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Rotational Woodlot Technology in Kigorobya Sub-County, Hoima District, Uganda

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Abstract: This study evaluates, using logistic and multiple regression analyses, the socioeconomic factors that influence farmers' decisions to adopt rotational woodlot technology in the farming systems of Uganda, based on a survey of 120 farmers in Kigorobya sub-county, Hoima district. The analyses demonstrate that farmers make decisions about woodlot technology based on household and field characteristics. The factors that significantly influenced adoption decisions included: gender, tree tenure security, seed supply, contact with extension and research agencies, soil erosion index, size of landholding, fuelwood scarcity and main source of family income. To promote greater adoption of rotational woodlot technology, particular attention should be placed on the use of appropriate socioeconomic characterization, to better target technologies to areas with greater adoption potential.

Key words: Rotational woodlot, adoption, socioeconomic factors, Hoima district, Uganda

INTRODUCTION

Many regions in Africa are presently facing severe shortages of fuel wood, fodder and food primarily due to increasing human and livestock populations and crop production using little or no external inputs (FAO, 2003; Sachez, 2002). Farmers resort to use of marginal and erosion-prone soils and to encroach forests (Nyadzi *et al*., 2003). In most parts of sub-Saharan Africa, the traditional long duration fallows and shifting cultivation, which helped to replenish soil fertility to some extent, are no longer possible.

One of the agroforestry technologies identified to address some of the above mentioned household problems is woodlots using fast growing trees. Woodlots are stands of trees planted on farms, community lands or degraded lands to produce fodder, wood for fuel, construction, or sale. Over 2 decades, woodlots have become popular among the development agencies in Africa as a means of improving firewood supply to rural communities and income generation for households (Jacovelli and Caevalho, 1999) Woodlots have also become important in other parts of Africa (Ramadhani *et al*., 2002), Southeast Asia and China (Yin and Hyde, 2000) to produce wood, fodder, replenish soil fertility and to rehabilitate degraded soils. Several communal woodlots were established in many parts of Africa through mass mobilization of farmers and local organizations, especially women and youth groups (Jacovelli and Caevalho, 1999).

A rotational woodlot is a method involving growing trees with crops for 2-3 years until trees start competing with crops. Thereafter, the woodlot is left as a source of fuelwood, building poles or fodder while restoring soil fertility until farmers start cutting down the trees and growing crops between stumps 4-5 years later (Nyadzi *et al*., 2003). Rotational woodlot technology involves growing trees and crops on farms in three inter-related phases an initial tree establishment phase in which trees are intercropped with crops, a tree fallow phase and a cropping phase after harvest of trees. Each of these phases can be managed specifically to provide products and services of economic, social and environmental value. The first phase simulates the 'Taungya' system of establishing forest plantations. During this phase, trees benefit from land preparation, weeding and other management operations executed for annual crops. Cropping is discontinued when tree roots and canopy are fully developed and no longer permit economic yields. During the tree phase, which may last for 2-4 years, the trees could be managed as fodder banks (Ramadhani *et al*., 2002).

Some studies in developing countries have stressed a scarcity of fuelwood as one of the key factors to motivate farmers in adopting rotational woodlot technology (Nyadzi *et al*., 2003; Jacovelli and Caevalho, 1999). As long as fuel wood could be collected without paying for it, farmers had little incentive to plant fuelwood producing trees (FAO, 2003). Several scholar, however, reported that high fuel wood demand

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stimulate tree production that this is only the case when there is a fuel wood crisis. Thus, the high cost of fuel wood may motivate farmers to establish woodlots (Yin and Hyde, 2000).

Past studies (Masangano, 1996; Omuregbee, 1998) have identified some of the farmers' characteristics that may influence adoption of agroforestry technologies including age of the household head, education level of family head, gender, wealth, family size, group membership and farm resources such as farm size, land tenure, credit, or other inputs and availability of labor. Farmers' adoption behavior, especially in low income countries is influenced by a complex set of socioeconomic, demographic, technical, institutional and bio-physical factors (Masangano, 1996).

