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Adoption of soil and water conservation technologies in the Rwizi catchment of south western Uganda

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Soil and water conservation technologies, such as mulching, grass strips and retention ditches, have been promoted in many areas of Sub-Saharan Africa. However, technology adoption rates have remained unsatisfactory. In this study, a logit model was used to examine the adoption of soil and water conservation technologies in the Rwizi catchment of Uganda using cross-sectional survey data from 271 smallholder farmers. Findings revealed that the likelihood to adopt these conservation technologies by smallholder farmers is explained by land size, tropical livestock units, access to extension services, value of gross output, gender of the household head and location of the farmers. Our results further showed that the quadratic term in land size was significant and negative, highlighting an acreage threshold to adoption. In general, our findings underscore the importance of information access and landownership in adoption of soil and water conservation technologies in the Rwizi catchment of Uganda.

Keywords: adoption; Uganda; catchment; logit; soil and water conservation

Introduction

The adoption of soil and water conservation (SWC) technologies has become an important concern in Sub-Saharan Africa (SSA). This stems from the high rate of land degradation and the resulting problems of widespread agricultural productivity and soil fertility decline in SSA (Bojö 1996; Franzel 1999; Mbaga-Semgalawe and Folmer 2000). Agricultural land productivity in most of the SSA region lags behind the rest of the world (Diao *et al*. 2010) and this leads to dwindling per capita crop yields (Sanchez and Leakey 1997). The situation is no different in the Lake Victoria basin and most parts of Uganda (NEMA 2001, 2007), where the effects of land degradation have manifested themselves in productivity decline and increased landslide occurrences in highland areas. In response, the smallholder farmers seek to increase crop production through the expansion of cultivated area (Nkonya 2002). This expansion leads farmers to cultivate marginal areas such as wetlands, steep hill slopes, forests, river banks and lake shores. Moreover, these areas are planted with annual crops that require clean tillage practices, with no fallow periods, thus further exposing them to erosion and nutrient mining and loss especially during harvest (Isabirye *et al*. 2007). Water erosion and nutrient mining are among the major causes of land degradation in Uganda (NEMA 2007). Soil fertility declines due to nutrient loss at harvest, water erosion and leaching (Wortmann and Kaizzi 1998, Pender 2004, Esilaba *et al*. 2005, Nkonya *et al*. 2005a, Isabirye *et al.* 2007) have been reported in Uganda as well.

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Moreover, per-capita inorganic fertilizer usage in Uganda is among the lowest in SSA (NARO and FAO 1999), making nutrient replenishment ineffective. Inappropriate agricultural production methods that accelerate soil erosion and nutrient mining have on-site and off-site implications and have been reported to be a major source of non-point source pollution in Lake Victoria (Lindenschmidt *et al.* 1988).

Many SWC technologies have been promoted and disseminated in Uganda to spur agricultural productivity and the sustainable use of land resources by smallholder farmers. However, despite the availability of various technological options the adoption rates have remained low, and soil fertility decline and land degradation continue unabated. The adoption of new technologies in agriculture has been widely studied. Starting with the critical review of Feder *et al*. (1985), the literature is replete with researchers who have pursued this topic in the context of SWC (Ervin and Ervin 1982, Rahm and Huffman 1984, Featherstone and Goodwin 1993, Zepeda and Castillo 1997, Swinkels and Franzel 1997, Lynne *et al*. 1998, Soule *et al*. 2000, Bayard *et al*. 2007, Moyo *et al*. 2007, Tiwari *et al*. 2008, Wauters *et al*. 2010).

In this study, we explore the factors that affect the adoption of SWC technologies by smallholder farmers in the Rwizi catchment of south western Uganda. We model the adoption of SWC technology using a dichotomous logit model, explore interaction and nonlinear effects and test model suitability using a likelihood ratio test on restricted and non-restricted logit models of adoption.

The remainder of this article is partitioned into four major sections. In the first section the different SWC technologies are outlined. Relevant literature on adoption of SWC technologies is reviewed in the second section. The third section describes the data and methodology used. The results and discussion are outlined in the fourth section. The article ends with brief concluding remarks about the study.

Soil and water conservation

SWC is defined as the rational use of land resources, the application of erosion control measures and water conservation technologies, and the adoption of appropriate cropping patterns to improve soil productivity and prevent land degradation and thereby enhance the livelihood of the user communities (Hudson 1987, Tiwari *et al.* 2008). In Uganda, the Ministry of Agriculture, Animal Industry and Fisheries (MAAIF) and other related agencies like the National Research Organization (NARO) have demonstrated, promoted and disseminated a number of technologies including SWC technologies with the objective of preventing soil erosion and land degradation. Moreover, various technology uptake pathways (TUPs) through which new technologies reach the end-users have been identified countrywide and specifically in the area of study. TUPs include community-based organizations, farmers' organizations, non-governmental organizations (NGOs), National Agricultural Advisory Services (NAADS) and Zonal Agricultural Research and Development Institutes (ZARDIs). These use various methods to disseminate technologies, such as Farmer Field Schools (FFSs), demonstration trials and plots, workshops, seminars, farmer exchange visits, and so forth. Some of the SWC technologies include

(1) Improved trash-lines used mainly in hillside fields where annual crops including sorghum, finger millet, beans and peas are grown. The recommended spacing between the improved trash-lines is 5–10 m, depending on the slope. Instead of removing the trash/crop residues, they are left in the fields and are arranged in lines parallel to the contour. The challenge is that there are competing uses for the crop residues, such as

animal feeds, fuel wood, house thatching and at times the decomposition rate is accelerated by the presence of termites.

(2) Mulching using crop residues (banana leaves, banana fibres, bean crop residues, maize and sorghum stovers etc.), coffee husks and papyrus and other grasses from swamps. This technology is used to encourage rain water infiltration, reduce evaporation, prevent soil from being washed away, control growth of weeds and conserve moisture. Mulching also helps to prevent the formation of a hard topsoil crust after each rainfall episode. Organic mulches also add plant nutrients to soils upon decomposition. Mulching using papyrus grass harvested from wetlands has been the most widely used technology in banana plantations in the study area.

