INTERNATIONAL JOURNAL OF SOCIAL Sciences and Information Technology
ISSN 2412-0294 www.ijssit.com

http://www.ijssit.com

DRIVERS OF SMALL HOLDER FARMERS' DECISION TO ADOPT AGROFORESTRY IN RULINDO DISTRICT, RWANDA

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Abstract*: The main objective of this study was to investigate the drivers of small holder farmers` decision to practice agroforestry in Rulindo District. Employing a two stage sampling technique, 270 farmers were 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 mixed effects on farmers' decision to practice agroforestry. For instance; land size, practicing livestock husbandry and household size had a positive and significant effect, whereas gender of the farmer and their occupation negatively influenced the decision to practice agroforestry. More specifically, an increase in land size and the practicing livestock husbandry had the likelihood of increasing farmer's decision to practice agroforestry by 32% and 41%, respectively.*

We concluded that inadequate knowledge and skills on Agroforestry and small land sizes are limitations on the farmers' decision to plant more trees on their farms. The results of the study imply that strengthening extension services and capacity building of local actors in agroforestry should be targeted. As recommendation government should invest in informing and sensitization on womens' roles and responsibilities in decision making, emphasizing uses and benefits of agroforestry products.

Keywords*: Agroforestry, Adoption, Probit model, small holder farmers*

1.0 Background Information

In Rwanda, around 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 rate of annual deforestation 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, depletion of biodiversity 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.

Leakey (2017) has 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. In Rwanda an 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).

Although adoption of trees on agricultural land provides a lot of opportunities as a 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). Farmers' decision to grow trees on their farms depends on many factors including social, economic, household characteristics, behavior and environmental factors. Local situation is important to consider when investigating reasons why farmers grow trees in association with crops because they are regional specific and cannot be easily generalized on all agricultural households at national scale (Ndayambaje et al., 2012). This paper provides a micro-perspective of effects of household socio-economic characteristics on decision to adopt agroforestry system on-farm in Rulindo District, Rwanda.

1.1 Impact of Agroforestry Adoption at Global Scale

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).

Hamado (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 J Pannell, 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.

1.2 Determinants of Agroforestry Adoption

Farmer`s adoption of agroforestry system on small scale is based on different factors and vary from one region to another, one farmer to another (Ndayambaje et al., 2012). From extensive literature on agriculture and forestry technology, five groups of determinants of agroforestry adoption were categorized as follows: preferences, resource endowments, market incentives, bio-physical factors, risk and uncertainty (Pattanayak *et al*., 2003).

Generally, preferences describe the objectives and motivations of the economic agents when choosing technologies. Resource inheritance enable their technology choices while market incentives and biophysical factors help the timing and the nature of the technology choices. Finally, risk and uncertainty can disrupt the return on investment made in long run.

