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Adoption intensity of soil and water conservation technologies: a case of South Western Uganda

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Abstract Important signs of agricultural land quality deterioration are apparent in many countries, including declining yields and a switch to crops that demand fewer nutrients. This is despite efforts to curb land degradation rates through the years, including the attempt to promote use of soil and water conservation (SWC) technologies. This study was done in Kabale district in the South Western highlands of Uganda. Data analysis was done using cross-sectional data from 338 households. A Tobit model was used to identify the factors that influence intensity of adoption of different SWC technologies at parcel level. Results indicate that higher proportions of individual parcels having SWC technologies are associated with availability of labor, education level, and age of the household head, access to SWC related training, more tropical livestock units, neighboring parcels having SWC technologies on them, high fertility levels, location of the parcel, and expected access to parcels in a given period of time. Large size of operated land and long distances from parcels to the homesteads are associated with lower adoption intensity. The importance of each of these aspects varies depending on technologies of focus. Measures to improve the quality of training and extension services have been recommended. In addition, improvement of physical infrastructure such as roads and institutional infrastructure such as tenure security enhancement has been recommended.

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1 Introduction

Majority of the populations in developing countries rely on agriculture for their survival, and yet continued use of agricultural land results in the reduction of both natural soil fertility and productivity (Barbier and Bishop 1995). Soil erosion is the most dominant threat to agricultural productivity (Sullivan 2004), yet it is an inevitable occurrence in any agriculture related activity, especially when efforts to restore lost nutrients and conserve land do not match the exploitation levels. Increased productivity and reduced degradation of land are the most important goals of future sustainable agriculture. The effort to reconcile the three objectives of increasing agricultural production, reducing poverty and ensuring sustainable use of the natural resources have been a continuing battle in many developing countries (Gebremedhin 2004). With two-thirds of arable land expected to be lost in Africa by 2025 (UNCCD 2004), land degradation remains an aspect that has to be addressed urgently.

In order to mitigate worsening soil conditions, growing water shortages and drought and desertification, promotion of soil and water conservation (SWC) technologies has been suggested as a key adaptation strategy for countries in the developing world, particularly in sub-Saharan Africa (Kato et al. 2009). If land management technologies are to be adopted sustainably and produce the desired impacts on productivity and other agronomic aspects, there is still need for rigorous research on what determines sustainable adoption and where particular land management interventions are likely to be successful (Kassie et al. 2010). Successful and sustainable adoption of technologies implies that there is uptake of technologies, and these technologies are used at sustainable rates (levels).

Like most developing countries, Uganda's economy is largely natural resource based, with over 80 % of the population living in rural areas and engaged in agro-pastoralism for food and income (NEMA 2001). Uganda's agricultural sector faces low production and productivity as one of its main challenges. This has been largely attributed to increasing degradation of agricultural land in form of soil erosion and soil nutrient depletion, deforestation, over-grazing and water contamination caused by poor agricultural practices (Tukahirwa 1988). In several regions of Uganda, important signs of soil degradation trends are apparent including declining yields and a switch to crops that demand fewer nutrients (Olson and Berry 2003), yet crops that are switched to may not necessarily be the most suitable to fight hunger and increase household incomes. The losses caused by degradation of the environment are very high especially in the highlands, and the dry lands which are the two areas with the most fragile ecosystems in Uganda (Kakuru et al. 2004). According to Zake et al. (1999), the highlands which account for 27 % of land area and accommodate close to 40 % of the total population, are the worst affected by land degradation in Uganda.

This study was done in Kabale district located in South Western highlands of Uganda. Kabale is a unique study area because it has one of the highest population densities in Uganda (about 300 persons per km^2) and population growth of about 2.2 % per annum (MFPED 2004). Agricultural land in the area is highly fragmented with per capita landholding of 0.1 ha (Kabale District Local Government 2011). As a result, land use pressure is high (Abesiga and Musali 2002) and so is land degradation level, which is up to 90 % in some areas (NEMA 2001). Several SWC technologies including terracing, mulching, trash lines, contour cultivation, agro-forestry, inter-cropping, use of cover crops, fallowing, crop rotation, use of organic manure, trenches and diversion channels have been disseminated in the area (Miiro 2001; Abesiga and Musali 2002; Nkonya 2002; Buyinza and Naagula 2009). While many studies on adoption of SWC technologies have been done in the study area (e.g. Miiro 2001; Nkonya 2002; Buyinza and Naagula 2009; Mugisha and Alobo 2012), no known study has analyzed intensity of adoption of these technologies in that specific area, even though some studies (e.g. Nkonya et al. 2004; Mugisha and Alobo 2012) have studied SWC technology adoption and others (e.g. Barungi et al. 2013) have studied adoption and intensity of adoption in other parts of Uganda.

