.

Moreover, the top-down approach to project implementation often excludes the target communities from crucial stages of the project cycle. For example, farmers might not be consulted during the problem identification phase, resulting in interventions that do not address their actual needs. Similarly, without involving farmers in planning and implementation, projects may overlook local knowledge and preferences, leading to solutions that are not practical or sustainable in the local context. This lack of community involvement extends to monitoring and evaluation, where feedback from farmers is rarely sought, preventing the adaptation and improvement of ongoing projects (A. Mukuralinda et al., 2016).

4.5.2 Farmers Perception on Government Interventions to Promote Agroforestry in Rulindo

The study analyzed interventions needed for increasing interest in agroforestry practices to identify points of entry. 34 percent of the surveyed farmers reported that farmers would be motivated to plant more agroforestry trees on their farms if they had market access, twenty one percent wished to plant fast growing species and eighteen percent highlighted that access to land would incentivize them to practice agroforestry. Market Accessibility having high ranking referred to distance to from farm to the selling point of agroforestry products.

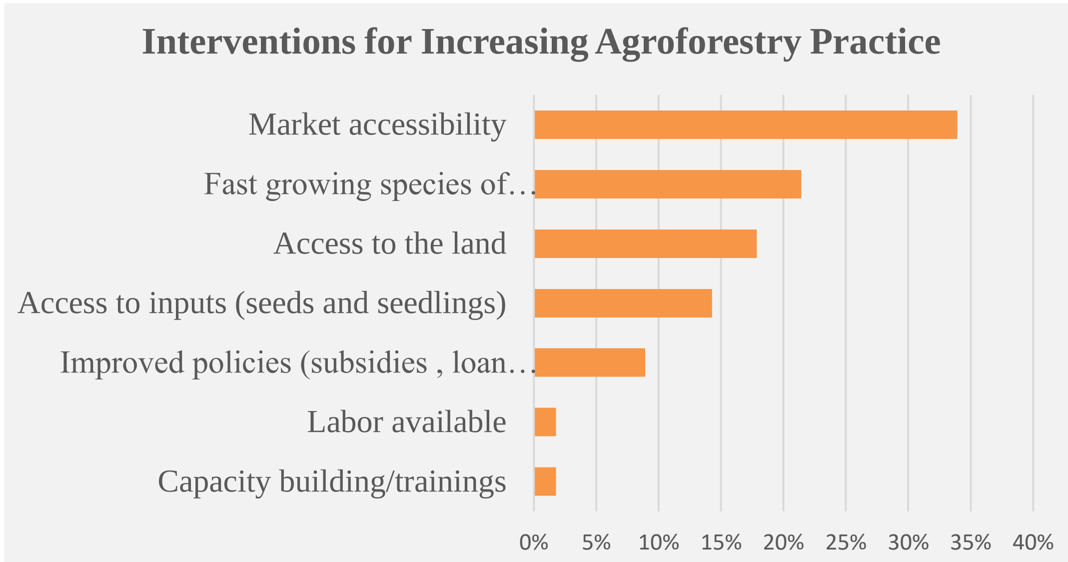

Figure 4.6: Interventions for Increase Practice of Agroforestry in Rulindo District

CHAPTER FIVE

DISCUSSION

5.1 Characterization of the Farmers in Rulindo District

Surveyed farmers revealed that 67 percent were practicing agroforestry on their land; this high adoption rate could be explained by the fact that farmers appreciated agroforestry and its potential linkage to food security and household welfare indicators. Kalaba et al. (2010) reported that agroforestry system contributed to the improvement of the socio-economic livelihoods of smallholder farmers in southern Africa and promoted conservation of biodiversity.

The average household size was about 5 persons per household, which was higher than Rwanda's national mean of 4.2 persons (NISR 2012). Additional working members in the household was giving more chance for the adaptation of labor intensive strategy like Agroforestry system as was also reported by Rodriguez and Arriaza (2013). On the other hand, size of the household could be a limiting factor for agroforestry adoption because having bigger family size with a limited land size would affect the decision to plant trees on farm as farmers would rather prefer to grow food crops to feed the family.

Agroforestry trees were an important source of fodder for livestock. Dawson et al. (2014) reported that farmers used tree fodders as a substitute for dairy meal or as a supplement to a basal diet. Cecchi et al. (2010) and Franzel et al. (2014) highlighted that agroforestry interventions to support livestock in East Africa have to date mostly focused on mixed faming systems. Similarly, this study found out that 74 percent of farmers in Rulindo district practiced dairy farming and more than 55 percent among them preferred to plant trees producing fodder to feed their livestock.

