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Extension for Agroforestry Technology Adoption: Mixed Intercropping of Crotalaria (*Crotalaria grahamiana*) and Maize (*Zea mays* L.) in Kabale District, Uganda

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Abstract: Understanding the factors that influencing farmer's adoption of improved technologies is critical to success of implementing agroforestry development programs. This study, investigates the adoption of mixed inter-cropping an agroforestry tree species, crotalaria (*Crotalaria grahamiana*) and maize (*Zea mays L.*) in Kabale district, Uganda. The factors influencing the adoption of *Crotalaria grahamiana* in terms of farmer's age, productive labourforce, extension contact, income sources, gender and other socio-economic variables were examined. Results from the maximum likelihood estimation of a logistic regression model suggest that the factors that influenced adoption were age of the household head, education level, extension contact, family labourforce and gender (all with significantly different coefficients from 0-10%). The other factors hypothesised to influence adoption did not have significant coefficients and, therefore, did not explain adoption decisions. They included sources of income, credit and farmer group membership. At the policy level, improving the quality of the extension systems is of paramount importance in Uganda.

Key words: *Crotalaria grahamiana*, *Zea mays L.*, agroforestry, adoption, Uganda

INTRODUCTION

Depletion of soil fertility is widely accepted to be the most widespread serious biophysical constraint to food security in sub-Saharan Africa (Siriri *et al*., 2000; Ayuk, 1997). Most soils in Uganda are older than 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 (Siriri and Bekunda, 2001).

In response to the problem, a number of soil conservation and fertility replenishment measures have been developed and promoted, including agroforestry technologies (Nyirenda *et al*., 2001; Swinkels *et al*., 2002). Agroforestry has the potential to make a long- and short-term contribution to farm production. Studies in several parts of Africa have demonstrated the economic and agronomic returns of agroforestry practices such as short-term improved fallow (Franzel *et al*., 2001; Thangata, 1998; Graene and Casee, 1998). However, adoption of agroforestry technologies has been low (ICRAF, 1996). Previous researches have primarily focused on the biophysical aspects of agroforestry with little attention to socio-economic issues in agroforestry (Ayuk, 1997; Osemeobo, 1990; Thangata, 1998).

Uganda has a significant comparative advantage for supplying the East and Central African regional market with maize and beans. The most prominent maize growing districts are Kapchorwa, Iganga and Kamuli. Bean production is concentrated mainly in Kabale and Mukono districts (MAAIF, 2000). Unfortunately little or no extension services are provided by the government and the private sector, resulting in low yields due to poor farming practices. The average yield of maize is about 1.2 t ha^{-1}, well below the potential yield of 4 t ha^{-1}, while, bean yield is about 0.75 t ha^{-1}. It is anticipated that by 1998 maize yields will increase by 33% and the focus will be the export markets in Kenya and Rwanda.

Investigation of why some technologies are more readily adopted than others requires key information about the socio-economic and biophysical interactions that affect farmer's decision making. Technologies that are proven successful through research trials may have low adoption rates because of many reasons including wrong targeting resulting from lack of farmer participation (Adesina *et al*., 2001, 1998; Osemeobo, 1990).

Adoption 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

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facing the decision maker as illustrated by Leagans (Alavalapati *et al*., 1995) in the Behavioural Differential Model. These alternatives and constraints are grouped into incentives and disincentives. Adoption proceeds only when a potential adopter feels that the incentives outweigh the disincentives. Different models have been suggested to explain the decision to adopt new technologies (Thangata, 1998; Rogers, 1995). Morris and Adelman (1988) have argued that there is no single theory of causation that can embrace all aspects of adoption and explain the traditional attitude of farmers towards technologies in developing countries. According to Masangano (1996) the adoption behaviour of an individual is a function of socio-economic and biophysical factors and the adoption is endogenous to the sum of the interacting forces of the farmers situation. Duvel (1994) observed that acceptance of technological packages, however, depends on a number of social and economic factors, extending far beyond the simple cost-benefit calculations.

Past studies (Masangano, 1996; Osemeobo, 1990; Franzel *et al*., 2001; Omoregbee, 1998) have identified some of the farmers' characteristics that may influence adoption rate 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 labour. Farmers' adoption behaviour, especially in low income countries is influenced by a complex set of socio-economic, demographic, technical, institutional and bio-physical factors (Franzel *et al*., 2001).