Benin et al. (2007), in their study of the impact of the National Agricultural Advisory Services Program (NAADS)[1] in Uganda, note that adoption of improved soil fertility management technologies was low compared to other agricultural technologies. While the concern of agricultural technology disseminating institutions is that the disseminated technologies are taken up in the best possible combinations and for the right length of time to realize results (Parvan 2011), Sserunkuuma (1999) argues that the most important driver of farmers to adopt is agricultural technology profitability. This means that the farmers, having decided to adopt agricultural technologies, must invest in them above break-even levels. Therefore, the level of use of technologies ultimately determines the sustainability of adoption decisions, due to its role in determining the economic feasibility of the enterprises in which investments are made.

In addition, incomparable differences in the (socio-economic, agro-ecological, institutional) settings under which decisions on whether or not to adopt and to what extent to adopt technologies are made, do not allow for generalization with regard to the important determinants of these important adoption steps (Bekele and Drake 2003; Anley et al. 2007). While efforts are geared toward increasing the adoption rates of the SWC technologies in the study areas, the approaches aimed at improving sustainable use of these technologies may have to be revised.

The objective of this paper is to explain the determinants of intensity of adoption of SWC technologies, in terms of the proportion of parcel area covered by SWC technologies. We argue that intensity of adoption of SWC technologies is a very important aspect of sustainable adoption of agricultural technologies which is still not widely researched in a country where agricultural production will still be key to development for many years to come. Basing on these factors behind degree of uptake, the paper recommends possible means to increase sustainable adoption.

The rest of this paper is organized as follows: Section two describes the materials and methods used, while section three presents the results. Section four discusses the results, and section five contains the conclusions of the study.

2 Materials and methods

2.1 Sampling and survey data collection

The sampling procedure followed three steps. First, the organizations disseminating SWC technologies in Kabale district were identified from the district headquarters. These were both government and Non-Government Organizations (NGOs) including Nature Uganda,

[1] NAADS is the main government body disseminating soil and water conservation technologies in Uganda.

Africa 2000 Network, CARITAS, Care Uganda, National Agricultural Advisory Services (NAADS), District Environmental Conservation Program, and District Forestry Offices. Second, lists of all households participating in SWC activities were obtained from these organizations. A compiled list comprised a total of 1,350 households from the three counties in Kabale district (Rubanda, Ndorwa and Rukiga). A sample of 273 households was randomly selected using a table of random numbers. The sample comprised of households using SWC technologies (adopters).

To select households that were not using any of the SWC technologies (non-adopters) in the same areas focused on by the organizations mentioned above, lists of all households in the communities at local council-one (LC1) level were obtained.[2] For every 10 sampled adopters, 2–3 non-adopters were randomly chosen from the LC1 list. The decision to choose 2–3 households of non-adopters was based on brief interviews done with each group of service providers of the organizations mentioned above from where adopters were sampled. The aim of these interviews was to establish a percentage of households using SWC technologies in the district. From these interviews, it was established that the estimated average percentage of adopters in the population was at least 73. Based on this information, we sampled 65 households of non-adopters, making a total sample of 338 respondents.

The data were collected between June and August 2012. Data collected included both household and parcel level information. The overall selected sample had an operated total of 1,299 parcels, 1,079 of which belonged to adopters. Due to missing observations and non-response to some of the key questions in the survey, our analysis at parcel level uses 976 parcels.

2.2 The technologies

The SWC technologies being used in the study area are a mixture of both traditional and modern/improved/disseminated. They include mulching, trash lines, fallowing, manure and compost, trenches/diversion channels, *fanya-chini* terraces, bench terraces, contour plowing, grass strips, intercropping, crop rotation, cover crops, *Fanya-juu* terraces, minimum tillage, alley cropping, and agro-forestry. In this study, we focus on the intensity of adoption at parcel level, and also at technology specific level. In the latter case, we focus on the improved SWC technologies that have sufficient observations (*fanya-chini* terraces, trenches and diversion channels, grass strips, and agro-forestry). Improved technologies that have sufficient observations in this case have been taken as those which were adopted by at least 30 farmers. Table 1 reports the technologies and their level of use in the sample.