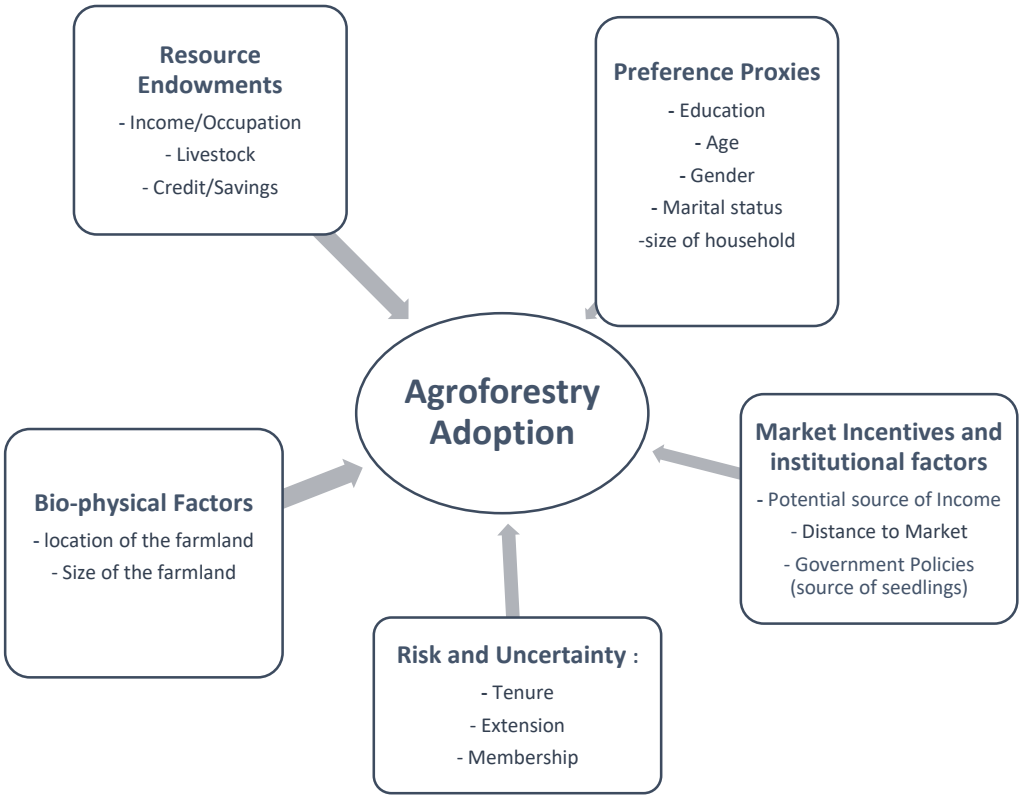

Figure 1: Conceptual framework for examining drivers of agroforestry adoption in Rulindo

Source: Adapted from Pattanayak *et al*., (2003)

2.0 Methodology

A quantitative research design was adopted and this was suitable for the case study providing insights and understanding effect of socio-economic household characteristics on decision to plant trees on farm in Rulindo District. The study used primary data collected from randomly sampled farmers who grow agroforestry trees in Rulindo District. Two hundred seventyindividual farmers were selected from six sectors namely Base, Bushoki, Tumba, Ngoma, Rusiga and Ntarabana. This method was suitable as it guarantees representativeness of the population of interest and is cost-saving (Anderson et al., 2011). Face-to-face interviews were conducted as they enable real-time clarification of questions (Doyle, 2014). This study also reviewed literature to collect secondary data.

2.1 Data Analysis Model

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

$$Yi^* = \beta 0 + \beta ijXij + ei$$

Where Yi* is the underlying index showing the utility difference among those who are practicing agroforestry and those who do not; β0 is the constant, βij is the vector of parameters to be estimated, Xij are the explanatory variables which explains the decisions to practice agroforestry, and ei is the error term.

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

$$\mathbf{P(Yi^* = 1|x) = F(\beta 0 + \beta ij Xij)}$$

Where F is the likelihood function of the decision to practice agroforestry and it is restricted between 0 and 1. Therefore a farmer practices agroforestry if $Yi^* > 0$, and otherwise if $Yi^* \leq 0$.

Both descriptive statistics and econometric model were used to analyze the primary data. Descriptive statistics were used to describe household characteristics of sample farmers including adopters and non-adopters of agroforestry system. Econometric model was used to identify the effect of socio-economic characteristics on the decision to plant trees on farm in study area.

3.0 Results and Discussion

3.1 Household Characteristics

Table 1. The results on socio-economic and household characteristics

Variable	Descriptive Statistic
Land ownership (% Yes)	96
Practice agroforestry (% Yes)	63
Average Land size (Ha)	0.285
Access to credit (% Yes)	44
Practice dairy farming (% Yes)	73
Use trees as fodder (% Yes)	55
Gender (% Male)	56
Average distance from farm to market (Kms)	5.0
Average family size	5
Membership in development group (% Yes)	69
Access to extension service (% Yes)	40

Descriptive statistics showed that, of the surveyed farmers, 56 percent were male and 44 percent were female. With regards to land ownership, 96% of the surveyed farmers owned land obtained it through family inheritance, purchase or lease arrangements and they had right to make choice on the land use system. Further, 63 percent of surveyed farmers were practicing agroforestry on their land, this high adoption 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) also 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 give more chance for the adaptation of labor intensive strategy like Agroforestry system and this also reported by Rodriguez & 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 are an important source of fodder for livestock. Dawson et al., (2014) reported that farmers use 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 73 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.

Decision-making in Agroforestry

Power in decision making to harvest trees in household was identified by respondents as an important factor affecting adoption of agroforestry. The results showed that in 38 percent of household surveyed, the decision to harvest the trees was made by the husband only and 19% of the decision was made by wife only (Figure 2). Womens' participation in decision making especially at the early stage of tree establishment and maintenance could affect agroforestry adoption in Rulindo.

