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Predictors of Agroforestry Technology Adoption and Land Conservation Strategies in the Highlands of South Western, Uganda

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Abstract: Soil erosion is a major agricultural and environmental problem in the highlands of Southwest Uganda. Agroforestry technologies have been developed as one way of solving the problem. Understanding the factors that influence farmers' adoption of agroforestry technologies is critical to the success of implementing land conservation efforts. However, information about the socio-economic factors that influence the adoption of these technologies is still scanty. A study was conducted in Muko and Bubare sub-county, Kabale district between November 2002 and July 2003, to investigate the socio-economic factors that influence the adoption of agroforestry technologies and land conservation strategies in the highlands of South Western Uganda. Semi-structured questionnaires were used to collect data from 60 households selected using a systematic purposive sampling procedure. Based on the logistic regression analysis, the factors that influence the adoption of agroforestry technologies are: farmer's age, education level, extension contact, size of family laborforce and gender of the household head. Sources of income, access to credit and membership to farmer organization had non-significant coefficients and therefore, did not explain adoption decisions. Furthermore, farmers have adopted different structural measures such as terraced farming, construction of waterways, check dams, retention walls and gull control. Similarly, they have adopted biological measures including alley cropping, bamboo plantation in gullies, mulching and use of organic and inorganic fertilizers to control land degradation.

Key words: Farmers, household characteristics, land degradation, land conservation, soil erosion

INTRODUCTION

Soil erosion is a major agent for land productivity declines as well as environmental degradation world-wide (Olderman *et al.*, 1990). Perhaps, the greatest victim is Africa where the problem is evidently severe but has not been adequately researched to provide realistic interventions. High soil erosion rates in the range of 10-500 t/ha/year have been reported in various parts of Africa (Finn, 1983; Lal, 1995). These rates, coupled with the spiraling human population growth in the continent (UNDP, 2000), cast a bleak future in terms of food security and sustainable environment management.

Depletion of soil fertility is widely accepted to be the most widespread serious biophysical constraint on food security in sub-Saharan Africa (Olderman *et al.*, 1990). Most soils in sub-Saharan Africa are >500 millions years and are in their final stage of weathering. These soils are inherently depleted and require good management of frequent moderate amounts of organic and inorganic inputs (Lal, 1995).

In response to the problem, a number of soil conservation and fertility replenishment measures have been developed and promoted in Uganda, including agroforestry technologies (Sanchez and Jama, 2002). For instance, in the highlands of Southwestern Uganda, households have planted leucaena (*Leucaena leucocephala* and *L. diversifolia)*, calliandra (*Calliandra calothyrsus*), sesbania (*Sesbania sesban*), desmondium (*Desmondium uncinantum*), mulberry (*Morus alba*), grevillea (*Grevillea robusta*), *Pennisetum purpureum* (napier), mexican lilac (*Griricidia speium*) and tephrosia (*Tephrosia candida*) on terrace risers, edges of farmlands and fallowlands (Nabalegwa *et al.*, 2007).

While, severe soil erosion and landslide have affected mainly upland-crop terraces, soil nutrient depletion has been a problem on virtually all types of lands in Uganda (Nabalegwa *et al.*, 2007). The problem is relatively less severe in areas where soil conservation measures have been promoted (Finn, 1983). Possessing only small landholdings, most farmers in South Western Uganda have been vulnerable to subsistence food supply

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due to steadily decreasing soil fertility caused by the combined effects of soil erosion, landslide and soil nutrient depletion (Nadhomi *et al*., 2006). Therefore, these problems need to be addressed as soon as possible. As suggested by Lal (1995) and Bekunda and Manzi (2003), effective control of particularly landslide and soil erosion in the highlands of Uganda requires replacement of the on-going arable agriculture by non-arable agriculture, which does not require regular hoeing and plowing of land. However, confronted with problems of small landholdings and scarce non-farming employment opportunities, farmers need to produce maximum possible amount of crops in order to fulfill their family demand for food. Therefore, land conservation programs should aim to facilitate a gradual change in the agricultural systems (Carswell, 2002), which would mitigate adverse impacts of arable agriculture as well as allow gradual inclusion of non-arable land use practices (Boffa *et al*., 2005).