2.3 Analytical methods

The intensity of adoption of technologies or the level of use of technology has been described as the second of two stages of the adoption process; the first stage being the decision to use a technology (Bett 2004; Sall et al. 2000). Farmers decide how to use their land in light of their objectives, production possibilities, and constraints (Lutz et al. 1994). Farmers are assumed to aim at maximizing their utility when making decisions. However, whereas the principal economic rationality assumption—the utility maximizing objective of individual farmers, might be the same for farmers everywhere, the specific attributes influencing the utility of farmers and adoption decisions are far from being uniform (Bekele and Drake 2003). The variability in how farming is organized and managed is a

[2] LC1 is the lowest administrative unit in Uganda.

Table 1 Soil and water conservation technologies in the study area

Technology	Percentage of adopting households ($n = 273$)
Traditional conservation technologies	
Manure/compost	57.14 (156)
Mulching	27.47 (75)
Trash lines	23.08 (63)
Crop rotation	22.34 (61)
Intercropping	15.38 (42)
Cover crops	13.55 (37)
Fallowing	5.13 (14)
Contour plowing	1.83 (5)
Alley cropping	0.73 (2)
Minimum tillage	0.37 (1)
Modern/improved technologies	
Fanya-chini terraces	69.23 (189)
Trenches/diversion channels	32.97 (90)
Grass strips	30.4 (83)
Agro-forestry	13.92 (38)
Bench terraces	2.93 (8)
Fanya-juu terraces	0.37 (1)

way of farmers' adopting different self-assurance strategies to minimize risks to their food security and livelihoods (Dessalegn 1991; Legesse and Drake 2005). This depends on the household characteristics and variations in the physical environment they operate in, access to resources, and prevailing institutional context (Dessalegn 1991).

Suppose that Y_{ij} represents a discrete choice of household i among j SWC technology alternatives. Let U represents the utility of technology j for a particular household i as a function (G_i) of parcel and household characteristics denoted by a vector X, plus a disturbance term ε with zero mean. The household is assumed to have preferences defined over a set of technology alternatives (Bekele and Drake 2003) such that:

$$U_{ij} = a_{ij}G_i(X_j) + \varepsilon_{ij} \quad i = 0, 1;\, j = 1, 2\ldots n \tag{1}$$

Whether a household adopts a technology or not, depends on the costs and benefits of each technology (Shiferaw and Holden 2001), which determine (unobserved) utility that is expected from adoption. Thus, a household will choose alternative j if U_{ij} is the largest of $U_{i1}\ldots U_{ij}$ i.e., if $U_{i1} > U_{i0}$.

After the household has decided and adopted SWC technologies, the next decision is to determine the intensity of adoption. To determine the intensity of adoption of SWC technologies, and following McDonald and Moffitt (1980), we assume that $G_i$is linear in Eq. (1), and the underlying stochastic model in Tobit form (Tobin 1958) is as follows:

$$\begin{aligned} Y_i &= Y_i^* \quad \text{if } Y_i^* > 0, (Y_i^* = \beta X_i + e_i) \\ Y_i &= 0, \ \text{otherwise} \end{aligned} \tag{2}$$

where Y_i^* is the unobservable latent variable, β_i represents a vector of unknown parameters to be estimated, e_i is a random error term that is assumed to be independently and normally distributed with zero mean and constant variance σ, and the rest of the variables are as defined earlier. The Tobit model uses maximum likelihood estimation methods and generates expected use rates of the technology in question for adopters and the expected elasticity of probability of adoption for non-adopters (Bett 2004). The change in the probability of the expected level of use of the technology for adopters and the elasticity of the probability of being an adopter are given by the relationship between the expected value of all observations E_Y and the conditional value above the limit E_Y^*. The relationship is as follows:

$$E_Y = F(z)\, E_Y^*, \tag{3}$$

where $F(z)$ is the cumulative density normal distribution function, and $z = X\beta/\sigma$. The effect of the kth variable on Y is as follows:

$$\partial E_Y/\partial X_k = F(z)\,(\partial E_Y^*/\partial X_k) = E_t^*(\partial F(z)/\partial X_k) \tag{4}$$

From Eq. (4), total change is then disaggregated into expected level of use of Y and the probability of being an adopter. In the study area, the proportions of land with SWC technologies are expected to vary between households and parcels, some households and parcels have zero adoption, which makes use of the Tobit model appropriate (Tobin 1958; McDonald and Moffitt 1980) for three reasons. First, the Tobit model is suitable for analysis of the intensity of adoption especially in cases where the dependent variable is continuous with lower and upper limits. Second, it gives efficient, unbiased, and normally distributed coefficients.