Farmers' welfare or utility maximization framework has been used in a number of studies to model farmer's adoption decision, including contingent valuation models (Lohr and Park, 1994; Greene, 2000), Tobit model (Nyirenda *et al*., 2001; Morris and Adelman, 1988) and discrete choice models (Adesina *et al*., 2001). The choice of any of these models depends on the issue of interest. Where, the interest is on examining the role of the farm and operator characteristics affecting adoption decisions, studies have used choice models such as Tobit or Logit (Adesina *et al*., 2001).

Purpose and objectives: This study, investigates the household characteristics that affect the adoption of the mixed inter-cropping an agroforestry tree species, crotalaria (*Crotalaria grahamiana*) and maize (*Zea mays L.*) technology, herein referred to as the agroforestry technology. The factors influencing the adoption of the agroforestry technology from a survey conducted in Kabale district, Uganda were examined. The differences between adopters and non-adopters in terms of their age, gender and other socio-economic characteristics were investigated.

MATERIALS AND METHODS

Study area: The study, was carried out in Kabale district is located in the Kigezi highlands of Southwest Uganda bordering with Rwanda. It lies between latitudes 1°45^1-1°30^{1}S and longitudes 29° 18^1-30° 50^1 E. The area has a bio-modal climate characterised by mean annual rainfall ranges of 1000-1500 mm, with a good rainy season lasting from November to April followed by scattered showers from May to July, the start of the dry season (May October). The topography is extremely rugged, consisting of narrow steep convex slopes (10-35°) and gentle (5-10°) slopes. The surrounding emergent hill crests lie at altitudes of 1,190 m in the north and 2,607 in the south. 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. The area is densely populated with an average of 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 rain fed crops. The intercropped range of rainfed crops vary with greater potentials for maize, banana, beans, cassava and sweet potatoes.

Data sources: A farm level study on the adoption of mixed intercropping crotalaria and maize agroforestry technology was conducted in Kabale district between March and July 2004. Sixty farmers were surveyed in three sub-counties of Bubare, Muko and Hamurwa of Rubanda. Farmers were categorized as adopters and non-adopters of agroforestry technology. A multistage sampling procedure was used to select 60 farmers for the survey. A structured questionnaire and interviews with respondents yielded information on the relevant socio-economic variables and agronomic practices in the area. This sample size was based on the recommendations that a sample size of 20-30% of the population is generally adequate in adoption studies (CIMMYT, 1993). Descriptive statistics were used to describe the farmers' socio-economic characteristics, while, simultaneous equation Logistic models were estimated in analysing the intensity of adoption (Maddala, 1983; Moris and Adelman, 1988; Greene, 2000). The conceptual and econometric underpinnings of the discreet choice models used to analyse the various socio-economic factors that influence adoption of the agroforestry technologies are outlined in the following sub-sections.

Conceptual model specification: In this study, the factors influencing the adoption of agroforestry technology were analysed using maximum likelihood estimation of a logistic regression model. The dependent variable, adoption of mixed inter-cropping an agroforestry tree species, crotalaria (*Crotalaria grahamiana*) and maize (*Zea mays L.*), 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 (Maddala, 1983). Instead a dichotomous logistic model techniques is used to regress adoption on asset of explanatory variables. Many studies have used the logistic analysis approach to examine similar issues in different agroecological zones and for different technologies (Alavalapati *et al.*, 1995; Ayuk, 1997; Adesina *et al.*, 2001). Given:

$$y_i^* = \beta' x_i + \mu_i \qquad (1)$$

where, y^*_i be unobservable, but determined by the dummy variable y defined by:

$$y = 1 \text{ if } y^*_i > 0$$
$$y = 0 \text{ otherwise} \qquad (2)$$

From Eq. 1 and 2, the probability that y = 1, a particular farmer will adopt agroforestry practice, is:

$$\text{Prob } (y = 1) = \text{prob } (\mu_i > -\beta' x_i) \qquad (3)$$
$$= - F(-\beta' x_i)$$

and the probability that y = 0, that the farmer will not adopt agroforestry, is:

$$\text{Prob } (y = 0) = \text{Prob } (\mu_i < \beta' x_i) \qquad (4)$$
$$= F(-\beta' x_i)$$