(3) Integrated runoff management. Runoff water from a hill top or road surface is harvested using diversion and retention ditches. The ditches are stabilized with grasses which are planted on top of the earthwork of the ditches. The purpose of the technology is to control soil erosion by running water from the hilltop and also to harvest and retain moisture in banana plantations which need adequate moisture for proper production.

(4) Tree farming/agro-forestry technologies: Farmers have been encouraged to plant trees to stabilize slopes and also to provide shade and wind breaks in the banana plantations. Agro-forestry technologies (multi-purpose trees and shrubs) such as fruit trees, fodder banks, hedgerow intercropping; provide a multiplicity of functions to the farmers in addition to stabilizing steep slopes.

(5) Strip cropping: Erosion prone crops such as perennials are planted along with erosion-resistant crops such as legumes that have extensive root systems and whose canopy intercepts and lessens the force of rain drops and enhances water percolation. In the study areas, the banana and coffee gardens were normally intercropped with legumes (beans and peas) which also acted as cover crops.

This farm-level study was motivated to explore predisposing factors to the adoption of any of the outlined SWC technologies in light of the increasing land degradation in the Rwizi catchment and the prevailing institutional and policy framework. In essence, the study attempted to answer these questions: What roles do institutions play in ensuring that smallholder farmers adopt SWC technologies, and are farm and farmer characteristics relevant in influencing smallholder farmers' adoption decisions of SWC technologies in the Rwizi catchment?

Factors that affect the adoption of SWC technologies

Adoption is defined as an innovation decision process involving a series of steps through which decision-making units pass from the time of awareness of the new technology to the time they actually use the technology. Rogers (1995) divides this process into five distinct stages: knowledge (awareness), persuasion, decision, implementation and confirmation. During the knowledge acquisition stage, the decision-making unit becomes aware of the new technology and learns about its merits and demerits. At the persuasion stage, the decision maker forms a favourable or unfavourable attitude towards the technology. In the decision stage, the individual engages in activities that lead to a choice to adopt or reject the technology. At the implementation stage, the individual actually starts using the technology and finally in the last stage, the individual evaluates the results of the technology decision. This sequence may not be necessarily linear and unidirectional, as decision makers can move back and forth and at times may adopt the technology at first only to reject it later and/or may reject a technology at first and then later make up their minds to adopt it. Technology adoption is a continuous process of decision making. At each stage of the decision-making process economic agents are constrained by a number of interacting factors to inform the next step in the decision cycle (Bayard *et al*. 2007). Therefore, the adoption process is a time-variant process as the decision process is refined over time as the agents accumulate information. The relative speed with which an individual goes through the decision-making process gives an idea about the degree of innovativeness.

In this study, adoption of SWC technologies was operationally defined as the presence or absence of any of the SWC technologies at the farmer's fields (Sanginga *et al*. 2007). There is a clear distinction between individual farm-level adoption, aggregate adoption and divisible versus non-divisible technologies[1] (Feder *et al*. 1985, Feder and Umali 1993). From economic theory, adoption of innovations at the farm level has been modelled mostly by assuming that economic agents seek to maximize the expected utility from their efforts and they face two decision alternatives: adopt or not (Amemiya 1981). The smallholder farmers assess the new technology in terms of feasibility, profitability and acceptability to inform their decisions (Swinkels and Franzel 1997). However, their decisions are affected by economic, institutional, bio-physical factors, availability of information, perceptions, attitudes and household's socio-economic characteristics (Moyo *et al*. 2007). The interrelations of these factors are depicted in Figure 1.

Socio-economic and wealth factors

In attempts to find answers to the uneven technology adoption pattern among farmers, researchers have investigated the impacts of socio-economic characteristics of the smallholder farmers on adoption, such as the farmer's age, farming experience, education level of the household head, marital status, family size and gender of the household head. Various studies have independently confirmed that education level of the household head, age, family size as a proxy for family labour and gender significantly influenced the adoption of new agricultural technologies (Ervin and Ervin 1982, Shiferaw and Holden 1998, Mbaga-Semgalawe and Folmer 2000, Bayard *et al*. 2007, Tiwari *et al.* 2008, Mugisha *et al*. 2012). Education of the household may increase the adoption of SWC technologies in the sense that educated farmers have better access to new information since they can read and write. However, more education may also be a gateway into more remunerative formal employment off the farms, making it negatively correlated with

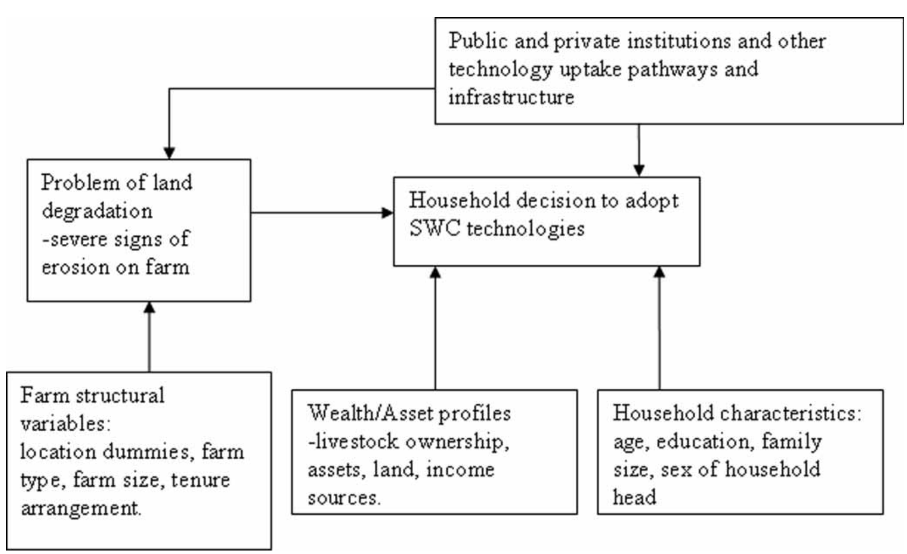

Figure 1. Decision-making process in SWC adoption in the Rwizi catchment.