From Eq. (2), the general analytical model estimated and suppressing the identification subscripts is as follows:

$$\mathrm{SWC}_{\mathrm{Intensity}\,g} = X_{\mathrm{hhd}}\beta + \delta X_{\mathrm{parc}}\alpha + \varepsilon \tag{5}$$

where $\mathrm{SWC}_{\mathrm{Intensity}}$ is the intensity of adoption of SWC technologies at g level, where g defines adoption at parcel level. Analysis was done at two levels; at the first level, intensity of adoption was defined as the proportion of parcel area with SWC technologies. This included all the improved SWC technologies focused on in this study which include *Fanya chini*, grass strips, trenches, and agro-forestry (Table 1). These were focused on because they were the improved SWC technologies that have sufficient observations. The second level of analysis was focusing on specific technologies, and in this case, the dependent variable was the proportion of the parcel area with a specific SWC technology. X_{hhd} and X_{parc} are vectors of household and parcel level characteristics, respectively. δ is an indicator equal to 1 if the analysis is at parcel level, and 0 otherwise. β and α are parameters to be estimated, and ε is the error term.

The correct identification of Eq. (5), however, may be problematic due to selection bias. Equation (5) is restricted to households that adopted particular SWC technologies which introduces selectivity bias arising from the fact that some households adopting SWC technologies may have different characteristics from non-adopters. Alternatively, even among the adopters, at parcel level, selectivity bias may arise from differences in parcel characteristics that lead to adoption or non-adoption of SWC technologies. However, since the decision to adopt SWC technologies is taken by the household, it is plausible to assume that correcting for selectivity bias is more appropriate at household level than at parcel level. This is due to the fact that if a household has already adopted SWC on some parcels, it is more likely that such a household adopts similar technologies on other parcels if the need arises, but non-adopter are less likely to do so. Although we recognize that the decision to adopt SWC technologies is likely to be influenced by the parcel level characteristics, if the household has limited ability in terms required resources then adoption of these technologies is less likely to happen. For these reasons, the test for selectivity bias is done at household level not parcel level, which allows the outcome indicator of intensity of adoption of SWC technologies among adopters to range from 0 acres for parcels without SWC technologies to an area >0 for parcels with SWC technologies.

To correct for selectivity bias in (5) requires the use of exclusion restrictions (Wooldridge 2010), whereby one needs to identify variables which directly influence the decision to adopt SWC technologies, but such variables should not have direct impact on the intensity of adoption. However, we face a challenge in identifying reasonably valid exclusion restrictions from our sample households. To overcome this problem, we utilize the control function estimator of Klein and Vella (2010). This approach does not require the use of exclusion restrictions to control for selectivity bias. This approach requires joint estimation of Eq. (5) and the household decision to adopt SWC technology as follows:

$$\mathrm{SWC_{di}} = X_{\mathrm{hhd}}\sigma + \upsilon_i \tag{6}$$

where $\mathrm{SWC_{di}}$ is household i's decision to adopt SWC technologies, X_{hhd} is as defined in (5), σ is the vector of parameters to be estimated, and υ_i is the error term.

To correctly estimate (5), we used a procedure developed by Klein and Vella (2010), who go through a complex theoretical procedure not repeated here, but we only provide the necessary identification steps. Klein and Vella show that if the errors ε or υ_i are heteroskedastic, it is appropriate to use these errors to generate the exclusion restriction variable. More specifically, if the ratio of standard deviation of ε in (5) to the standard deviation of υ_i in (6) varies with the covariates, then identification is attained and no exclusion restriction is required. Then, the generated ratio of standard deviations is used as an exclusion restriction variable in Eq. (5). If the coefficient on this ratio is significant, then we reject the null hypothesis that there is no selectivity bias in the intensity of adoption of SWC technologies at parcel level in Eq. (5), but if the coefficient is insignificant, we fail to reject null hypothesis. In case of failure to accept the null hypothesis, the standard errors are bootstrapped to correct for the generated regressor (ratio of standard deviation of ε to that of υ_i). The estimation of standard deviations followed two steps.