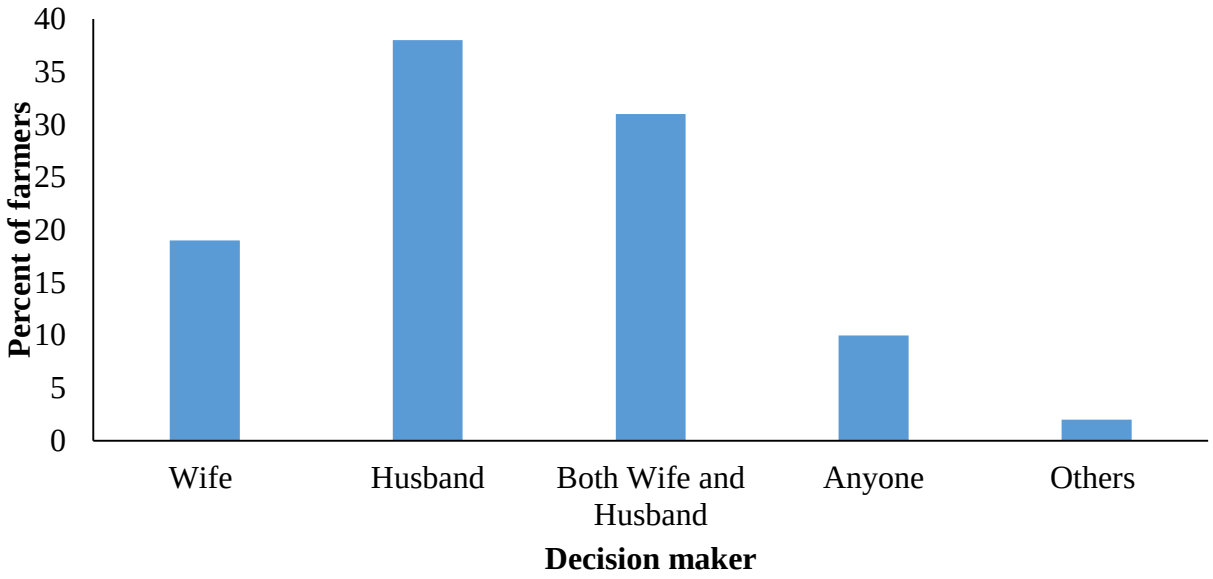

Figure 2: Decision in harvesting of trees

Source of Seedlings

Source of agroforestry inputs was also considered as an important aspect and this study has shown that in Rulindo District. 33 percent of seedlings were provided by the government and 22 percent were provided by development partners as shown in Figure 2. Meaning around 55 percent of tree seedlings were provided to the farmers for free. 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 3). This reduced the revenue spent by households in purchasing seedlings and thus motivated Rulindo farmers to grow more trees.