Where, in Eq. 3 and 4, F is the cumulative distribution function. We assume that μ is independent of X, the vector of characteristics associated with agroforestry $farmer_i$ and has a standard logistic distribution (Morris and Adelman, 1988) and β is the vector of estimated coefficients. A combination of Eq. 1 and 2, yields the probability that a farmer will adopt agroforestry as:

$$1 - F(-\beta' x_i) = \frac{\exp(\beta' x_i)}{1 + \exp(\beta' x_i)} = \lambda(\beta' x) \qquad (5)$$

and the likelihood (Maddala, 1983) is:

$$L = \prod_{yi=0} F(-\beta' x_i) \prod_{yi=0} \left[1 - F(-\beta' x_i)\right] \qquad (6)$$

The confidence interval is another goodness-of-fit measure. After estimating the βs, the Confidence Intervals (CI), a statistical inference for the model parameters can be performed to help judge the magnitude of the significance (Maddala, 1983). A confidence interval only has the specified probability of containing the parameter if the sample data on which is based is the only information available about the value of the parameter by using the formula in Eq. 7.

$$\beta \pm z_{\alpha/2}(\text{ASE}) \qquad (7)$$

Where, ASE is the asymptotic standard error and z is the α/2 critical value from a t-distribution with (n/k) degrees of freedom.

The magnitude of changes in the probability of adoption as the regressor changes is best illustrated by the marginal effect, usually evaluated at its mean of the explanatory variable. Following Greene (2000), we denote the logistic cumulative function by λ(.) as the standard logit in Eq. 3, we find the marginal effects of the regressors on the probability as:

$$\lambda\,(1-\lambda)\beta \qquad (8)$$

The derivatives of the likelihood estimates of the coefficients yield the probability of being in one of the dichotomous groups, an adopter or none-adopter. This will give the measure of strength of response for the independent variables. However, the change in probability can be expressed in percentage change by multiplying with 100.

The equation used to estimate the parameters is:

$$E(Y_i) = \alpha + \beta_1 GND + \beta_2 AGE + \beta_3 EDUC + \beta_4 MBR +$$
$$\beta_5 EXT + \beta_6 INCOM + \beta_7 FLBR + \beta_8 CRDT + \mu_1$$

Where,

Y_i : The dependent variable, adoption of agroforestry.
α : The constant.
βs : The coefficients of each explanatory variable.
μ : Random errors.

The μ_1 are unknown parameters representing the threshold values and are estimated with βs.

Table 1: Description of farmers socio-economic variables used in the logit analysis for adoption agroforestry technology in Kable district, Uganda

Variable	Variable 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 scored =>10 points; 0 otherwise)
CRDT	Access to credit (1 if got credit from microfinance institution; 0 otherwise)
EXT	Contact with extension staff (1 if household scored 5; 0 otherwise)

In the model above i = household (1-60) and all variables except size of Family Labourforce (FLBR) and size of the farm (LSIZ), are transformed into binary form. The details of cut off values used in transforming variables into binary form are given in Table 1.
The working hypothesis for this study are:

Farmer's Gender (GND): It has been reported that women in sub-Saharan Africa face challenges in managing improved fallow tree species and maize (Nyirenda *at al*., 2001) due to gender bias in land allocation and inheritance systems or rights to plant and own a tree. Furthermore, women headed households are constrained by lack of active labourforce (Masangano, 1996). It is hypothesised that GND is negatively related to the adoption of mixed inter-cropping an agroforestry tree species, crotalaria (*Crotalaria grahamiana*) and maize (*Zea mays L.*) in Kabale district, Uganda.

Farmer's Age (AGE): It is hypothesised that with increasing age a farmer will be less likely to adopt agroforestry technologies. We expect the Age (AGE) of the household head to have a negative relationship with adoption of agroforestry technologies.

Education level of household head (EDUC): A higher level of education increases a farmer's ability to obtain, process and use adoption information of agroforestry. Education thus expected to have a positive effect on the decision to adoption of agroforestry technologies. Agroforestry is a knowledgeable and management intensive technology, requiring ability to manage the tree-crop combinations to achieve optimal results. Lack of proper management can lead to poor tree performance (Jama *et al*., 1997).

Income generating activities (INCOM): The wealthier households expected to can afford to buy agro-chemicals to fertilizer their soils and will not need to agroforestry technologies for soil conservation. It is hypothesised that INCOM will have a negative relationship with agroforestry adoption.