adoption. Nkonya *et al*. (2005b) contended that farmers who had completed primary education were less likely to apply manure and mulch compared with their non-educated counterparts. Sidibe (2005) found education and training to positively and significantly influence adoption of SWC in Burkina Faso. The age of the household head is believed to influence adoption, because it reflects life cycle impacts on investment behaviour. An older farmer may have a wealth of experience but may be unwilling to invest in long-term soil conservation given his or her short time horizon (Featherstone and Goodwin 1993). Young farmers may be more agile, dynamic and energetic in the adoption of technologies especially those that are labour intensive. The younger farmers also have a longer planning horizon and their willingness to make agricultural technology investments with long payback periods may be higher than that of older farmers. The length of farming experience can generate or erode confidence in a new technology. Therefore, with more experience, a farmer can become more or less risk averse to new technologies such that the effect of experience on adoption is not clear. However, age and farming experience are always highly correlated and there is a trade-off as both cannot be included in the same model (Zepeda and Castillo 1997).

The wealth endowments: physical assets, human, financial and social capital, household income activities (on-farm and non-farm incomes sources), land size and tenure security, have all been reported to influence the adoption of new technologies. Physical assets are a form of saving for smallholder farmers and include land, livestock, houses, tools and farm equipment among others. These physical assets may be used to enable the farmers to buy the inputs like fertilizers, improved seeds and other fertility-enhancing technologies. Therefore, it is most likely that wealthier farmers will invest more in land-management technologies compared to poorer farmers (Scoones 1995, Shiferaw and Holden 1998, Fairhead and Scoones 2005, Nkonya *et al.* 2005b, Langyintuo and Mungoma 2008). Land size, tenure security and access to financial capital have also been reported to influence adoption of new technologies (Knowler 2004). Livestock ownership also plays an important role in affording the household a form of saving on the one hand while playing a crucial role in nutrient cycling on the other hand. Crop residues are fed to livestock while manure from the animals is applied in farm plots to enhance their fertility. Positive crop–livestock interactions have been reported in smallholder farming systems (Nkonya *et al*. 2005b). Family income is also important in facilitating investment in new technologies on the farm. For example, Tiwari *et al.* (2008) reported that net income from vegetable farming and family member occupation significantly influenced the adoption of improved soil conservation technology in central Nepal. Bayard *et al*. (2007) also reported a positive and significant relationship between per capita income and the adoption of alley cropping. Off-farm income may ease the liquidity constraint needed for soil conservation investments or the purchase of fertility enhancing inputs. It may also signal increasing dependence on non-agricultural activities, which may lower the economic significance of soil erosion; however, the reduced pressure on the land may reduce the erosion problem in the long run (Shiferaw and Holden 1998). Therefore, off-farm income may exhibit mixed effects on the decision to adopt SWC technologies.

Institutional and diffusion factors

Smallholder farmers in Uganda obtain information and technical expertize from the NARO, MAAIF, NAADS and sometimes NGOs. Farmers act on this information in the light of their personal characteristics, perceptions and attitudes, biophysical and economic factors to influence decisions on SWC technology adoption. Institutional support services especially public extension services were found to influence the adoption of new technologies (Shiferaw and Holden 1998, Mbaga-Semgalawe and Folmer 2000, Läpple and Rensburg 2011). Access to agricultural information through contact with extension service providers and access to affordable credit (Lee 1980) have been reported to significantly influence adoption (Bekele and Drake 2003, Nkonya *et al*. 2005b, Mugisha *et al*. 2012). The extension service providers are the major source of new agricultural information in typical rural settings like the Rwizi catchment of south western Uganda and therefore they create a vital link in the smallholders' decision to learn and adopt new SWC technologies. The smallholder farmers are trained either individually in what is known as training and visiting or they may be encouraged to form groups, through which they can access vital services. Bayard *et al*. (2007) revealed that group membership and training in soil conservation practices significantly and positively influenced the adoption of alley cropping in Haiti. Tiwari *et al.* (2008) found that membership in conservation and development groups and credit access significantly influenced the adoption of improved soil conservation technology in central Nepal. The unavailability of technical expertize to support the new technology and the inaccessibility of information has been shown to limit the possibility of smallholder farmers from investing in soil productivity improvement (Knowler 2004). Farmers must be able to perceive the problem (degradation/soil erosion) on their farms, and be able to observe the array of possible options and incentives before they respond (Mbaga-Semgalawe and Folmer 2000, Jones 2002).

Unsupportive policy environments, unfavourable product and input pricing and limited local and international marketing opportunities present serious constraints for investment in land management technologies (Fairhead and Scoones 2005). Access to markets by smallholder farmers has been reported to strongly impact on agricultural production through its influence on the profitability of agricultural output, household incomes and overall household wealth accumulation (Pender *et al*. 2001). Any surplus incomes obtained may be invested in land improvement technologies provided the required inputs that complement the technologies are also accessible in the markets. Through poverty reduction strategies, the government of Uganda has promoted soil management by focusing on increased access to markets, education, extension services and provision of agricultural inputs (MAAIF, MFPED 2000).

Attributes of SWC technology and farm characteristics

The characteristics of the technology promoted and the underlying farm types may play important roles in determining the adoption of such technologies. The technologies are assessed by the end users in terms of relative advantage and compatibility with the existing production systems. These factors may be categorized into three groups: those affecting feasibility, profitability and acceptability of the technology (Swinkels and Franzel 1997). Feasibility refers to financial resources, knowledge and experience which enable smallholder farmers to choose particular components from a given technological package. It also pertains to institutional support like extension services, credit and marketing infrastructure. Profitability relates to returns, as perceived by the farmer, of the new technology in the light of existing or alternative technologies. Profitability of a technology is determined by the opportunity cost of labour, land and input and output prices among others. Acceptability on the other hand entails the suitability of the technology, its riskiness, cultural/social acceptance and compatibility with other farm enterprises. Sanginga *et al.* (2007) reported that in the highlands of south western Uganda, most conservation measures required high physical labour input and therefore the gender division of labour was found significant as the men normally made the conservation structures while the women were responsible for production and farm maintenance.