Farmers of the highland areas of Southwestern Uganda use their land resources efficiently for growing different crops for their livelihood. Integrated nutrients management system is used for the crop production. The important practices adopted by the farmers for maintaining soil fertility and sustaining crop productivity are compost application, chemical fertilizers, inclusion of grain legumes in the crop rotation, mulching, short fallows, slicing and incorporation of weeds, in-situ manure and green manure (Nadhomi *et al*., 2006). Despite farmland being the major sources of highland people's livelihood, little attention has been paid to the socio-economic factors that influence the adoption of different land conservation strategies by the local communities (Ellis-Jones and Tengberg, 2000). Most studies carried out resources in the highland of Uganda have focused on the ecological and technical impacts of land degradation (Carswell, 2002).

Previous researches conducted in Uganda have primarily focused on the biophysical aspects of land conservation strategies with little attention to socio-economic factors that affect the adoption of agroforestry and land conservation strategies in general (Nabalegwa *et al*., 2007; Briggs and Twomlow, 2002; Bagoora, 1988). The objective of this study was to investigate the socio-economic factors that influence the adoption of agroforestry technologies and land conservation strategies in the highlands of South Western Uganda.

Model specification and description: Adoption of agroforestry technology was conceptualised as a function of farmers characteristics. The decision to adopt agroforestry technologies is a behavioural response arising from a set of alternatives and constraints facing the decision maker as shown by Leagans (Masangano, 1996) in the Behavioural Differential Model. In the model, the dependent variable, adoption of agroforestry technology, is dichotomised by assigning a value of one if the farmer is an adopter and zero otherwise. Given that the dependent variable is dichotomous, the regression is non-linear in nature and ordinary least squares will not provide useful estimators. Instead, a dichotomous logistic model technique was used to regress adoption on asset of explanatory variables.

MATERIALS AND METHODS

The study was carried out in Kabale district, located in the Kigezi highlands of Southwest Uganda, bordering with Rwanda. The district lies between latitudes 1°45'-1°30'S and longitudes 29°18'-30°50'E. The area has a bi-modal rainfall distribution with annual mean rainfall ranging from 1000-1500 mm (Wortmann and Eledu, 1999). The topography is extremely rugged, consisting of narrow steep convex slopes (10-35°) and gentle (5-10°) slopes (Bagoora, 1988). Annual temperatures range from a minimum of 10-12°C, to a maximum of 20-24°C. The soils are typically andosols, humic, dystric, entric, nitosols and ferralsols with declining fertility due to continuous cultivation (Wortmann and Eledu, 1999). The area is densely populated with an average of 840 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 rain fed crops. The intercropped range of rainfed crops vary with greater potentials for maize, banana, beans, cassava and sweet potatoes.

The study was based on a detailed household survey conducted in sub-counties of Muko and Bubare in the north-western part of Kabale between November 2002 and July 2003. These sub-counties were selected as study sites because they are belong to the AFRI-CARE Agroforestry development area. AFRI-CARE International promotes the use of agroforestry practices as an integral component of their farming systems, however, little is known about their rates of adoption. A systematic purposive sampling method was adopted to select 60 households for the questionnaire survey. A structured questionnaire was administered during the survey to obtain information on the socio-economic variables that influenced adoption of agroforestry and land conservation strategies, namely, age of the household head, education level, extension contact, size of family laborforce, gender, sources of income, credit and farmer group membership to organization) and agronomic practices in the area.

Table 1: Explanatory variables used in the logit analysis for adoption of agroforestry technology in Kable district, Uganda

Variables	Variables definition
AGE	Age of household head (1 if ≥30 years old; 0 otherwise)
GND	Sex of head of household (Female = 0, Male = 1)
EDUC	Education level of household head (1 If ≥6 years of schooling, 0 otherwise)
MBR	Membership to organization (1 if household scored ≥4; 0 otherwise)
FLBR	Number of productive family labourforce (persons)
INCOM	On and off farm income generating activities (1 If household scored ≥10 points; 0 otherwise)
CRDT	Access to credit (1 if household got credit from microfinance institution; 0 otherwise)
EXT	Contact with extension staff (1 if household scored 5; 0 otherwise)

The main limitation of the questionnaire survey was that it could not obtain all information required for the causal analysis of land resource management problems. In view of limitations of the questionnaire survey, detailed information on land management practices adopted by farmers and their experience on landslide, soil erosion, soil fertility and crop yield trend was collected through group discussions held with farmers. Special attention was paid to location specific characteristics of farm-plots undergoing degradation, its causes and land management practices adopted by farmers to control land degradation.