First, the decision to adopt SWC technologies Eq. (6) was estimated using an ordinary probit regression to generate generalized residuals for identification of the outcome model (Freedman and Sekhon 2010) regardless of the error structure (Klein and Vella 2010). An estimate of the standard deviation of υ_i was obtained as the square root of the expected value from the regression of squared generalized residuals υ_i on X_{hhd}. To improve the efficiency of the estimates, following Klein and Vella (2010), we repeated the first step and estimated Eq. (6) using a procedure similar to generalized least squares where explanatory variables are normalized using the estimated standard deviation.

Second, similar to the first step, the standard deviation of ε was obtained by running a Tobit regression in Eq. (5) to obtain generalized residuals (ε) following Cameron and Trivedi (2009). Then, the squared residual (ε) was regressed on X_{hhd} and X_{parc} to obtain the standard deviation.

3 Analysis results

3.1 Respondent and parcel level characteristics

Table 2 reports both household and parcel level characteristics. For household level characteristics, we also report non-adopters results. The sample households are headed by

Table 2 Characteristics of the respondent households and parcels

Variables		Mean (SD)	
		Adopters ($n = 273$)	Non-adopters ($n = 65$)
Household level			
Fraction of operated parcels with SWC technologies on them		0.713 (0.297)	0.000 (0.000)
Household size (Number of persons)		6.681 (2.699)	5.369 (2.702)
Proportion of household members aged 15–65 years		0.592 (0.253)	0.673 (0.250)
Tropical livestock units (TLU)		0.940 (1.349)	0.467 (0.669
Land operated in 2011 (Hectares)		1.064 (0.717)	0.742 (0.586)
Proportion of land that is titled		0.071 (0.224)	0.072 (0.234)
Age of the household head (Years)		43.8 (13.329)	42.646 (15.768)
Education level of the head (years in Sch.)		5.861 (3.602)	5.277 (3.955)
Gender of the household head (% male)		87.18	86.15
Participation in soil and water conservation related training (% Yes)		75.46	10.77
Total parcels accessed in 2011		3.956 (1.477)	3.354 (1.595)
	Entire sample $n = 976$	Adopted on ($n = 665$)	Not adopted on ($n = 311$)
Parcel level (adopters only)			
Proportion of parcel area covered by SWC technologies	0.359 (0.392)	0.523 (0.371)	0.000 (0.000)
Distance of the parcel from the homestead (Km)	1.32 (1.19)	1.26 (1.18)	1.41 (1.19)
Number of SWC technologies on a parcel	1.96 (2.63)	3.47 (2.64)	0.00 (0.00)
Neighboring parcels have SWC technologies (% yes)	22.01	31.17	10.2
Household expects to still access the parcel in 2 years (% yes)	86.15	88.7	82.81
Household expects to still access the parcel in 5 years (% yes)	82.92	86.9	77.73
Fertility of the parcel is perceived as poor (% yes)	7.22	5.57	9.38
Fertility of the parcel is perceived as high (% yes)	43.42	42.02	45.12
Fertility of the parcel is perceived as moderate (% yes)	49.36	52.41	45.51

Table 2 continued

	Entire sample $n = 976$	Adopted on ($n = 665$)	Not adopted on ($n = 311$)
The parcel is located in the valley (% yes)	29.31	27.26	31.84
The parcel is located on a hillside (% yes)	61.34	63.55	58.59
The parcel is located on a hilltop (% yes)	9.35	9.19	9.57

Figures in parentheses are standard deviations

Table 3 Estimated parcel level Tobit model results for factors that influence proportion of the parcel area covered by SWC technologies