It is therefore important to decipher the interplay of the various factors and the processes of adoption of SWC technologies by smallholder farmers. The theoretical framework applied in this paper leans on classical economic theory of expected utility maximization, where the economic agents (households) are assumed to optimize the benefits that accrue from the adoption, or non-adoption of SWC technologies. However, smallholder farmers may be affected by a number of factors that may hinder them from taking favourable decisions towards the adoption of SWC technologies. These factors are depicted in Figure 1.

Data and methodology

Study area

This study was carried out in selected subcounties in the districts of Mbarara, Bushenyi and Ntungamo, Uganda. These districts form part of the river Rwizi catchment in south western Uganda. The Rwizi catchment covers an area of 2282 km^2; the altitude varies from 1262 m above sea level (m a.s.l) at the outlet to 2168 m a.s.l. at the source of River Rwizi. The major part of the catchment receives bimodal rainfall ranging from 1000 to 1500 mm per annum. Banana, coffee and a range of annual crops are grown in this area, and livestock density is high (Uganda National Livestock census, 2008). Livestock production is not fully integrated with crop production, as there are distinct areas/subcounties mostly for livestock keepers. Other economic activities which take place in the catchment, including water extraction for domestic and industrial use, sewage treatment, cattle rearing, brick making, basket making, mats and art pieces, agriculture and agro-forestry. However, the main economic activity is crop production which employs 87.4, 94 and 89.4% of the population in Mbarara, Bushenyi and Ntungamo, respectively (Uganda Bureau of Statistics, 2002).

Sampling, sample selection and data collection

Nine subcounties were purposively sampled, these being strategic hotspots where major wetland encroachments and land degradation were observed. The subcounties and villages/cells sampled are presented in Table 1 and the location of the Rwizi catchment relative to Lake Victoria and these nine subcounties is shown in Figure 2.

A multistage random sampling procedure (Stern *et al*. 2004) was used to select a target sample of 300 smallholder farmers from the compiled village sampling frame. A Microsoft excel program 'Randbetween' was used to randomize the actual respondents. Out of the total sample of 300

Table 1. Sub-counties, parishes and villages sampled in the Rwizi catchment.

No.	Sub-county	Village	Remarks
1	Bukiro	Kaziga A and Kaziga B	Hotspot for wetland encroachment and land degradation
2	Bubaare	Rwobuyenze Kyantamba	Extensive grazing (local and exotic cattle)
3	Rwanyamahembe	Kaburiishe and Muko	Predominantly cattle grazing area
4	Rwengwe	Nsiika and Kazirwa	Origin of the Rwizi
5	Bugamba	Nyaruhandagazi and Kitooha	Hotspot for wetland encroachment and land degradation
6	Kyangenyi	Muzira and Rushambya	Origin of Rwizi
7	Rugando	Rugarama and Kakitanga	Hotspot for wetland encroachment and land degradation
8	Ndeijja	Ndeijja and Kyesika	Hotspot for wetland encroachment and land degradation
9	Itojo	Nyakakiri cell Kyakahetsi cell	Visible gullies from the hill tops and important sediment sources

Source: Compiled from field observations October 2010 and August 2011.