Contact with Extension agents (EXT): Agricultural extension services are a key variable in developing a favourable attitude among farmers towards agroforestry. Therefore, it is hypothesised that extension contact will have a positive impact on adoption of agroforestry technologies (Siriri *et al*., 2000).

Credit (CRDT): Access to credit increases the probability of farmers adoption of agroforestry technologies.

Membership in an organization (MBR): Members of organizations (farmer groups, co-operatives and NGOs) have better access to information on agroforestry practices. Being a member of an organization is hypothesised to be positively associated with adoption of agroforestry.

RESULTS

Some differences were observed between households adopting the agroforestry technology and those not adopting them. The summary of descriptive statistics presented in Table 2 shows that 65% of the farmers had adopted agroforestry. On average, 0.97 ha of the farm was under mixed inter-cropping an agroforestry tree species, crotalaria (*Crotalaria grahamiana*) and maize (*Zea mays L.*), which represent 13.4% (defined as the a ratio of the area under agroforestry). The adopters were younger than non-adopters and female headed (15% of households) were younger than male heads (85% of households surveyed). The adopters and male heads had more extension contact relative to the none-adopters and female heads. Adopters and female heads had more productive labourforce than non-adopters. The female heads had less education than the male heads. Similar results were obtained in Ghana (Doss and Morris, 2001). One interesting result, however, is that on average non-adopters' and female farmers scored higher membership to organizations than adopters and male farmers. The results also show that there is little difference between the 2 groups in their sources of income. Adopters as a group had more incomes than none-adopters and male heads had more income sources than the female heads.

The logistic regression model was estimated using Shazam version 8 (Shazam, 1997). The results are reported in Table 3. All the parameters estimates have the expected

Table 2: Characteristics of adopter and non-adopters of agroforestry technology

	Sample (n = 60)		Adopters (n = 30)		Non-adopters (n = 30)		Male (n = 30)		Female (n = 30)	
Variable	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
AGE	48.30	12.74	46.11	12.52	50.80	11.50	52.2	13.40	45.2	10.55
EDUC	3.70	2.30	3.92	2.33	2.50	3.20	3.52	3.41	2.50	3.20
MBR	2.43	1.32	2.03	1.45	2.62	1.38	2.04	1.27	2.62	1.38
EXT	3.57	2.49	4.65	2.24	2.33	2.00	4.01	2.58	2.33	2.00
INCOM	11.00	3.60	11.72	3.06	12.00	1.75	12.3	2.45	11.4	2.24
FLBR	3.22	1.64	4.22	1.89	3.66	1.68	3.66	1.68	2.66	1.68

signs. Among the factors hypothesised to influence the intensity of adoption of agroforestry technology, the 4 significant variables were AGE, EXT, GND, EDUC and FLBR (Table 2). While, education, membership to an organization, access to credit and sources of income were not significant.

Explanatory variables EXT and FLBR are both significant at the 1% level and have the expected sign. AGE has a negative effect on adoption of agroforestry and it is significant at 5% level. The likelihood ratio statistics of 18.89 (7df) shows that the model is different from zero and significant at the 5% level. The model has a correct prediction of 73%, correctly predicting adopters at a rate of 85% and non-adopters at 38%. The age of the household head is an important factor (AGE), with coefficient of -2.01. Using the same reasoning, this indicates that the younger farmer has a 50% higher probability to be an agroforestry adopter than an older farmer. Consistent with other studies (Jama *et al*., 1997; Thangata, 1998; Osemeobo, 1990), the variable AGE is negatively related to adoption of agroforestry technologies ($p<0.05$). Other variables held constant, the probability of adopting the mixed intercropping of crotalaria tree and maize falls with increasing age. With respect to the marginal effect of age on adoption, it is shown that the probability of adopting agroforestry decreases by 6% as the household head grow older than the 30 years. There is a positive coefficient of the EXT variable suggests the importance of increased extension work in adoption of agroforestry technologies. The probability of adopting agroforestry increases by 2% with greater extension contact. More adopters (72%) than non-adopters (76%) had access to extension.

The Education level of household head (EDUC) has a positive impact on agroforestry adoption. Better educated farmers tended to use improved fallow species in improving the chemical and physical properties of the soil. There is close relationship between family productive labourforce FLBR and the adoption of agroforestry. The relationship is significant ($p<0.001$). Holding other factors constant, when FLBR increases by 1 unit, there is an increase of 2% in the probability that the household will adopt the agroforestry technology.