Average level of education of respondents shown that more than half of the respondents, equivalent to 58%, had attained primary level of education. According to fourth population and housing census, only 57% of the national resident population aged three and above, had attained primary school (NISR 2012). This level of education could influence decision making at household on practicing agroforestry system in Rulindo. Kekuru et al. (2014) reported that an educated farmer possesses good decision-making ability and thus is able to take steps to plant trees on farm for conservation of natural resources and produce goods and service from agroforestry trees. Wireko (2011) similarly reported that technologies are knowledge-intensive and thus require high level of education.

Access to credit was analyzed as a key determinant of farmers' ability to purchase inputs, hire labor and invest in improving farming practices including integration of agroforestry trees on farmland. Matata et al. (2010) identified access to credit as important factor for adoption of agroforestry technology. An important part of the loan (32%) of surveyed farmers was used to buy food to complement farmers produce. This showed that surveyed farmers did not produce sufficient food for their households.

Surveyed farmers in Rulindo greatly valued collective action; results showed that approximately over two thirds of the surveyed farmers were in development groups. Lambrecht and Asare (2015) reported that strong collective action could remove barriers for adoption of long-term investment such as tree planting and improvement of natural resources. However, these farmers highlighted challenge that they were facing including lack of innovative ideas or projects for development and group members were failing to pay the loan received. These challenges were affecting development of farmers' cooperative that could contribute to reduce poverty in rural areas.

Annual income from farm produce was analyzed in survey farmers to understand economic benefits from practice of agroforestry system in Rulindo District, the results showed that adopters have higher income compared to non-adopter, 28.42 percent estimated their annual farm income between 12,000 and 50,000 Rwf while non-adopters 26, 67 percent annual income was less than 12,000 Rwf. Djalilov et al. (2016) also reported that agroforestry could be economically viable land use option on the environmental rehabilitation and sustainable agricultural development.

5.2 Factors Affecting the Decision to Practice Agroforestry in Rulindo

The average land size per household of the respondents was 0.49 ha (Table 2). This study found that the average land size had a positive and significant effect on the decision to practice agroforestry. This is because trees require large space, so that after planting cash and food crops, there was limited space for planting of trees. Tesfaye et al. (2014) similarly reported that land size was linearly correlated to the decision to plant trees or investment in soil conservation measures.

Gender had a positive and significant effect to the decision to practice agroforestry in Rulindo district, particularly, being man increased the probability of the decision to practice agroforestry. This could be attributed to the fact that traditional patriarchal socio-cultural norms provide men power on the household and agricultural decisions while women often have little or no formal access to productive assets. These results were similar to other studies (Mariola et al., 2020; Remesh & Robert, 2021; Meijer et al.,2015) who reported that intra-household decision making played a big role on selection of commodity to be grown on the farm.

Household size had a positive effect on decision to plant trees on farm in surveyed farmers (Table 2). A probable explanation for these findings could be that, a larger household size is viewed as a proxy for labor so the availability of additional labor in household could be instrumental in planting and taking care of agroforestry trees.

Access to extension had a positive effect to the decision to practice agroforestry in Rulindo District, extension provides information, guidance and services that farmers need to plant agroforestry trees. Maponya et al., 2019; reported the same results that research, extension services and training are key drivers to agroforestry adoption in Limpopo Province, south Africa.

Rulindo district is composed by 17 sectors, Ngoma sector had a positive and effect on the decision to practice agroforestry. This could be explained by the fact that farmers from this sector received support of seedlings from different organizations including FAO, Vi-Agroforestry and IUCN to promote agroforestry in the Area. Srijna et al., 2021 reported similar results in Tanzania, farmers supported by the projects have access to seedlings which will motivate them to practice agroforestry.

5.3 Limitation of Farmers to Adopt Agroforestry in Rulindo District

Despite the benefits derived from agroforestry system by surveyed participants, some farmers did not adopted this system in their production activities. Results indicated that lack of knowledge and skills was ranked highest in rank one and three. Agroforestry system practices requires involvement of farmers in planning and implementation from the grass root level, for example farmers can see firsthand how integrating trees with crops can improve soil fertility, reduce erosion, and increase overall farm productivity.

This hands-on approach helps farmers understand the practical applications and benefits of agroforestry, making them more likely to adopt these practices on their own farms. This is also reported in farmer participation evaluation in Zambia by Kuntashula et al (2005). Emphasis of training of farmers as trainers to sustain technological transfer and scale up of adoption should be targeted.