MATERIALS AND METHODS

Description of study site: The study was conducted in Kigorobya sub-county, Hoima district in western Uganda (1°00'N - 2°00' N, 30°30'E - 31°45' E) between July and September 2005. The district is at an altitude of over 600 m above sea level and it covers a total area of 59327 Km^2. The climate is characterized with small variations in temperature and humidity throughout the year. Mean annual rainfall ranges from 700-1000 mm, most of which is received between October and April. Mean annual temperature is approximately 28°C with a range of 15-32°C. Vegetation is very varied ranging from medium altitude moist forests through forest/savannah mosaic, swamp to post cultivation communities. The soils are mainly yellowish-red clay loams on sedimentary beds and they occupy parts of Bugahya and Buhaguzi counties. There is a high human density of approximately 246 persons km^{-2} and the growth rate is 2.3%. Subsistence agriculture is the major economic activity employing about 84% of population (UBOS, 2002). The bulk of agricultural production is from manually cultivated rainfed crops such as tobacco, cotton, sugarcane and food crops.

The study region is economically backward with a subsistence agronomic economy. There exists well documented secondary data on farmers that had adopted the woodlot technology and an informed assessment by key informants on the extent of adoption of rotational woodlot technology in each village.

Survey: Data for the study were collected through a cross sectional farm-level survey by means of a structured questionnaire administered to 120 farmers supplemented with focused group discussions to determine the profile of farmers' socio-economic variables and farm characteristics. The survey was done in two stages. In the first stage, focused group discussions were used to obtain background information on the adoption of rotational woodlot technology. This information was used to design a structured questionnaire administered to respondents during the second stage of the survey. Selection of the survey villages was accomplished through a stratified random sampling procedure. A complete list of villages where rotational woodlot technology has been previously introduced was available.

Sample villages were selected based on the number of years of farmer exposure to woodlot technology, number of farmers exposed to woodlot technology and an informed assessment by key informants on the extent of adoption of rotational woodlot technology in each village. From each selected villages, lists were developed of all farmers who had been exposed to woodlot technology and of those without such knowledge. A random sample of farmers was taken from each of the two groups of farmers.

Descriptive statistics were used to describe the farmers' socio-economic characteristics, while simultaneous equation logistic models were employed to estimate the intensity of adoption (Maddala, 1983; Moris and Adelman, 1988; Greene, 2000). A series of explanatory variables included: gender of farmer, farmer education, family size, memberships to farmers' organization, contact with extension agency, tree tenure security, fuel wood scarcity index, supply of planting materials, household source of income and size of landholding. Descriptive statistics for all the variables in the empirical model are given in Table 1.

Analytical model: A two-stage regression approach was adopted. In the first stage, a discrete variable logit assessment of the choice to adopt or not was carried out. In this case, a 100% sample was included in the model because it is a reasonable first choice for any farmer. The choice of the farmer to adopt woodlot technology or not can be framed as binary-choice models which assume that individuals are faced with a choice between two alternatives and the choice depends on identifiable characteristics. Let T_i represent a dichotomous variable that equals 1 if the farmer adopted woodlot technology over the last year and 0 if no adoption occurred.

The probability of adopting choice, $Pr(T_i = 1)$, is cumulative density function F evaluated at $X_i\beta$, where X_i is a vector of explanatory variables and β is a vector of unknown parameter (Maddala, 1983). This kind of cumulative density function can be modeled using logistic probability function, which has the following form:

$$\begin{array}{c}\text{Choice to adopt}\\ \text{rotational woodlot}\end{array} = \Pr(Ti = 1) = \frac{\exp(x_i\beta)}{1+\exp(x_i\beta)}$$

Table 1: Farm household socioeconomic characteristics in the study area

Variable	Percentage
Percentage of sample farmers (120) that adopter woodlot technology	72
Farmers age	
<18	43
19-29	23
30-39	62
≥40	51
Education per family in schooling year	
0	21
<5	64
≥6	15
Mean	03
Size of household members	
1-4	20
5-7	40
8-10	23
≥10	17
Amount of landholding	
<1ha	32
1-2	32
2.1-5	22
≥5	14
Mean	2.4 ha
Source of family income	
Agriculture	57
Non-agriculture	43
Sources of information about woodlot technology	
NAADS	40
NGO	23
Self experimentation	02
Farmer to farmer	33
Other sources	02
Farmers aware of forestry extension activities	
Aware	27
Not aware	73

The Statistical Package for Social Scientists (SPSS VER. 11) program for Windows was used for the analysis. The estimated model was:

$$\begin{aligned} WOOD = & b_0 + b_1(GND) + b_2(HSIZ) + b_3(EDUC) + \\ & b_4(EXT) + b_5(EROS) + b_6(FINC) + \\ & b_7(FWD) + b_8(TENUR) + b_9(ORG) + \\ & b_{10}(LND) + b_{11}(SEED) \end{aligned} \quad (2)$$

The qualitative dependent variable is woodlot technology (WOOD), which takes on the value of 1 if the farmer adopted woodlot technology and its variants and 0 if no adoption occurred. Explanatory variables and justification are discussed below.