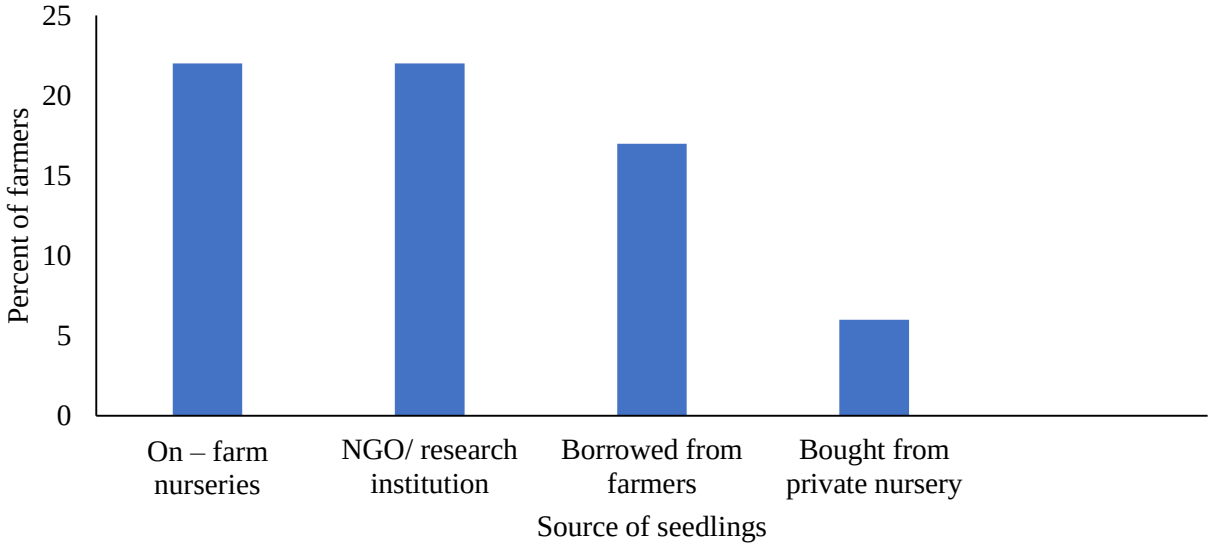

Figure 3: Source of seedlings for use in agro-forestry

Level of formal education of farmers

Level of education of respondents was also considered and the study revealed that more than half of the respondents, equivalent to 58%, had attained primary level of education. A greater proportion of respondents (28%) were illiterate, this low level of education could affect the adoption of agro-forestry technologies in the district. However this level of education observed in surveyed farmers was above national average. According to fourth population and housing census, only 57% of the national resident population aged three and above, had attained primary school (NISR 2012).

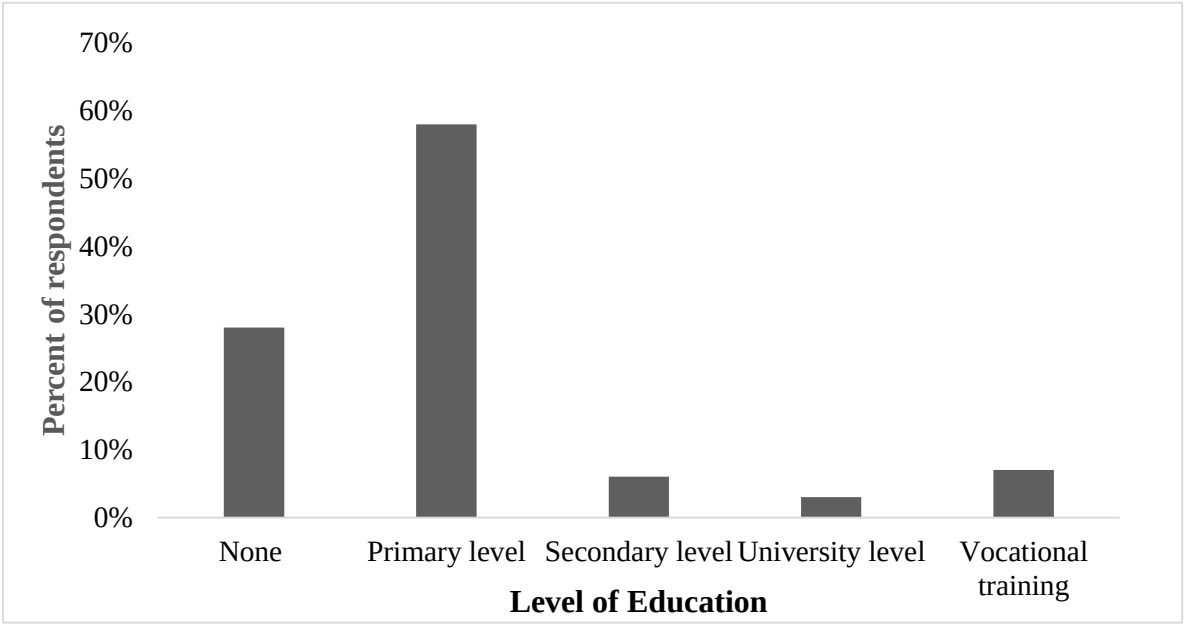

Figure 4: Distribution of farmers in terms of highest level of formal education

Education level could also influence decision making at household on adopting agroforestry. 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

Access to credit is analyzed as a key determinant of farmers' ability to purchase inputs, hire labor and invest in improving farming practices including integration of trees on farmland. 44% of surveyed farmers in Rulindo District had access to credit and 30% of the loan received was used on purchasing agricultural inputs including tree seedlings. Matata et al. (2010) identified access to credit as important factor for adoption of agroforestry technology. Another important part of the loan (32%) was used to buy food to complement farmers produce. This showed that surveyed farmers did not produce sufficient food for their households. The figure below depicts the use of credit in support of different obligations.