Demonstration plots are practical and simple tools of effective training for rural communities, diversification of production system was very attractive in Rulindo District. Lack of knowledge and skills for a good agroforestry system was the limiting factor for the farmers to plant more trees on their farms. Similarly, Noordin et al. (2001) reported that different community-based approaches were important to scale up agroforestry and other biological options to improve soil fertility among resource poor smallholders.

5.4 Government Interventions to Promote Agroforestry Practice in Rulindo District

Market accessibility, capacity building, access to inputs, improved policies, fast growing species, access to the land, stakes for climbing beans, labor available and more available fruits trees were major factors perceived by farmers in Rulindo to motivate them to pant more trees on their farms. The findings revealed that, predominantly respondents highlighted market accessibility as major motivating factor at 34%. Oduro et al. (2018) reported that trees on farm were perceived as economically beneficial in Ghana and market access could boost adoption of trees on farms.

In Rulindo, agroforestry system was developed for subsistence production level of trees, little attention was paid to the markets of agroforestry products, while a lot of different tree products came from diverse agroforestry systems and included food, fodder, timber and service wood, fuel, medicines and drugs, resins and gums, and indirect products such as honey and mushrooms. Garrity, D.P (2004) similarly reported that the rate of return to investment on tree crops was quite high, but enterprise development and enhancement of tree-product marketing has been badly neglected.

Combination of factors of availability of fast growing species and access to the land was also factors contributing to 35% of motivating factors. Farmers reported significant high land holding, however the study found that lack of ownership on land presented a risk for the farmers to plant trees because these require long time to mature, farmers would rather prefer to adopt fast growing tree species, which would be harvested before the end of leasing period. Similar observation is made by Nyaga et al. (2015) who reported that households with secure tenure in Rift valley, Kenya had higher tree diversity than those without who had higher species richness and opted for fast growing fodder and fertilizer/firewood trees.

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

6.1 Summary of Results and Conclusions

Agroforestry was considered as a system of integrating agricultural production and forestry to provide multiple benefits that could contribute to food security, energy, source of income and resilience to climate change. Rwanda has developed an agroforestry Strategy and Action Plan to promote leadership and synergies in agroforestry and engage coordinated action and implementation.

Despite the country efforts in controlling soil erosion and diversification of farm production system through provision of increased yield by crops, wood and fodder, in Rulindo District practices of agroforestry system was still limited. Those who were participating in agroforestry were majorly engaged for subsistence production and this has created interest to identify determinants of smallholder farmes`decision and limitations of agroforestry adoption in Rulindo, identify needs and priority actions to facilitate development and implementation of agroforestry system according to agro-ecological zone and land use systems in the area. This study provided the empirical evidence of determinants of smallholder farmer`s decision to practice agroforestry in Rulindo District.

This study characterized farmers in Rulindo based on Socio-economic characteristics, household decision making, source of seedlings of agroforestry trees, level of education, access to credit, membership of development groups, challenges facing in development groups, farm income between adopters and non-adopters. Agroforestry trees were an important source of fodder for livestock and farmers practicing agroforestry system on their farms have higher income compared to the farmers who do not practice agroforestry system.

The analysis highlights that land size, gender, household size, access to extension services, and regional factors (specifically the Ngoma sector) were significant determinants of agroforestry adoption. In contrast, factors such as credit access, subsistence crop sufficiency, age, group membership, occupation, education level, marital status, and being in the Bushoki or Buyoga sectors do not significantly influence adoption rates.

The Government interventions that perceived by the farmers to boost agroforestry system were to increase access to market for agroforestry products, access to fast growing tree species and having land ownership as security for long term investment.

6.2 Recommendations

Based on this study on agroforestry systems in Rulindo, the following the following was recommended:

1. The study revealed that women were less involved in the decision to promote agroforestry system. Women empowerment needed particular attention at all level of the value chain from production to market or consumption if agroforestry production is aimed. Policies supporting women organization in cooperatives for agroforestry based activities should be strengthened and Government should invest in informing and sensitization women`s role and responsibilities in decision making, emphasizing uses and benefits of agroforestry products. Rural women cooperatives should be empowered in developing agroforestry based projects and work with financial institutions.
2. Land shortage inhibited long-term investments such as agroforestry in Rulindo. I recommend to conduct research to develop new agroforestry planting materials that mature quickly. Additionally, investigate the symbiotic relationships between these early-maturing tree species and food crops to optimize their coexistence and benefits.
3. Access to market for agroforestry products produced in Rulindo District was found as driving factor for farmer’s motivation for practicing agroforestry system. To support this, policies should promote the marketing and value chain development of these products, ensuring smallholders can participate effectively. The

government should invest in building farmers' capacity in producing quality agroforestry products, marketing techniques, and project management. Additionally, creating a supportive policy environment and structures to incentivize private investment in agroforestry is crucial. Prioritizing public-private partnerships based on stakeholder mobilization, technical requirements, and opportunities for value addition will further enhance the agroforestry sector.