This study relied on information provided by farmers on the basis of their memory recall, as farmers do not keep record of agricultural inputs and outputs. Despite not being able to quantify the severity of degradation, the subjective information provided from years of experience was as valid as information generated through formal research and therefore, very useful for formulating land management strategies and policies.

With regard to land conservation strategies, the degree of adoption was rated based on percentage of farmers adopting particular land management practice. The percentage of farmers adopting a particular land management practice was rated as high (>80%), medium (40-80%), low (20-40%) and poor (<20%). Adoption of land conservation strategies, however, varied from one farm household to another, depending on their socio-economic condition, bio-physical characteristics of lands and institutional support services provided.

The socio-economic factors influencing the adoption of agroforestry technology and land conservation strategies were analysed using maximum likelihood estimation of a logistic regression model. Using a logistic regression analysis technique the differences between adopters and non-adopters in terms of their age, gender and other socio-economic characteristics were investigated. Stepwise regression analysis was applied to find out the factors influencing the adoption of land conservation strategies. The details of cut off values used in transforming variables into binary form are shown in Table 1. Descriptive statistics were used to describe the farmers' socio-economic characteristics, while logistic models were used to estimate the intensity of adoption. Primary data collected were analyzed using Statistical Package for Social Sciences (SPSS ver. 11.0) and simple descriptive statistics such as frequencies, means and cross tabulations were performed to establish the socio-economic profile of the area under study.

RESULTS

Demographic and household socio-economic characteristics: Seventy two percent the farmers had adopted the agroforestry technology. The average size of landholding is 2.4 ha. Sixty four percent of the households own <2 ha and only 14% of the remaining households own over 5 ha of land. The mean household size is 6.2 members. The household economy and employment were dominated by agriculture, thus agriculture provides livelihood to approximately 57% of the households. The majority of the adopters were young in age compared to non-adopters (Table 2). The male heads had more extension contact compared to the female heads. Adopters and female heads had more productive labourforce than non-adopters. The female household heads had attained less education levels than their male counterparts. On average non-adopters' scored higher with regard to membership to farmer organizations than adopters.

Econometric model estimations: The results of the empirical model are shown in Table 3. The Logit model was significant at 5% level. The model correctly predicted 73% of both adopters and non-adopters. Correctly, predicting adopters 89% and non-adopters 44%. Four variables were significant in explaining the adoption of agroforestry technologies: farmer's age (AGE), contact with extension agencies (EXT), farmer's sex (GND), education level (EDUC) and size of productive family labourforce (FLBR). Whereas membership to an organization (MBR), access to credit (CDRT) and sources of income (INCOM) were not significant.

From the coefficients with all the variables in this study, gender (GND) was clearly the most important. The second most important factor was the farmers' age (AGE), with coefficient of -2.01 indicating that a younger farmer had a 50% higher probability of adopting the technology than an older farmer. Farmers' age is negatively related to

Table 2: Demographic and socio-economic characteristics of adopter and non-adopters of agroforestry technologies, Kabale district, Uganda

Variables	Sample (n = 60)	Adopters (n = 30)	Non-adopters (n = 30)	Male (n = 30)	Female (n = 30)
Farmer' age	48.32±12.74	46.11±12.52	50.80±11.50	52.2±13.40	45.2±10.55
Education level	3.7±2.3	3.92±2.33	2.50±3.20	3.52±3.41	2.50±3.20
Farmer organization	2.43±1.32	2.03±1.45	2.62±1.38	2.04±1.27	2.62±1.38
Contact with extension	3.57±2.49	4.65±2.24	2.33±2.00	4.01±2.58	2.33±2.00
Sources of income	11.04±3.60	11.72±3.06	12.00±1.75	12.3±2.45	11.4±2.24
Size of household	3.22±1.64	4.22±1.89	3.66±1.68	3.66±1.68	2.66±1.68

Table 3: Logistic regression model for the adoption of agroforestry technology, Kabale district, Uganda

Variables	Coefficient estimate (B)	SE	t-ratio	Marginal effect
Constant	-0.24	1.22	-0.24	-
AGE	-2.01	1.11	-2.02**	-0.04
GND	-2.21	1.06	-2.15**	-0.05
EDUC	2.81	1.14	2.43**	0.11
MBR	-0.54	0.84	-0.56	0.18
EXT	3.31	1.37	2.49***	0.01
INCOM	-0.72	0.69	-1.06	-0.12
FLBR	1.68	0.51	2.32***	0.02
CRDT	52.80	23.10	1.40	0.17