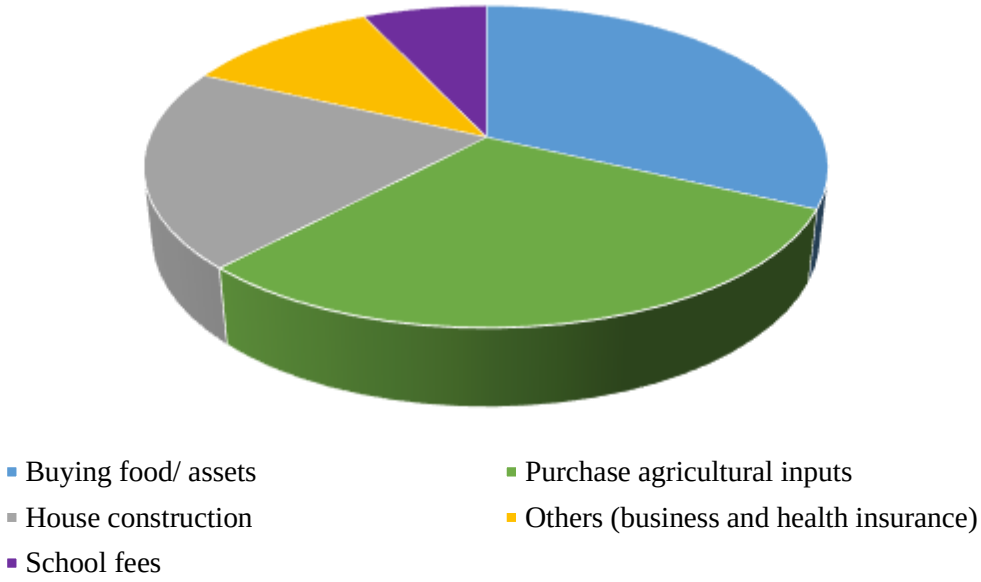

Figure 5: Use of credit by smallholder farmers

Farmer's membership in development groups

Surveyed farmers greatly valued collective action, results showed that approximately over two thirds of the surveyed farmers were in development groups. Lambrecht & Asare (2015) have reported that strong collective action could remove barriers for adoption of long term investment such as tree planting and improvement of natural resources. Categories of groups observed includes women group, youth group, farmers` cooperatives, producer and marketing groups and saving and credit groups.

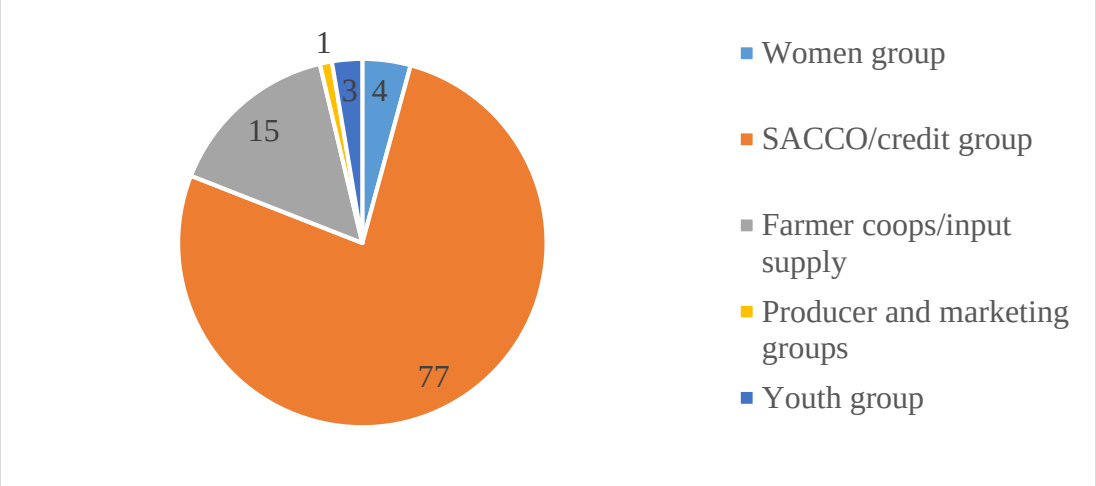

Figure 6: Category of farmer groups present in Rulindo District

3.2 The effect of socio-economic characteristics on the decision to plant trees

Table 2: Estimates from a Probit model highlighting the determinants of decision to participate in agroforestry among farmers

Variables	Coefficient	Marginal Effects	P - Value
Average land size*	0.32	0.09	0.07
Access to credit	0.11	0.03	0.59
Crop production enough for subsistence	0.22	0.07	0.23
Practice dairy farming*	0.41	0.12	0.06
Gender of respondent ***	-0.44	-0.13	0.01
Age of respondent	0.01	0	0.13
Size of the household***	0.16	0.05	0
Group Membership	0.29	0.08	0.19
Access to extension services	0.16	0.05	0.41
Occupation (Farmer as base)			
Casual workers	0.17	0.05	0.66
Public or private Servant*	-0.77	-0.24	0.06
Business Man/Woman	0.24	0.07	0.61
Distance from farm to the market	-0.15	-0.04	0.64
Level of education	0.1	0.03	0.68
Land tenure	0.14	0.04	0.52
Farm Location	0.3	0.09	0.13

Notes: ***, **, * significance levels at 1, 5 and 10 percent respectively.