Gender (GND) is a dummy variable that indexes the gender of the farmer, it has a value of 1 for men and 0 for women. It was hypothesized that GND is negatively related to adoption of rotational woodlot technology.

Size of household (HSIZ) measures the number of people living in the household. It is expected that the larger the number of members in the household the greater will be the availability of family labor for woodlot establishment and management.

Farmer Education (EDUC) measures the level of education of the farmer. It takes the value 1, if no formal education; 2, if completed primarily level; 3, if completed secondary level and 4 if University graduate. Education thus is expected to have a positive effect on the decision to adopt woodlot technology.

Contact with Extension (EXT) measures the contact of farmers with research and development or extension agencies that work on woodlot technology. Agricultural extension services are a key variable in developing a favorable attitude among farmers towards woodlot technology. It takes the value of 1 if the farmer had contacts with such agencies and 0, otherwise. It was hypothesized that EXT positively influenced decision to establish woodlot of the farm field.

Source of Income (FINC) measures the farmer's main source of income and it takes the value 1, If the main source is agriculture and 0 if otherwise. Studies have shown that agriculture as the main source of income has negative impacts on adoption of new agroforestry technologies (Adesina *et al*., 2000; Nyirenda *et al*., 2001).

Fuelwood scarcity (FWD) indexes the extent of wood scarcity in the village where the farmer is located. It takes the value of 1, if fuel wood is abundant in the village; 2, if scarce and 3, if very scarce. It is hypothesized that as the extent of fuel wood scarcity intensifies, farmers may have greater incentives to adopt woodlot technology.

Soil Erosion level (EROS) measures the extent of soil erosion in the village where the farmer is located. It takes on the value of 1, if no erosion problem at all; 2, if it is a minor problem and 3, if it is a severe problem.

Tree Tenure security (TENUR) indexes the security of tree rights on the private farm. It takes the value 1 if farmer has secure tenure rights and 0 otherwise. TENUR is positively related to adoption of woodlot technology. It is expected that if farmers have a complete bundle of rights, the likelihood of adopting rotational woodlot technology will increase.

Membership to farmer Organization (ORG) indicates if the farmer is a member of farmers' association. Membership to farmers' organization was hypothesized to positively influence the adoption of woodlot technology. Farmers that join farmer associations may be those generally more receptive to new innovations or interventions in the community which may affect their attitude to the adoption of new technologies.

Size of Landholding (LND) is a dummy variable, which indexes whether the farmer has sufficient land. It takes the value of 1 if yes and 0 otherwise. It is expected that farmers owning big portions of land may face less pressure to establish woodlots on their own farms and this may negatively affect adoption of woodlot technology.

Supply of planting material (SEED) measures the extent of availability of planting materials in the village. The seed supply takes the value 4, if National Tree Seed Center is the major source of planting materials; 3, if own farm and 2, if from open market and 1 if it is from other sources.

RESULTS

Field survey results: The results presented in Table 1 show that average size of landholding in the area is 2.4 ha of land. Approximately 64% of the households own less than 2 ha and only 14% of the remaining households own over 5 ha of land. Thus, a considerable number of farmers possessed a very limited amount of farm land to be used for production of household food and fuel wood. The median size of household members was 8 persons. Agriculture was the main source of income for approximately 57% of the households. Forty percent of the farmers reported that they obtained technical information on rotational woodlot technology from the National Agricultural Advisory Services (NAADS) (40%) and non-government organizations (23%) in the area. Only 27% of the farmers were aware of the activities of the forestry extension programs. About 48% of the respondents mentioned natural regeneration as their source of seedlings and few farmers (4%) acquired planting materials from the National Tree Seed Centre (NTSC). The soil erosion index was rated high (60%) and therefore many farmers planted trees on their private farm fields. All respondents (99%) rely on biomass as a source of energy. Due to the general poverty in the rural areas, only 1% of the households can afford to purchase the commercial fuels such as electricity and petroleum products.

Empirical model: Binary logit coefficients (Table 1) showed that seven explanatory variables were significant in explaining farmers' adoption of rotational woodlot technology. These were: tree Tenure security (TENUR), Seed supply (SEED), contact with Extension and research agencies (EXT), soil Erosion index (EROS), size of landholding (LND), Fuel Wood scarcity index (FWD), main source of Family Income (FINC) and Gender of the farmer (GND).