Maddala R^2 0.32; McFadden R^2 0.29; Chow R^2 0.32; LHT test 18.89 (7 df); Right prediction (37) 75%. Symbols: * = 10% (p = 0.1), ** = 5% (p = 0.05), *** = 1% (p = 0.01) significance level, respectively; overall cases correctly predicted (%) 72.95; correctly predicted adopters (%) 88.69; correctly predicted non-adopters (%) 43.87; sample size 60

adoption of agroforestry technologies ($p<0.05$). There was a positive coefficient of EXT toward the adoption of agroforestry technologies. The probability of adopting agroforestry increased by 2% with greater extension contact. More adopters (72%) than non-adopters (76%) had access to extension. Similarly, the education level of household head (EDUC) had a positive impact on agroforestry adoption. There was significant relationship between family productive labourforce (FLBR) and the adoption of agroforestry ($p<0.001$). When, FLBR increased by 1 unit, there was an increase of 2% in the probability that the household adopted the agroforestry technology. The explanatory variables INCOM, CDRT and MBR were not statistically significant.

Adoption of land conservation strategies: The common land management treatments involved different structural, biological and use of artificial fertilizers to mitigate against the negative effect of land degradation (Table 4).

Fertilizer adoption: Factors that influence fertilizer use were analysed by estimating a linear model since the dependent variable is quantitative (kg/fertilizer/ha) and almost all farmers use fertilizers (Table 5). Two models are estimated: the first model uses total fertilizer use expressed (kg ha^{-1}). The second model uses total phosphorous (kg ha^{-1}). Two models are estimated: the first model uses total fertilizer use expressed (kg ha^{-1}). The second model uses total phosphorous (kg ha^{-1}). Only three factors, labour hire, credit and education of

Table 4: Adoption of land conservation strategies by farmer in Bubare and Muko sub-county

Land conservation strategies	Sub-county (rating) Bubare	Muko
Structural		
Terraced farming	High	High
Waterways	High	High
Gully control	Low	Poor
Retention walls	Low	Poor
Check dams	Poor	Poor
Biological		
Alley cropping	Low	Poor
Tree plantation along escarpments	High	High
Vegetative measures for landslide control	High	Medium
Mulching	Medium	Low
Application of fertilizers		
Farmyard manure	High	High
Compost	Poor	Low
Green manure	Low	Poor
Legume cultivation	Low	Low
Chemical fertilizer	High	Medium

household head had a significant effect on the quantity of fertilizer used. Hiring of labour increased the amount of fertilizer used by 43 kg ha^{-1}, while using credit increased it by 58 kg ha^{-1}. The education level of the household head had a negative impact whereby for each additional year of formal schooling, fertilizer use decreased by 8 kg.

The second model uses the amount of phosphorous per hectare. Labour hire is significant and increases phosphrous use per hectare by 5 kg, however credit access is not significant. Education level of the farm is significant and for each additional year of schooling increases P use by 3 kg. Farmer's age is also significant and increases P use by 0.48 kg for each year.

Soil erosion: The area undergoing severe soil erosion is assessed from farmers' experience. According to four fifths of surveyed farmers, soil erosion is a common phenomenon in both sub-counties. Upland-crop terraces and homesteads are mainly affected by serious erosion. Nearly, half of the upland-crop terraces in Muko and two-fifths in Bubare are undergoing severe soil erosion (Table 6).

Landslide: Farmlands in both Bubare and Muko sub-counties are affected by landslides, though their density and size vary from one type of land to another. Density of landslides in all types of lands, except on hill-slope terraces, was significantly high ($p\leq 0.05$) in Muko sub-

Table 5: Linear regression model for fertilizer use

Explanatory variables	Total fertilizer ($kg\ ha^{-1}$) Coefficient estimate (B)	SE	P ($kg\ ha^{-1}$) Coefficient estimate (B)	SE
Age household head (year)	-1.500	0.92	0.48	0.3*
Education level (year)	- 8.200	3.90**	2.60	1.4**
Gender (0 = female, 1 = male)	10.300	40.20	4.50	13.1
Farm manure (1 = yes, 0 = no	-44.800	34.70	1.60	10.7
Labour hire (1 = yes, 0 = no)	42.600	24.20**	5.20	7.2**
Extension contact (1 = yes, 0 = no)	-1.600	25.70	5.54	8.2
Credit access (1 = yes, 0 = no)	58.100	23.90*	0.70	7.6
Member to farmer organization (1 = yes, 0 = no)	-39.100	43.40	10.80	13.4
Landholding size (acre)	-1.500	3.88	0.65	1.4
R	0.412		0.15	
Sample size (no.)	60.000		60.00	