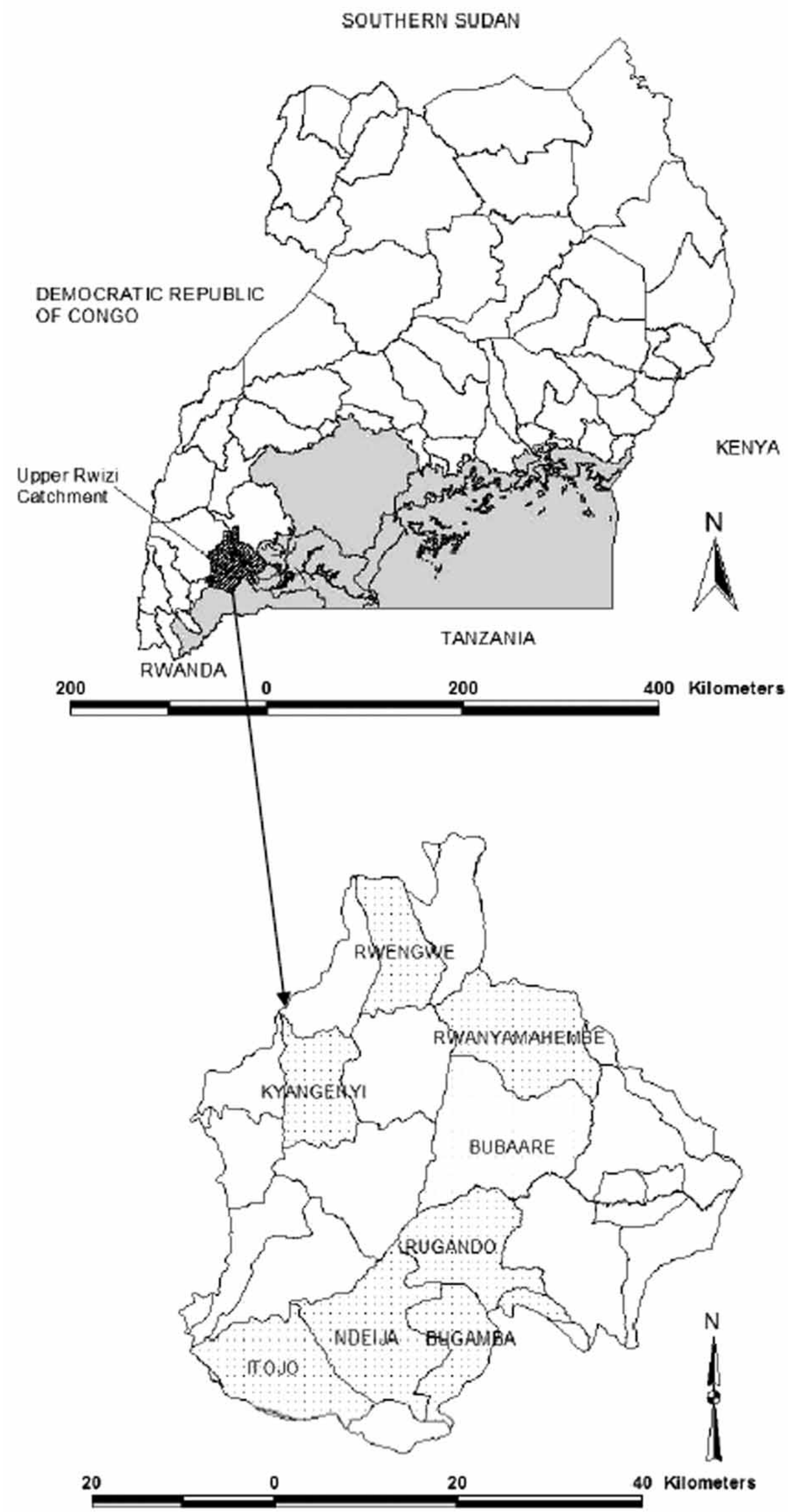

Figure 2. Map: relative location of the Rwizi catchment and the sampled sub-counties. Source: Riparian Lake Victoria project 2010.

respondents targeted, 271 respondents were surveyed resulting in a response rate of 90.3%. Data were collected through a cross-sectional survey using a pre-tested questionnaire administered from July to October 2010 and repeated in May to August 2011. The second sample was done to capture information for the two growing seasons in the study area.

Data and choice of explanatory variables

Table 2 gives the various explanatory variable definitions along with their *a priori* expected signs based on previous empirical research and economic theory. A positive role is anticipated for education, age, gender of the household head, land size, livestock, access to extension services and gross value of output. Total monetary value of productive assets owned by the household[2] and livestock measured in tropical livestock units (TLU) equivalents[3] are also expected to be positively correlated to the adoption of SWC technologies. The total gross value of crop output was calculated by apportioning the crop yield to its different uses and then imputing a value based on the prevailing market prices at the time of the study. Exploratory data analysis was conducted to cross check for issues of multicollinearity, outliers, skewness and kurtosis. Tests for multicollinearity were conducted using correlation matrices and those explanatory variables that were strongly correlated were eliminated ($r \geq 0.5$) (Paudel and Thapa 2004).

Modelling of adoption of SWC

In order to fit the logistic regression model, the dependent variable was hypothesized to be influenced by a number of explanatory variables as shown in Table 2. The dependent variable, adoption of SWC technologies, was measured as equal to 1 for adopters and 0 otherwise. The logistic regression model defines the probability $P(\mathrm{SWC} = 1)$ as follows (Amemiya 1981):

$$P(\mathrm{SWC} = 1) = \frac{\exp(\beta_0 + \beta X)}{1 + \exp(\beta_0 + \beta X)} \tag{1}$$

Table 2. Definition of variables used in the logit models.

Short form	Definition	*A priori* sign
SWC	Dependent variable; presence of SWC (1: yes; 0: otherwise)	
Age_hhhead	Age of household head in years	+
Edu_hhhead	Years of progressive schooling of household head	+
Family_size	Family size (number of people in the household)	+/−
Land	Size of land owned by household in hectares	+
TLU	Tropical livestock unit size	+/−
lngrossoutput	The natural log of total gross value of banana, coffee, beans and peas	+
Main-income	Main source of income (1: agriculture; 0: otherwise)	+/−
Sex_hhhead	Sex of the household head (1: male headed; 0: female headed)	+
Sub county	jth subcounty of the respondent, $j = 1, 2, \ldots, 9$	+/−
Acc_agrexten	Has access to agricultural extension services (1: yes; 0: otherwise)	+
Dum_erosio	Dummy variable: severe signs of erosion (1: yes; 0:otherwise)	+
Manure_use	Uses manure on the farm (1: yes; 0: otherwise)	+
lnvalue_asset	Natural log value of the sum of productive assets in shillings	+
Sqr_Land	Square of size of land owned by household in acres	−
Sqr_age_hhhead	Square of the age of the household head	+/−
Sqr_tlu	Square of Tropical Livestock Unit	+/−
Inte_age_land	Interaction effect of age × land	+/−

in which X is a vector of predictor variables, either numerical or categorical and βs are the parameter coefficients to be estimated. The odds that SWC takes the value 1 are given by

$$\text{odds}(\text{SWC} = 1) = \exp(\beta_0 + \beta X)$$

The log of the odds that SWC takes the value 1 is then given by fitting the following logistic regression to the data using Maximum Likelihood estimation:

$$\text{Log(odds)} = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + ... + \beta_k x_n + \varepsilon$$

Exploring interaction and nonlinear effects

We also tested for interaction and nonlinear effects in the model using a restricted and an unrestricted model and compared the performance of the two using the likelihood ratio statistic. The likelihood ratio statistic is the difference between the log likelihood of the full model and that of the restricted model (Wooldridge 2009, Wauters *et al*. 2010). This statistic follows under the null-hypothesis that the included variables in the full model all have zero coefficients; it has a χ^2 distribution with the number of degrees of freedom equal to the number of restrictions (q).

$$\text{LR} = 2(\text{LL}_\text{F} - \text{LL}_\text{R}) \approx \chi^2_q$$

Where the subscripts F and R refer to full (nested) and restricted (non-nested) logit models and q is the number of restrictions.

Results and discussions

Descriptive statistics

The socio-economic attributes of the sampled farmers are summarized in Table 3. The average age of the household head in the Rwizi catchment was 45.7 years, with average number of years of progressive schooling of 5.8 years. The farmers had on average 23 years of farming experience and there were about six persons per household.

When the socio-economic characteristics were disaggregated and compared between adopters and non-adopters of SWC technologies using *t*-tests and cross-tabulations, significant mean differences were registered in farming experience, value of farm tools and equipment, gross value of farm output, TLU and distance to input and output markets (Table 3). This implies that on average, the adopters had more farming experience, tools and equipment, reported higher values of farm output and had more livestock as measured by the TLU.