N=270

Prob > chi^2 = 0.0000

Pseudo R2 = 0.19

Log likelihood = -142.40487

The average land size per household of the respondents is 0.285 ha (Table 2). The high rate of increase in population in district has led to fragmentation of land. This study found that the average land size had a positive and significant effect on the decision to plant trees. A one hectare increase in the size of land increased the probability of the decision to plant trees by 9% (Table 2). This is because trees require large space for growth and maturity so that after planting cash and food crops, there is limited space for planting of trees. Tesfaye et al., (2014) similarly reported that land size was linearly related to the decision to plant trees or investment in soil conservation measures.

Gender had an inverse relationship to the decision to plant trees in Rulindo district, particularly, being male decreased the probability of the decision to plant trees by 13% (Table 2). This can be attributed to the fact that men are usually interested in trees for commercial purposes while women are more inclined to tree products or subsistence use such as soil fertility improvement, firewood, stakes for bean, fruits and fodder. This study found that in Rulindo, women were more focused in growing fruit trees for home consumption and other agroforestry trees were planted on steep land to protect the land against erosion. These results are also similar to Meijer et al., (2015) who reported that intra-household decision making processes play a big role on selection of commodity to be grown on the farm.

Dairy farming had a positive and significant effect on farmer`s decision to plant trees of their farms in Rulindo District. Close to three quarters (73%) of respondents were practicing dairy farming in Rulindo and 55% among them had planted agroforestry trees which were providing fodder to their livestock among other benefits (Table 1). Being a dairy farmer increased the likelihood of adopting agroforestry system by 12 % in Rulindo (Table 2). Wambugu et al., (2011) reported the same results that farmers use calliandra as a substitute for dairy meal or as a supplement to a basal diet in Rwanda, Kenya, Uganda and Tanzania. (Franzel et al., 2014) explained this new approach involving growing mostly exotic tree fodders along the field boundaries, where they do not compete with crops, and along contours to help to limit soil erosion.

This study revealed that being a public or private servant as the main occupation decreased the probability of planting trees on farm by 24% (Table 2). This could be explained by the fact that agroforestry system requires allocation of time for managing the trees including pruning and weeding to avoid competition with other crops. Depending on Public or private institution as the main source of income could explain the decrease of willingness to invest in Agriculture which was perceived as risk investment due to weather conditions, pest or diseases and provision of low return on investment. These findings contradicted Jamala et al. (2013) who had presumed that di-occupational farmers had acquired capital formation through other sources of income to support their farming activities including agroforestry.

Increasing family size, with land holdings held at the community had a strong positive effect on decision to plant trees on farm in surveyed farmers (Table 2). Based on simulation results, a potential tension between food security within farm households and adoption of fruit-tree based agroforestry may exist. Fruits as

alternative of source of food and income provided an opportunity to maximize agricultural potential and larger family provided additional labor in household to plant and take care of trees planted on farm land.

4.0 Conclusion

Results from the study revealed that some socio-economic factors had a positive and significant effect on farmer`s decision to plant trees of their farms in Rulindo District. The study therefore concludes that Dairy farming had a strong influence on farmer's decision to adopt agroforestry as source of feeds for the animals. The study concluded that increase of the size of the land could motivate famers to plant more trees on their farms. Larger family provide additional labor in household to take care of planted trees and therefore could increase level of adoption in Rulindo.

The results indicate that Gender and farmers occupation had an inverse relationship. The study concluded that less involvement of women in decision making reduced the chance to plant trees on farm and farmers who have alternative source of income have the capacities to purchase household needs without relying on his/her farm income, therefore they do not attach importance of agroforestry system.

5.0 Recommendations

The study concludes that Gender had an inverse relationship to the decision to plant trees in Rulindo district, it is therefore recommended that the government should invest in sensitization of equal opportunities in decision making among men and women and emphasize the value agroforestry products and services. 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.

Future research should provide information on existing agroforestry models and technologies in various site conditions and potentials to give more products, services and revenues.

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