NB: Dependent variable is total fertilizer use ($kg\ ha^{-1}$) and phosphorus ($kg\ ha^{-1}$). Symbols * = 10% (p = 0.1), ** = 5% (p = 0.05), *** = 1% (p = 0.01) significance level, respectively

Table 6: Farmlands affected by soil erosion in Bubare and Muko sub-counties

	Bubare sub-county			Muko sub-county		
Land types	Surveyed area (ha)	Farmlands seriously affected	Percent of total farmlands seriously affected	Surveyed area (ha)	Farmlands seriously affected	Percent of total farmlands seriouslyaffected
Valley-land	10.6	0.8	8.0	28.2	2.8	10.0
Hill-slope land	66.0	10.6	16.0	47.5	7.6	16.0
Upland-crop terraces	8.3	3.3	40.0	17.3	8.3	48.0
Homesteads	15.7	3.1	20.0	15.0	4.1	27.0
Total	100.6	18.0	18.0	108.0	22.8	21.0

Table 7: Farmlands affected by landslides in 2002 (NEMA, 2001)

	Bubare sub-county				Muko sub-county			
Variables	Valley land	Hill slope land	Upland crop terraces	Home steads	Valley land	Hill slope land	Upland crop terraces	Home steads
Surveyed area (ha)	11	67	8	16	28.2	48	18	17
Number of landslides	92	755	149	24	35	654	186	132
Density (No. ha^{-1})	10*	11*	18*	14*	1*	14*	11*	10*
Land affected by landslides (%)	14	6	35	18	5	8	37	14
Labor spent on landslide repair (work-day ha^{-1})	4*	11*	21*	14	2.0*	17*	16*	12

NB: *Significantly different at 0.05 confidence level (t-test, $p \leq 0.05$)

county. Most landslides in both sub-counties are small, ranging from 2-150 m^2 with an average size of 10 m^2. About one-third of lands in Bubare sub-county and slightly more than that in Muko sub-county were found affected by landslides (Table 7). Valley lands are not much affected by landslides (Bekunda and Manzi, 2003).

DISCUSSION

Econometric model estimations: The logistic regression coefficients showed that younger heads of households are more likely to adopt the agroforestry technology compared to the older farmers. This is probably because the younger households are ready to take risk relative to older households and thus likely to adopt agroforestry technologies. This finding is consistent with previous studies (Nyirenda *et al*., 2001; Adesina *et al*., 2001), which reported that adoption decreases with advanced age.

The probability of adoption was higher for men than women farmers. This is perhaps due to the gender-equity issues in the introduction of technology to farmers. We can attribute the lower agroforestry adoption by women to the fact that in the study area, women still do not have secure land and tree tenure due to the largely patrilineal inheritance systems (Buyinza and Nabalegwa, 2007). Only old women, widows and female-headed households are often able to have access to more secure land rights. Studies conducted in Malawi (Nyirenda *et al*., 2001) and Kenya (Sanchez and Jama, 2002) showed that the average female-headed household did not adopt agroforestry technology compared to the male-headed farm household. It is important to address this inequality by introducing women farmers to other technologies that do not require secure long-term land and tree rights.

The uptake of new technologies is often influenced by the farmers' contact with extension services (Nyirenda *et al*., 2001). The study supports the findings of Adesina *et al.* (2001) and Masangano (1996), who reported that adoption of any innovation, technology or agricultural practice will be accelerated if farmers have an accurate understanding of the cost-benefits accruing from the technology.

The education level of the head of house was found to be an important determinant of agroforestry adoption. Similar findings (Nyirenda *et al*., 2001; Masangano, 1996) revealed that education is positively associated with probability to adopt agroforestry technologies. They based their argument on the fact that formal and informal training has the potential to increase the rate of adoption by directly increasing awareness, imparting skills and knowledge of the new technology.