Only 45% of the respondents reported using at least one of the SWC technologies compared with 55% non-users. This shows that the adoption rate of SWC technologies in the Rwizi catchment is still low. When the respondents were asked whether they had observed any severe signs of soil erosion on their farms, nearly every one (92%) answered ‘yes’. During the data collection exercise, sizeable gullies and bare hilltops were observed. From these observations, it appears that soil erosion is a real problem on many smallholder farmers’ farms in the Rwizi catchment. As Knowler (2004) noted, the starting point in having any soil management improvement is to determine whether the farmers correctly perceive and understand the problem of land degradation. Table 3 also presents the disaggregated information of adopters and non-adopters in terms of household characteristics. Forty-eight percent of male-headed households adopted SWC

Table 3. Socio-economic and farm characteristics in the Rwizi catchment.

Characteristic	Adopters $n = 122$ Mean	Non-adopters $n = 149$ Mean	Mean difference	Total $N = 271$ Mean
Age (years)	46.6 (13.4)	45.0 (14.4)	1.6	45.7 (13.9)
Education level (years)	5.8 (3.9)	5.7(3.7)	0.1	5.8 (3.8)
Family size	7.0 (2.8)	6. 8 (2.9)	0.3	6.9 (2.7)
Farming experience (years)	24.3 (13.7)	22 (13.8)	2.3*	23 (13.7)
Land owned (hectares)	1.7 (1.4)	1.5 (1.3)	0.2	1.6(1.4)
Value farm assets (Uganda Shillings)	37596 (32772)	29973(18796)	0.8***	33405(26256)
Value output (Uganda. Shillings)	399328(515282)	269013(422338)	0.13**	327679(470087)
TLU	2.8(7.3)	1.25 (3.0)	1.6***	2.0 (5.4)
Distance farm plots (minutes)	30.4(33.2)	29.76 (30.4)	0.7	30.1(31.6)
Distance markets (minutes)	75.5(49.9)	92.47 (76.8)	17.0**	84.8 (66.5)
Sex household head				
1: Male headed (%)	48	52	79	
0: Female headed (%)	34	66	21	
Use of SWC technology				
1: Yes (%)	45	–	45	
0: No (%)	–	55	55	
Severe signs of erosion				
1: Yes (%)	45	55	92.	
0: No (%)	48	52	8	
Main source of income				
1: Agric (%)	47	53	85	
0: Non-Agric (%)	33	67	15	
Belongs to farmers group				
1: Yes (%)	47	53	30	
0: No (%)	44	56	70	
Access to agric extension				
1: Yes (%)	58	42	39	
0: No (%)	37	63	61	
Access to agric credit				
1: Yes (%)	50	50	42	
0: No (%)	41	59	58	
Off-farm income				
1: Yes (%)	44	56	58	
0: No (%)	53	47	42	

$n = 271$ households.
Standard deviations are presented in parentheses.
$^{***}P < 0.001$; $^{**}P < 0.05$; $^{*}P < 0.1$.

compared with 34% of the female headed ones. Of the smallholder farmers who reported severe signs of erosion on their farms (92%), only 45% adopted SWC technologies in the Rwizi catchment. Only 39% of the respondents reported having accessed agricultural extension service during the two growing seasons. However, more than half of those who accessed information through extension workers adopted SWC technologies in the Rwizi catchment (58%).

The relative distance to markets measured in terms of travel time, the access to agricultural credit, access to agricultural extension services, membership in farmers' group, main sources of household incomes (agricultural and non agricultural incomes) and presence of off-farm income are all shown in Table 3.

Figure 3 further differentiates among the adopters of SWC technologies in the Rwizi catchment. The percentages of farmers who had only mulching were about 7%, mulching plus drainage ditches were about 13% while 25% combined three or more SWC technologies on their farms. Overall, all the adopters of the different SWC technologies, had mulching as the starting point upon which other measures were added. The farmers mostly mulched their banana fields using papyrus grass that was cut from nearby wetlands. However, the respondents reported that scarcity of mulching materials especially the papyrus grass had become a severe constraint. This is attributed to the fact that most wetlands where the papyrus grass used to be available have been turned into private farms for livestock[4].

Adoption decision of SWC technologies: logit results

The overall goodness of fit as measured by the significance of the χ^2 statistic is presented in Table 4 for the two (restricted and full) logit models. In both models there is a significant relationship between the adoption of SWC technologies and the postulated explanatory variables. This implies that the selected explanatory variables in the models jointly are good predictors of the probability to adopt SWC technologies in the Rwizi catchment as the very low P values indicate ($P_R = 0.0000$) and ($P_F = 0.0000$). The two models also registered high correct prediction percentages at 69 and 73% for the restricted and full models, respectively.

The full model does not perform any better than the restricted model in terms of significant variables (Table 4). In the full model, only one more variable becomes significant: the quadratic term on land; and there is a marginal increase in the pseudo R^2 from 15 to 16%. The coefficients of the interaction term and the squared TLU term are all insignificant and very small. From the likelihood ratio statistic (3.92) at 3 degrees of freedom at a 5% critical value of 7.815, we reject the null-hypothesis that the restricted model is nested in the unrestricted logit. This implies that testing for interaction and nonlinear effects is probably inconsequential except for the quadratic term on land area. The restricted model is otherwise sufficient in explaining the factors that affect adoption of SWC technologies in the Rwizi catchment.