Table 2: Socio-economic and bio-physical field conditions

Variable	Percentage
Source of seeds and planting materials	
National Tree Seed Centre	4
Natural regeneration	48
Market	16
Own nursery	12
Other farms	20
Location of trees on farm	
Homegarden	27
Crop land	7
Home compound	50
Boundaries	4
Woodlots	8
Roadside	3
Public land	1
Source of energy	
Firewood	93
Charcoal	3
Agricultural residues	3
Commercial fuels	1
Distance in hours	
<1 h (including on farm sources)	80
1-3 h	18
>3 h	2
Soil erosion index	
High	59
Low	40
Reasons for adopting rotational woodlot technology	
Domestic consumption (Fuel wood, construction materials, food) supply	68
Source of household income	54
Social and financial safe net	38
Soil conservation and protection of ecological balance	42
Wind breaker	18
Biodiversity and wildlife habitat	5
Ornamental	4
Others	2
Constraints to establishment of woodlots	
Seedling supply	20
Lack of technical knowledge	21
Land scarcity	23
Land and tree tenure	9
Culture and traditions constraints	1
Lack labor and capital	10
Lack of interest	3
Others e.g diseases, competition with food crops	11

1 US$ = 1880 shillings (in 2005)

DISCUSSION

The study revealed that farmers' adoption of rotational woodlot technology is influenced by the interacting farm household socio-economic characteristics such as gender of farmer, contact with extension and research agencies, soil erosion index, tree tenure security, seed supply, size of landholding, fuel wood scarcity index and main source of family income.

Gender of the farmer was found significant and positively related to adoption of woodlot technology. This suggests that men are more likely to establish woodlots on their fields than women. Some studies have argued that because rotational woodlot farming is primarily a tree-based technology women may be less likely to adopt it because of either lack of rights to grow trees or secure land rights (Adesina *et al.*, 2000; Fabiyi *et al.*, 1991). The men are more likely to adopt woodlot technology than women. This result may reflect the traditional bias against women in inheriting lands or having secure land or tree rights, or the inherent gender-bias in testing and demonstration of the technology. Other studies have found that female farmers are less likely to use new technologies (Masangano, 1996). Our field observations revealed that limitation of women to decision making process and participation in forestry related matters further reinforces their limited access to forest resources.

The dissemination of information through farmers' contact with extension and research agencies can influence the adoption of new agroforestry technologies (Adesina *et al*., 2002; Salama *et al*., 2000; Nyirenda *et al*., 2001). The contribution of NAADS to encourage farmers establish woodlots, has been poor and only 23% of the farmers access NAADS (Table 2). Thus, more widespread knowledge of the activities of the forestry extension programs could have a positive impact on farmers' decision to manage woodlots on their farm fields.

Contact with extension was significant at 5% level and positively related to adoption. This suggests that farmers with contact with extension and research agencies have greater likelihood of adopting woodlot farming. Our study supports the findings of Adesina *et al*. (2000), Alavalapati *et al*. (1995) and Masangano (1996), that adoption of any innovation, technology or agricultural practice will be accelerated if farmers have an accurate understanding of the principles underpinning extension recommendations. At the policy level, this implies that improving the quality of the NAADs system is of paramount importance in Uganda. The farmer's contact with the extension staff is still more important in this study area. The uptake of new technologies is often influenced the farmer's contact with extension services.

For sustainability of adoption of woodlot technology, sustainable supply of planting materials in form of seeds and seedlings is one of the pre-requisites. The majority of farmers interviewed depend on natural regeneration (48%) and open market as sources of planting materials (Table 2). Currently, the NTSC is not popular among farmers and only 4% of the farmers interviewed obtained seeds from NTSC. Farmer preferred to collect seedlings from own superior trees (12%) or from neighbors within the village. These results concur with those of Nyadzi *et al*. (2003), who reported that rotational woodlot technology depends on reliable supply of quality planting materials.