Farmer's membership to local organizations influences adoption of agroforestry technologies in that the previous farmer organizations had led to high expectations and unfortunately ended up with less impact on the farmers welfare, hence, male farmers with busy schedules were reluctant to join organizations. AFRICARE project gave most of Calliandra seeds free of charge and 60% of farmers in Bubare sub-county that adopted agroforestry technologies had benefited from the project. The research supports farmers with technical advise on the sources of quality planting materials, postharvest handling and marketing to organized groups of farmers. The size of family labourforce has a positive impact on adoption of agroforestry technology. Combining tree resources and food crops on the farm is labour demanding and families constrained with labourforce may not be able to practice agroforestry. Only labour-saving agroforestry technologies will be adopted.

Structural land conservation measures: Terraced farming is an important structural land management practice adopted by farmers in the highlands of Southwestern Uganda to control soil erosion. Regardless of land type, most terraces in both sub-counties were constructed several years ago. Some of them were however, constructed in response to ever-increasing food demand for a steadily growing household size. Farmers have reduced terrace risers to increase the area under crop production. Uncontrolled surface runoff moving down slope damages terrace risers and removes fertile soils from the farmlands, eventually aggravating crop yield and increasing the cost of terrace maintenance. Construction and maintenance of waterways was another structural measure adopted by farmers. Waterways are integral part of the terraced farming system. Uncontrolled surface runoff moving down slope damages terrace risers and removes fertile soils from the farmlands, eventually aggravating crop yield and increasing the cost of terrace maintenance (Wortmann and Kaizzi, 1998). To cope with this natural hazard, farmers in both watersheds have constructed waterways. The proportion of farmers constructing waterways is found equal and adoption rate is found high in both sub-counties.

Biological measures: Farmers in both watersheds have adopted several types of biological land management practices. Evolved over past several centuries, these practices have contributed to control land degradation at relatively low cost. Confronted with miniaturizing landholdings and dwindling forest fodder and fuel-wood supply caused by deforestation and restriction on free access to forest, farmers in both watersheds have increasingly practiced alley cropping to fulfill subsistence requirements. Planting fodder trees including palatable species like *Artocarpus lakoocha*, *Ficus auriculata*, *F. lacor*, *F. nemoralis* and shrubs on edge of terrace risers began in the early 1950s. During the 1980s large tree species were gradually replaced by nitrogen fixing, dwarf, high fodder yielding and deeply rooted shrub species, including *Calliandra calothyrsus*, *Leucaneia leucocephala* and *Tephorosia Candida*, as crop yield under the shade of tall trees declined. In Bubare sub-county, some exotic species, including *Leucaneia leucocephala* have been promoted, while in Muko sub-county mostly indigenous species are found. Overall adoption of alley cropping is low in Bubare and poor in Muko sub-county. Establishing bamboo species in deep gullies and along stream banks has been a traditional practice adopted to control soil erosion, river bank cutting and gully expansion. Bamboo species propagate rapidly and have fibrous root systems with excellent soil binding capacity. There is no variation in the adoption of this practice in both sub-counties.

Establishing bamboo species, including *Bambussa balloca*, *Bambussa spp* and *Arundinaria raccam* in deep gullies and along stream banks has been a traditional practice adopted to control soil erosion, river bank cutting and gully expansion. Bamboo species propagate rapidly and have fibrous root systems with excellent soil binding capacity. There is no variation in the adoption of this practice in both sub-counties. However, the project farmers adopted this practice in the 1970s, while the non-project farmers adopted in the 1990s after they learned from the farmers in Bubare sub-county.

Farmers were increasingly using vegetative measures for landslide control in both watersheds. Farmers in both watersheds pile 50-80 cm long logs of fast propagating tree species, including *Erythrina abyssinica, Eucalyptus sp.*, *Ficus gnaphalocarpa, Casuarina sp.* and *Markamia lutea* for the construction of terrace risers, retention walls and check dams. After few months, roots and shoots sprout out of these logs and steadily grow. Roots growing vertically and horizontally on the ground reinforce the foundations of terrace risers, retention walls and check dams. Lands affected by landslides are re-vegetated with several tree and shrub species as they facilitate speedy recovery. Farmers in both watersheds are increasingly adopting this measure, but the adoption is high in Bubare and Muko sub-county.

Farmlands in the hill slopes are vulnerable to moisture loss during the dry seasons. To prevent this, farmers with relatively large household size and small land holdings covered the tilled land with crop residues, leaves and twigs. Mulching is also practiced to prevent seedbeds from getting exposed to the sun and rain and to protect seedlings from heavy rains, which occurs almost every year (Briggs and Twomlow, 2002). Adoption of this technology is medium in Bubare and low in Muko sub-county.