Among the household characteristics, the gender of the household head was important in explaining SWC technology adoption. This is shown by the significant and positive odds ratio of 2, which implies that the likelihood of adopting SWC technologies doubles if the household is male-headed ceteris paribus. It should be noted that resource ownership and control in

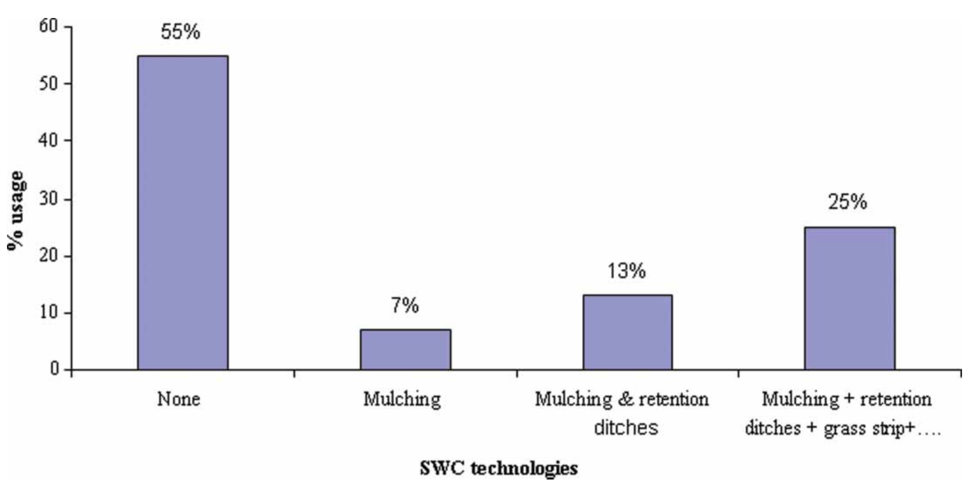

Figure 3. Adopters and non-adopters of SWC technologies in the Rwizi catchment.

Table 4. Fitted restricted and full logit adoption models of SWC technologies in the Rwizi catchment.

	Restricted logit (*R*)[a]			Full logit (*F*)[b]		
Dependent variable (SWC)	Co-ef (β)	Odds ratio	d*y*/d*x*	Co-ef (β)	d*y*/d*x*	Odds ratio
Family_size	0.1(1.0)	1.1	0.01	0.1(1.0)	0.01	1.1
Land	0.12(2.1)**	1.1	0.02	0.36(1.8)*	0.10	1.4
Age_hhhead	0.002(0.2)	1.0	0.001	0.004(0.2)	0.001	1.0
Edu_hhhead	0.04(0.8)	1.0	0.01	0.04(1.0)	0.01	1.0
Lngrossoutput	−0.80(−4.0)***	0.4	−0.16	−0.90(−4.2)***	−0.17	0.4
lnvalue_assets	0.10(0.3)	1.1	0.02	0.02(0.1)	0.004	1.0
TLU	−0.10(−1.7)*	0.9	−0.02	−0.11(−2.0)**	−0.02	0.9
Acc_agrexten(1)	0.95(3.1)***	2.6	0.20	1.10(3.4)***	0.21	2.9
Sex_hhhead(1)	0.70(1.8)*	2.0	0.14	0.82(2.1)**	0.16	2.3
Mainincome(1)	0.47(1.1)	1.6	0.10	0.52(1.2)	0.10	1.7
Dum_erosio (1)	0.13(0.2)	1.1	0.03	0.13(0.2)	0.03	1.1
Manure_use (1)	0.30(0.99)	1.3	0.06	0.32(1.1)	0.06	1.4
Subcounty1	1.24(1.90)*	3.5	0.23	1.10(1.6)	0.20	2.9
Subcounty2	0.99(1.53)	2.7	0.20	0.80(1.2)	0.16	2.4
Subcounty3	0.21(0.34)	1.2	0.04	0.04(0.1)	0.01	1.0
Subcounty4	0.99(1.50)	2.9	0.21	0.82(1.2)	0.16	2.3
Subcounty5	0.65(0.94)	2.0	0.14	0.72(1.0)	0.14	2.1
Subcounty6	0.92(1.41)	2.5	0.18	0.84(1.3)	0.17	2.3
Subcounty8	1.83(2.66)***	5.9	0.36	1.70(2.5)**	0.34	5.7
Subcounty9	1.32(2.03)**	3.8	0.27	1.31(2.0)**	0.26	3.7
Sq_land	–	–	–	−0.01(−1.9)*	−0.003	1.0
Sq_tlu	–	–	–	0.04(0.8)	0.01	1.0
Inter_age_land	–	–	–	−0.0001(−0.03)	$1*10^{-5}$	1.0
_constant	7.03(2.3)**	–	–	7.84(2.5)**		–

[a]Log likelihood = −159, $N = 271$, LR χ^2 (20) = 54.96; P < 0.0000, Pseudo R^2 = 15%. ***$P < 0.001$; ** $P < 0.05$; *$P < 0.10$. *Z* values are in parentheses, 69% correctly predicted d*y*/d*x* is marginal effect at average.
[b]Log likelihood = −157, $N = 271$, LR χ^2 (23) = 59, $P < 0.0000$, Pseudo R^2 = 16%. ***$P < 0.001$; **$P < 0.05$; *$P < 0.10$. *Z* values are in parentheses, 73% correctly predicted.

Uganda favours men. This finding is consistent with others, such as Sanginga *et al.* (2007) who found gender to be significant in the adoption of soil conservation structures which required physical labour in south western Uganda. Other household characteristics – age of household head, education level and family size – were not significant.

From the wealth variables category, size of land owned, gross value of output and TLU were found to be significant predictors. The odds ratio for land was 1.1 which implies that the likelihood of adopting SWC technologies in the Rwizi catchment increased with approximately a 12% increase in land/farm-size owned ceteris paribus. Mbaga-Semgalawe and Folmer (2000) also found farm size to be significant in the adoption of improved conservation in North Pare and West Usambara Mountains in Tanzania. Moreover, the quadratic term on land area was also significant and negative signalling that there is probably a land area threshold for adoption of SWC technologies. This implies that initially the partial effect of land increases the likelihood of adoption but has a diminishing effect as acreage increases beyond a certain point. When the partial effects at average were calculated (Table 4), the overall partial effect of land was 0.097 ((coefficient on land) − (coefficient on land square) multiplied by the scale factor).

The coefficients of the gross value of output and the TLU were significant but negative and the square of TLU was not significant in the full model. The gross value of output had a very significant but small negative coefficient and a very small corresponding odds ratio. This meant that the likelihood of adoption of SWC technologies decreased by about 0.4 as the gross value of output increased ceteris paribus. However, this contradicts our expectation that value of output should increase with SWC technology adoption. This might be attributed to the fact that the SWC technologies considered here may not increase output in the short run as no inorganic fertilizers were used and organic manure usage was very limited.