Table 3: Logistic regression model for the intensity of adoption of agroforestry technology

Variable	Estimate	Standard error	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 (7df); 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

Table 4: Confidence interval for AGE, EDUC, GND, FLBR at 95% confidence interval

Variable	Estimate	SE	Lowest CI	Upper CI
AGE	-2.01	1.01	-3.74	-0.03
EXT	3.31	1.37	0.61	5.62
FLBR	1.68	0.51	0.28	3.05
GND	2.21	1.06	0.89	2.78
EDUC	2.81	1.14	2.43**	0.11

The explanatory variables INCOM and CDRT are not statistically significant. There is a negative relationship between adoption and INCOM (p = 0.15). This suggests that farmers with diversified sources of income are less likely to adopt agroforestry technology. The farmer's Membership to organizations (MBR) is positive but not significant. From Eq. 7, we later computed the Confidence Interval (CI) for the significant variables (1 and 5% levels). Table 4 highlights the CI for parameter β for the four variables; AGE, EXT; FLBR and GND in the logistic regression model. All the variables that are significant in the logistic model have intervals that do not include the no effect value 0, at the 95% CI, so we are confident of the effect.

DISCUSSION

The logistic regression coefficients (Table 2) showed that younger heads of households are more likely to adopt the agroforestry technology compared to the older farmers. This is because the younger households are ready to take risk relative to older households and thus likely to adopt the mixed intercropping of crotalaria and maize. This finding is consistent with previous studies (Alavalapati *et al*., 1995; Adesina *et al*., 2001; Doss and Morris, 2001) that reported that adoption decreases with advanced age.

The gender variable showed a negative coefficient showing that the probability of adoption was higher for men than women farmers. This may be the result of the lack of consideration of gender-equity issues in the design and introduction of technology to farmers. We can attribute the lower agroforestry adoption by women to the fact that in the study are, women still do not have secure land and tree tenure due to the largely patrilineal inheritance systems. 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 (Swinkel *et al*., 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. This could include improved fallow technologies with leguminous shrubs or mixed intercropping with leguminous shrub species.

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 (Doss and Morris, 2001). Farmers with access to technical information through extension contact will have more accurate information to do a cost-benefit analysis of the agroforestry technology. Our study, supports the findings of Adesina *et al.* (2001), Alavalapati *et al.* (1995), Omoregbee (1998) 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.

Active family labourforce has a positive impact on adoption of agroforestry technology. Combining *Crotalaria grahamania* with maize on the farm is labour demanding and families constrained with labourforce may not be able to practice agroforestry (Rogers, 1995). The survey showed that farmers are already making significant modifications to the conventional mixed intercropping of woody tree species and annual maize crop.

The education level of the head of house was found to be an important determinant of agroforestry adoption in this study. Similar findings (Thangata, 1998; Nyirenda *et al*., 2001; Masangano, 1996; Ayuk, 1997) reported 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.

The positive sign on EDUC shows that farmer education positively influences the probability of introducing mixed, intercropping of crotalaria and maize in the farming system. This maybe because better-educated farmers are able to better understand the nutrient cycling processes underlying the technology. They therefore, modify the technology to incorporate the benefits of a fallow as they traditionally do in their bush fallow rotation system.

The number of productive family members working fulltime on the farm positively influenced adoption of agroforestry technologies because the more people available to work fulltime on the farm, the higer the probability of adopting agroforestry (Masangano, 1996).

The study found that there is a negative relationship between farmer's membership to local organizations and adoption of agroforestry technologies. This is because previous farmer organizations had led to high expectations and unfortunately end up with less impact on the farmers welfare, hence, male farmers with busy schedules were reluctant to join organizations.

CONCLUSION AND RECOMMENDATIONS

This study, examined the factors influencing the adoption of mixed inter-cropping of an agroforestry tree species, crotalaria (*Crotalaria grahamiana*) and maize (*Zea mays L.*) in Kabale district, Uganda. Factors that influenced adoption were age of the household head, extension contact, productive family labourforce and gender (all with significantly different coefficients from 0-10%). The other factors hypothesised to influence adoption did not have significant coefficients. They included education of household head, sources of income, credit and farmer group membership. There is, therefore, a need for gender mainstreaming as a strategy aimed at achieving equal participation and access to benefits and resources in agroforestry interventions. The policy implication is that strengthening and improving the quality of the extension services is important in agroforestry technology adoption. 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.

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