There is prospect for promotion of application of several types of biological fertilizers, including legume, green manure and compost, for improving land productivity. Because of very heavy workload on household labor force, farmers are unlikely to adopt land conservation measures intensively, which require high labor input. Therefore, discussion should be held with them about problems and prospects of promotion of different types of biological fertilizers.

Use of organic and inorganic fertilizers: Farmers depend on different organic and inorganic fertilizers to improve soil fertility. The proportion of farmers using Farmyard Manure (FYM) to fertilize the land was high in both sub-counties. Farmers began to apply compost to maintain soil fertility in their farmland as the production of FYM declined gradually over the time. However, compost application is poor in Bubare sub-county and low in Muko sub-county. Confronted with declining FYM supply, a considerable proportion of farmers in Bubare started applying chemical fertilizers provided cost-free by the AFRICARE project since the late 1990s. Farmers in Muko sub-county are just starting to use chemical fertilizers in the early 2000s, as they could not receive any external assistance. Overall application of chemical fertilizer was high in Bubare and medium in Muko sub-county. Farmers also apply green manure species, namely *Calliandra calothyrsus*, *Leucaneia leucocephala* and *Tephorosia Candida*, to fertilize the farmland in both sub-counties. According to farmers, these plant species have more than double NPK content as compared to FYM. Some of these species are helpful for controlling weeds and pests. Normally, green manure is applied to vegetable seedbeds (Sanchez and Jama, 2002). However, application of green manure was low in the Bubare and poor in Muko sub-county. The need for increasing cropping intensity coupled with maintaining land fertility has increasingly attracted farmers in both sub-counties to legume cultivation, which was not a usual practice until recently.

While, increased application of FYM and compost seems to be a suitable solution for replenishing soil nutrient, it is not an easy option for farmers. Increasing the supply of these fertilizers requires increasing livestock herd size and collection of more leaf litter. Both of these are not preferred choices of farmers, as they would put additional burden on already over stressed household labor force. Farmers should also be made aware as to how the way that they keep and apply FYM lead to loss of valuable soil nutrients and as to how composting of FYM can help to improve fertility of their farmlands. In the long term, a land use strategy that would promote agricultural enterprises, including livestock raising, requiring relatively small quantities of fertilizers and contributing to control accelerated soil erosion needs to be implemented.

Soil erosion: The area undergoing severe soil erosion is assessed from farmers' experience. This type of assessment also serves as a basis for mustering strong public participation in land conservation programs. According to four fifths of surveyed farmers, soil erosion is a common phenomenon in both watersheds. Upland-crop terraces and homesteads are mainly affected by serious erosion. Nearly half of the upland-crop terraces in Muko and two-fifths in Bubare sub-county are undergoing severe soil erosion. Although based on farmers' assessment, this finding is consistence with field experiments carried out elsewhere in the highland regions of Uganda (Nadhomi *et al*, 2006). Even the hill-slope lands are not spared of erosion, although not as seriously as upland-crop terraces. Upland-crop terraces are undergoing severe soil erosion due to their outward facing slope. Farmers in Bubare were provided financial assistance to hire labor required for conversion of outward facing terraces into inward facing terraces in order to control soil erosion. Besides, a large number of waterways, check dams and gully control measures were constructed under the technical and financial assistance provided by the AFRI-CARE project. This is why considerably low percentage of upland-crop terraces in Muko sub-county is undergoing severe erosion. In Muko sub-county, where such AFRI-CARE support was not provided, the proportion of upland-crop terraces undergoing severe erosion is considerably higher.

On-going farming practices are also responsible for aggravating soil erosion. Therefore, they plough lands immediately after the harvest of crops and leave them exposed without any vegetative cover for a period of up to several weeks, depending on cropping intensity. Even hill-slope lands are not free from erosion. Normally, valley lands are puddled for transplantation of horticultural crops (Wortmann and Kaizzi, 1998). In events of heavy rainfall immediately after the horticultural crop transplantation, terraces are flooded and the loose soil is easily washed away. Particularly terraces not protected by waterways are severely affected. A normal, low intensity rainfall does not cause such problem (Briggs and Twomlow, 2002).