4. Finally, proposed policies should be oriented towards promoting agroforestry systems that meet the key goals of food security, poverty reduction, gender equity and sustainable management of natural resources.

6.3 Limitations of the Study and Suggestion for Further Research

1. The study was conducted in one District which has a different agro-ecological zone and poverty index level; this means that some inferences made in this study may only apply to the study region and not the whole Rwanda as the country has six agro-ecological zones.
2. This study focused on the determinants of smallholder farmers decision to practice agroforestry in Rulindo District, future research should provide information on existing agroforestry models and technologies in various site conditions and potentials to give more products, services and revenues with clear roadmap
3. A potential limitation of the methodology used is the reliance on secondary data, which may not always be up-to-date or entirely relevant to the specific context of the study. Future research should consider employing mixed-method approaches, such as combining qualitative interviews with quantitative surveys, can provide a more comprehensive and nuanced understanding of the factors influencing agroforestry practices.

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APPENDICES

Appendix I: Questionnaire for Small Holder Farmers

Drivers for Agroforestry adoption for small holder farmers in Rulindo District, Rwanda. (These questions are for research only and not for any other purpose. Your cooperation in answering questions will be highly appreciated).

Sector ……………………… Cell …………………… village…………………………..

Date of visit …………………………………………………………………………….

Interviewee's Name …………………………………………………………………

Screening question if NO please thank the respondent and go to the next interview

1. Do you own a farm land: (1 = Yes , 0 = No)
1. What is the tenure of your land? (1= purchased land/owned, 2= Leased land, 3= public land, 4 = communal land, 5= other (specify______________________________)
2. If land is leased what is the duration of the lease in Yeas?_______________
2. What is the average size of your farm in Ha?_________________

   Please describe the location of your farm ? (1=Steep land, 2= leveled Lowland, 3= leveled High land, 4= Both Steep and leveled land, 5= Other (specify): ………………………)

3. Do you plant trees on your farm? (1 = Yes , 0 = No***) if NO please proceed to question 7***
4. Who makes the decision to plant trees on the farm? (1= Wife, 2 = Husband, 3 = Both wife and husband, 4 = Children, 5 = anyone, 6= Other (Specify): …………
5. Who decides when and how to harvest them? (1= Husband, 2= Wife, 3= Husband and wife, 4 = Children, 5= anyone)

6. What is the **MAIN** reason why you plant trees on your farm? (1= Protect my land from erosion/soil degradation/ soil cover, 2 = Fuelwood, 3 = Home consumption, 4 = Fodder of livestock, 5 = Source of income, 6 = Government low, 7= traditional/cultural purposes 8= Other (Please specify)……………………………
7. What is your **MAIN** reason for not growing trees on your farm? (1= Lack of tree seeds and seedlings, 2= Land shortage, 3= Low level of knowledge and skills, 4= Market access, 5=other, specify)
8. Will you be willing to practice agroforestry (1= Yes, 0 = No).
9. What will be the **MAIN** motive that will drive you to practice agroforestry? (1= capacity building/trainings, 2= provide incentives (inputs), 3= market accessibility, 4= improved policies, 5= fast growing species, 6= other (specify)……………………..
10. Have you had access to extension service over the last one year?(1 = Yes , 0 = No) ***if yes fill in the table below***

Source	Did you receive extension service from this source: (1= Yes, 0=No)	Frequency over the last 12 months	What kind of information did you receive from this source: 1=pests and diseases, 2=markets and prices, 3=government initiatives, 4= good agricultural practices, 5=agroforestry, 6= other, specify(____________)	Was this information timely (1= Yes, 0=No)	Was this information reliable (1= Yes, 0=No)	Was this information helpful/relevant in your agricultural activities (1= Yes, 0=No)
Extension officer (govt)						
Researchers						
Farmer to farmer						
Tv/radio						
Out grower (seed companies)						