The positive and significant sign on FWD implied that farmers in villages facing increasing fuelwood scarcities were more likely to adopt woodlot technology. Adesina ***et al.*** (2000), found that most of the fuel wood consumed by the farm households in forest margins of southwest Cameroon come from their food crop fields. Incidentally, its within food crop fields that farmers establish woodlots. Woody perennial trees used in woodlots can further help farmers to increase the supply of fuel wood from their food crop fields (Buyinza and Nabalegwa, 2006). Since, farmers in villages with fuel wood scarcity were found to have higher likelihood of establishing woodlots, development efforts should target such villages, provided the level of fuel wood scarcity is not very serious. If it were, wood lots would be more appropriate in these areas. Tree farming requires that farmers set aside a part of their land for growing trees, the cultivatable area under food crops have to be reduced.

There was a negative relationship between the size of landholding and adoption of woodlot technology. The farmers that have big landholdings are less likely to adopt woodlot farming. Farmers in villages where land is scarce are less likely to adopt woodlot farming because they fear trees might compete with the food crops. Wood fuel accounts for about 90% of energy used in Uganda (Falkenberg and Sepp, 1999). Growing trees as woodlots on farms in rotation with crops is considered a potential technology to overcome the shortage of wood, which is a common problem to many parts of Uganda (Jacovelli and Caevalho, 1999).

There was a negative relationship between the size of landholding and adoption of woodlot technology. The farmers that have enough land are less likely to try out woodlot farming. Because woodlot farming requires that farmers set aside a part of their land for growing trees, the cultivable area under food crops have to be reduced. Farmers with smaller plots of land may view tree planting as competing with food crops, thus reducing incentives to establish woodlots. Nyadzi *et al*., (2003) and Buyinza and Nabalegwa (2007) reported that farmers in villages facing high land pressure may lack enough land for experimentation with agroforestry technologies. Since land availability is an important factor that determines development of each of the components in the woodlot farming system, variation in the size of holding affects the tree cropping intensity.

Agriculture as a main source of income had a negative influence on farmers woodlot management decisions (Table 2). The relationship was statistically significant at 5%. This provides some confirmation of the earlier assumption that agriculture, even in case that is the main source of family income, tends to discourage farmers from planting woodlots on their farm fields. Farmers motivated to plant trees are faced with a shortage of available labor food crop production (Adesina *et al*., 2000). Thus, farmers whose main source of income is agriculture might be discouraged to allocate family labor for woodlots activities. About 10% of the farmers reported that a shortage of labor and capital to allocate for woodlot activities was a constraint to woodlot practices (Table 3).

Table 3: Binary logit model of the household characteristics influencing adoption of rotational woodlot technology in the study area

Variable	Coefficient estimate	Standard error	p-value
Constant	-9.869	3.855	0.0143
GND	1.258	1.137	0.0926*
EDUC	0.548	0.139	0.3706
HSIZ	-0.097	0.304	0.7503
EXT	2.811	1.143	0.0139**
EROS	-0.102	0.051	0.0442**
FINC	-0.442	0.197	0.0202**
FWD	-1.954	0.567	0.0006***
TENUR	2.886	0.875	0.0009***
ORG	7.071	9.466	0.4552
LND	-0.435	0.186	0.0242**
SEED	2.07	0.802	0.0011***

Unrestricted Log likelihood function - 36.60; Restricted Log likelihood Function (-57.6); Degrees of freedom 45; Significance level (0.01) McFadden's R^2 = 0.36; Chi Squared (42.02). The asterixes: *, **, *** refer to significance at p = 10, 5 and 1%, respectively

The survey results showed that fuelwood supply was negatively related with farmers planting of woodlot decisions and the relationship was statistically significant at 1% (p= 0.0006). Wood is the dominant domestic fuel for rural people in Africa (FAO, 2003). Trees provide at least 96% of the energy requirements in the study village (Table 2). In Uganda, biomass fuel is the principal energy source for household needs and about 52% of the biomass fuel comes from trees. Uganda is facing increasing fuel wood shortages.

The data on the reasons for and constraints on, adoption of rotational woodlot technology are presented in Table 2. The farmers adopted woodlot technology mainly to provide for domestic consumption requirements such as firewood, construction materials (68%) and source of household income (54%). About 42% of the farmers interviewed reported that they had established woodlots as a financial security measure during declining revenues from the current marketable food crops. Many studies have shown that fuel wood demand is an important factor in the inducement to plant trees (Salama *et al*., 2000).

CONCLUSION

The results of the study showed that the factors that are household and farm-level characteristics such as gender, size of landholding, fuel wood scarcity, main source of family income, tree tenure security, reliable seed supply, contact with extension and research agencies and soil erosion index of village impact on the adoption of rotational woodlot technology.

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