On the other hand, the size of the livestock herd as measured in TLU impacts on the adoption of SWC technologies. The odds ratio of adopting SWC technologies in the Rwizi catchment decreased by 0.9 as the farmers' TLU increased, ceteris paribus (Table 4). This finding is as expected because, as the livestock herd increases, there is a trade-off between crop and livestock production. The two enterprises transition from the complementary range to the competitive range. The crop–livestock synergy reported by Nkonya *et al*. (2005b) may be feasible for smaller TLU numbers, but at a certain size livestock farmers cannot coexist with crop farmers and eventually congregate with other large-scale livestock producers to avoid conflict.

From the category of institutional variables, access to information measured by the contact with agricultural extension service providers was found to be positive and a highly significant predictor of adoption. This is supported by the very high odds ratio of extension access. The odds ratio of adopting SWC technologies increased by 2.6 in the restricted model or by 2.9 in the full model, as the farmer accessed extension services, holding other factors constant. In Uganda, most of the new agricultural technology information dissemination is extension led thus making extension service provision very important to famers. In this context, the farmer's access to information is vital for technology adoption (Nkonya *et al*. 2005b; Läpple and Rensburg 2011). Generally, in Uganda, smallholder farmers mostly rely on agricultural extension workers who either visit individual farmers or famer groups, to receive information on new technologies.

The dummy variable on soil erosion was not significant in either model. While this dummy was intended to capture information on the biophysical aspects of the farms relative to their locations, its effect was probably more captured by the location dummies represented by the individual sub-counties. That is, the adoption of SWC was significantly different in sub-counties 1, 8 and 9, Bukiro, Ndaija and Itojo, respectively (Table 4). From Table 1, it can be observed that these are the sub-counties that were reported as being degradation hotspots and had extensive wetland encroachments. Branches of NEMA were active in sensitizing and mobilizing encroachers to leave the wetlands in these sub-counties. NAADS was also present in these areas and many farmers were observed to have mulched their banana plantations. These results are consistent with our field observations where we noted a number of gullies on the hillsides, heavy wetland clearance and heavily mulched banana plantations. However, there are two exceptions: sub-county 5 (Bugamba), a land degradation hotspot was found insignificant in contrast to our expectations and sub-county 7 (Rugando) was used as a reference base and was left out from the analysis. In analysing n-categorical cases, one needs to include only $n-1$ of the categorical variables. Likewise, another variable, manure usage dummy which was intended to capture biophysical information, was also found to be insignificant in both models.

These findings are consistent with empirical results on adoption studies elsewhere, such as Mbaga-Semgalawe and Folmer (2000), Nkonya *et al.* (2005b) and Tiwari *et al*. (2008). The only exceptions were observed in the variables age of the household head, education level of household head, family size, main sources of income and visible signs of erosion on the farms that were not significant in contrast to the *a priori* expectations.

Conclusions

This paper explores the factors that influence smallholder farmers in their decisions to adopt SWC technologies in the Rwizi catchment of south western Uganda. The study used cross-sectional survey data collected from 271 households in nine sub-counties in Mbarara, Busheny and Ntungamo districts of south-western Uganda. We used logit models of adoption and compared the performance of restricted against non-restricted logit models of adoption of SWC technologies. The restricted model did not have any interaction or quadratic terms while the non-restricted model had interaction and quadratic terms. As such, the restricted model is taken to be a subset of the full model enabling a likelihood ratio test statistic to be constructed for testing joint exclusion and specifications. The purpose of including quadratics in the non-restricted logit was to discern whether land and TLU had thresholds beyond which adoption of SWC technologies would not be applicable. Age and land were interacted to determine whether land accumulations increased with age in the Rwizi catchment. The results of testing the performance of the restricted and unrestricted models revealed that the full model did not outperform the unrestricted model using the likelihood ratio test.

In addition, the empirical results from our logit models of adoption have underscored the importance of institutional support to the adoption of SWC technologies through the provision of agricultural extension services. Therefore, government support can facilitate long-term soil conservation in these fragile areas. This includes support for research and extension services to facilitate SWC technology generation and dissemination. Information dissemination channels have to be effective and efficient in order to relay this information to the farmers. The importance of well-functioning support institutions cannot be overemphasized. Just as our findings have manifested, the availability of an effective and an efficient public extension system is crucial for farmers to adopt new technologies. A good extension system should be able to invigorate smallholder farmers to be more conscious of their vital soil resources and to use them judiciously for current and posterity generations.

Land size was also found to be significant and positively influenced the adoption of SWC technologies. Since land suitable for agricultural production is limited and given the increasing population, all efforts should be to ensure sustainable utilization of this vital resource for current and future generations. Moreover, the likelihood to adopt SWC technologies increased with land size at first and then decreased as indicated by the quadratic term on land. This is an important signal that there is a land size threshold beyond which the smallholder farm operators may not effectively adopt and employ SWC technologies probably due to limitations of labour and other input resources.

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Notes

1. Farm-level adoption occurs at the individual unit, a farm or household while aggregate adoption is diffusion of a technology in given geographical area or given population. Certain technologies are introduced in packages that include several components, for example, high-yielding varieties, fertilizers and corresponding land preparation practices (Feder *et al.* 1985). However, for SWC technologies in the study area this was not the case. The farmers could choose any of the five SWC technologies independently, hence no issues of divisibility.
2. This was calculated from the straight line method of depreciation using sample average, initial cost of the asset and average useful life for the asset as estimated by the farmers. All the assets were assumed to have a salvage value of zero. This assumption is plausible given that small holder farmers rarely dispose

off any assets. The book values of the individual assets were summed to obtain the total monetary value of productive assets.

3. The TLU was calculated using conversion factors, where one TLU is equivalent to an animal of 250-kg live weight (Jahnke 1982, FAO 1991, Scoones 1995).
4. The future of wetlands in Uganda generally appears threatened from competing land uses, given the rapid conversion rate. Many of the vital products and services they provide will be forfeited if there is no reversal of the status quo.

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