Even hill-slope crop lands are not free from erosion. Normally, rice lands are puddled for rice transplantation. In events of heavy rainfall immediately after the rice transplantation, terraces are flooded and the loose soil is easily washed away. Particularly terraces not protected by waterways are severely affected. A normal, low intensity rainfall does not cause such problem. Declining fertility is worst on fields far from the homesteads, where over half of the fields are suffering from declining fertility. Another study by Briggs and Twomlow (2002), which measured the impact of biomass transfer from the far to the nearby fields also found significant yield declines in the far fields. In comparison, only 27% of fields near the homestead have declining fertility. Certain crops are being particularly affected by soil degradation. The traditionally grown cowpeas are no longer producing high yields and therefore are being planted on a small scale. Similarly, Irish potatoes and beans are also affected, with beans now very susceptible to diseases (Carswell, 2002).

Livestock grazing also accelerates soil erosion particularly on hill-slope lands, which are opened for grazing immediately after the harvest of horticultural crops in November and remain so until the next crop cultivation. Regular trampling of lands by a large number of livestock leads to disintegration of soil particles and compaction of soil structure (Finn, 1983). The disintegrated soil particles are easily washed way by rainwater. Upland-crop terraces and homesteads, cultivated with two to three crops per year are not much affected by livestock grazing, as these lands are intensively utilized for crop cultivation.

While, severe soil erosion and landslide have affected mainly upland-crop terraces, soil nutrient depletion has been a problem. The problem is relatively less severe in Bubare sub-county because of soil conservation measures promoted by the AFRI-CARE project. Possessing only small landholdings, most farmers in the study area have been vulnerable to subsistence food supply due to steadily decreasing soil fertility caused by the combined effects of soil erosion, landslide and soil nutrient depletion. Therefore, these problems need to be addressed as soon as possible. As suggested Nadhomi *et al.* (2006) and Lal (1995), effective control of particularly landslide and soil erosion in the highland areas requires replacement of the on-going arable agriculture by non-arable agriculture, which does not require regular hoeing and plowing of land. Although, both sub-counties are located relatively close each other, which provides opportunity for suitable non-arable, commercial agriculture, a radical shift to this type of agriculture is not possible until the near future.

Landslides: Landslides of different magnitude, a common phenomenon in the highland of South Western Uganda, have severely affected the productivity of farmlands (Carswell, 2002). Therefore, intensity and magnitude of landslide is another indicator used to examine the status of land. Farmlands, according to local people, are highly vulnerable to landslide, especially when thunderstorms last for several hours. The rainwater percolates through the coarse texture, porous soil and reaches to the bedrock, comprising slate, eventually saturating rocks and soils and weakening their load bearing strength. Particularly in Bubare sub-county, the occurrence of landslides is accelerated by the existence of several fault-lines running across the sub-county. As a result, farmlands in Bubare sub-county are more affected by landslides compared to farmlands in Muko sub-county.

CONCLUSION

The factors that are key to the adoption of agroforestry technologies in the highlands of South western Uganda include: age of the household head, gender, extension contact and size of productive family labourforce. There is a need to consider the farmer's education level, gender, frequency of contact with extension agencies and size of family labourforce. The farmer's adoption behaviour is a function of a complex set of socio-economic, demographic, technical, institutional and bio-physical factors. The research and extension policy should now move away from its prescriptive focus of recommending pre-packaged techniques towards emphasis on effects meant to make up for low educational attainments in rural farming communities. At the policy level, improving the quality of the extension systems is of paramount importance toward the accelerated adoption of agroforestry and land conservation technologies in Uganda.

Farmers in both sub-counties are seriously concerned about the dwindling status of their land. Any negligence in land management would make them vulnerable to food security under the situation of shrinking landholding size and undergoing process of land degradation due to interactive natural and cultural factors. Farmers, therefore, have increasingly adopted different land conservation strategies to maintain the fertility of land. Increasingly they have adopted different structural and biological land conservation strategies developed by their forefathers and consolidated by line agencies and NGOs and used different organic and inorganic fertilizers to maintain soil fertility. Adoption of gulley control measures, construction of retention walls, alley cropping, use of vegetative measures for landslide control, mulching, use of green manure and chemical fertilizer are found high in Bubare sub-county compared with Muko sub-county due to the financial and technical support to project farmers, whereas use of compost is relatively high in NPV because farmers were not supported with subsidized chemical fertilizers.

The degree of adoption of land conservation strategies varies from one farmer to another, depending on several ecological, social and institutional factors. Specific factors significantly influencing adoption of land conservation strategies are extension service, farmers' tribe affiliation, agricultural labor force size, landholdings, farmers' training, education level of household head, participation in joint land management activities and landslide density in farmlands.

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