10 Do extension officers provide seedlings for tree planting? (1=Yes, 0 =No) ***if NO skip to question 12***

11 If yes in the question above, for what? (1 = Fruits for food security, 2 = Fodder for livestock, 3 = Timber for landscape restoration, 4= trees for bean sticks, 5= Fruits for market, 6= trees for firewood, 7= trees for poles, 8 = Other (specify)………………………………………

12 If no, what is the MAIN source of your tree seedlings? (1 = From on-farm nurseries, 2 = Bought from private nurseries, 3 = Borrow from friends, 4 = NGO or research institution, 5=Others, specify ………………………………)

13 Are you a member of any development group since 2016? (1= Yes 0= No) if **YES** please fill the details in the table below: If **NO** skip to **14**

Type of group	Member to group(1=Yes, 0=No)	If yes duration of membership	What is the most **(ONE)**important group function: 1=produce marketing 2=input access 3=savings and credit 4=farmer trainings 5=transport services 6=other, specify	Role in the group: 1=official 0=ordinary member	One main challenge in the group: 1=non cooperative members 2=poor mgt and corrupt officials 3=no ideas/projects for devpt 4=absconding metings, 5=lack of capacity, 6.=other, specify
Women group					
SACCO/credit group					
Farmer coops/input supply					
Producer and marketing groups					
Youth group					
Other (specify)					

14 If you are **NOT** a member of any development group/organization, why not? (1=Not available, 2=time wasting, 3=Doesn't want to be a member, 4=corruption in the group,5= expensive membership, 6=other, specify____)

15 Have you ever applied for credit over the last three years? (1=Yes, 0=No)

16 if **YES** what was your main source of credit? (1= Farmer group/cooperative, 2=Money Lender, 3=Bank, 4=Sacco, 5=Relative, 6=Neighbor/friend)

17 Apart from tree farmig what other **MAIN** farming enterprises do you engage in?(1=Vegetables, 2=Cereals (maize, sorghum, rice, wheat, etc), 3=Tubers (cassava, potatoes), 4=Cash crops (coffee, tea, stevia), 5=Livestock production (Dairy, Beef, shoats, pigs), 6 = Poultry farming, 7=other (specify)………………..

18 Does crop production from your farm meet your household food requirements? (1=Yes, 0=No)

19 If No, where is the **MAIN** source that you get income for food supplements: (1=From selling milk and buying food, 2=Selling fruits, 3=Sell of timber, 4=Work for neighbours to get food, 5= Civil employment, 6=Businesses, 7= Others (specify): ………………………………………………………………

20 Do you practice Dairy farming? (1=Yes, 0=No)

21 Do the trees on your farm act as feeds for the animals you keep? (1=Yes, 0=No)

If yes, which ones do you **MAINLY USE** (tree species for fodder)? (1= Calliandra , 2 = Alnus, 3= markhamia)

22 What is your total annual income from the farm produce? ________________(*indicate average amount*)

1. < 12,000 Rwf
2. Between 12,000 and 50,000 Rwf
3. Between 50,000 and 120,000 Rwf
4. Between 120,000 and 360,000 Rwf
5. More than 360,000 Rwf

23 What is the distance from your farm to the market in km?_______________________________

24 What is the distance from your household to the market in Km?______________________________

25 What do you see as **MAJOR 3** constraints to tree planting in Agro forestry production systems?

Rank 1 (1= Lack of tree seeds and seedlings, 2= Land shortage, 3= Low level of knowledge and skills, 4= Market access, 5=other, specify)	**Rank 2** (1= Lack of tree seeds and seedlings, 2= Land shortage, 3= Low level of knowledge and skills, 4= Market access, 5=other, specify)	**Rank 3** (1= Lack of tree seeds and seedlings, 2= Land shortage, 3= Low level of knowledge and skills, 4= Market access, 5=other, specify)

26 Sex ………… (1) Man (2) Woman,

27 Age:

28 Marital Status: (1=Married, 2=Single, 3=Widowed/widowered, 4= Divorced/ separated)

29 What is the highest level of formal schooling completed? (1=None, 2=Primary level, 3=Secondary level, 4=University level, 5=Vocation training, 6=Other (please specify): ………………………..)

30 What is the average number of years of formal schooling completed? _____

31 What is the size of your family? ....

32 What is your Occupation (N.B: If is more than one occupation, please indicate the time allocated to each activity in percentage)?

1. Farmer
2. Casual workers
3. Employed: Civil or public Servant/Teacher/etc
4. Business Man/Woman
5. Other (Specify): ……………………………………………