Variables	General		Trenches		*Fanya Chini*		Grass strips		Agro-forestry	
	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
Coefficients (Robust SE)										
Proportion of household members aged 15–65 years	0.198 (0.121)	0.112 (0.196)	0.100 (0.145)	0.103 (0.139)	0.273 (0.177)	0.056 (0.293)	0.497** (0.248)	0.548* (0.289)	−0.097 (0.094)	−0.103 (0.095)
Education of the household head (years in school.)	0.001 (0.009)	0.000 (0.014)	0.001 (0.013)	−0.001 (0.011)	0.010 (0.014)	0.004 (0.021)	−0.010 (0.017)	−0.011 (0.017)	0.024*** (0.008)	0.024*** (0.007)
Age of the household head (Years)	0.000 (0.003)	0.001 (0.004)	−0.001 (0.004)	−0.001 (0.003)	−0.000 (0.004)	0.001 (0.006)	−0.004 (0.006)	−0.005 (0.006)	0.007*** (0.002)	0.007*** (0.002)
Household accessed SWC training (1 = yes)	0.129* (0.072)	0.405* (0.234)	0.062 (0.101)	−0.045 (0.208)	0.300** (0.127)	0.815** (0.355)	0.208 (0.165)	0.047 (0.358)	0.013 (0.091)	0.045 (0.139)
Gender of the household head (1 = Male)	0.059 (0.090)	0.018 (0.136)	−0.053 (0.102)	−0.035 (0.106)	0.046 (0.110)	−0.008 (0.169)	0.048 (0.130)	0.068 (0.139)	−0.229* (0.133)	−0.238** (0.113)
Land operated (Ha)	−0.146*** (0.036)	−0.106* (0.060)	−0.258*** (0.046)	−0.273*** (0.051)	−0.148*** (0.049)	−0.087 (0.076)	−0.104 (0.066)	−0.120* (0.072)	−0.079** (0.033)	−0.070 (0.046)
Proportion of land operated that has a title	0.053 (0.079)	0.165 (0.139)	0.086 (0.117)	0.011 (0.201)	0.266 (0.185)	0.344 (0.345)	0.063 (0.193)	0.058 (0.490)	−0.068 (0.046)	−0.049 (0.091)
Tropical livestock units (TLU)	0.034 (0.026)	0.065 (0.053)	0.029 (0.029)	0.016 (0.037)	0.031 (0.039)	0.078 (0.072)	0.144*** (0.044)	0.138*** (0.045)	0.006 (0.014)	0.012 (0.025)
Distance of the parcel from the homestead (Km)	−0.073*** (0.021)	−0.072*** (0.023)	−0.032 (0.022)	−0.031 (0.022)	−0.076** (0.031)	−0.073** (0.034)	−0.096** (0.038)	−0.097** (0.043)	0.018 (0.016)	0.018 (0.016)
Neighbors' parcels have SWC technologies (1 = yes, 0 = No)	0.178*** (0.061)	0.181** (0.090)	0.012 (0.087)	0.008 (0.100)	0.168* (0.098)	0.170 (0.139)	0.116 (0.126)	0.119 (0.116)	0.006 (0.050)	0.003 (0.048)
Expectation to access the parcel in 2 years (1 = yes, 0 = No)	−0.396** (0.179)	−0.375* (0.221)	−0.169 (0.196)	−0.165 (0.231)	−0.289 (0.246)	−0.234 (0.319)	0.205 (0.304)	0.202 (0.273)	−0.608*** (0.193)	−0.600*** (0.156)
Expectation to access the parcel in 5 years (1 = yes, 0 = No)	0.590*** (0.169)	0.575*** (0.201)	0.396** (0.186)	0.386* (0.212)	0.650*** (0.224)	0.622** (0.302)	0.151 (0.266)	0.150 (0.232)	0.573*** (0.180)	0.567*** (0.144)

Table 3 continued

Variables	General		Trenches		*Fanya Chini*		Grass strips		Agro-forestry	
	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
Fertility of the parcel is perceived as high##	0.478*** (0.116)	0.4981*** (0.144)	0.199 (0.123)	0.208* (0.122)	0.388*** (0.138)	0.395** (0.165)	0.614*** (0.167)	0.610*** (0.169)	0.144 (0.194)	0.146 (0.108)
Fertility of the parcel is perceived as moderate##	0.197* (0.109)	0.200 (0.134)	−0.028 (0.116)	−0.022 (0.117)	0.129 (0.128)	0.136 (0.156)	0.209 (0.157)	0.208 (0.160)	−0.061 (0.192)	−0.058 (0.111)
The parcel is located on a hillside###	0.018 (0.065)	0.021 (0.077)	−0.001 (0.073)	−0.001 (0.067)	−0.011 (0.085)	0.000 (0.096)	0.301** (0.119)	0.299*** (0.112)	0.110 (0.086)	0.108* (0.060)
The parcel is located on a hilltop###	0.094 (0.106)	0.098 (0.122)	−0.093 (0.163)	−0.093 (0.169)	−0.026 (0.131)	−0.040 (0.120)	0.351** (0.164)	0.346** (0.153)	0.087 (0.156)	0.083 (0.109)
Control function		0.275 (0.184)		−0.102 (0.177)		**0.571*** (0.310)		−0.159 (0.325)		0.030 (0.113)
Constant	−0.270 (0.213)	−0.601 (0.416)	0.293 (0.263)	0.439 (0.352)	−0.556* (0.297)	−1.179* (0.603)	−0.864** (0.373)	−0.663 (0.545)	0.137 (0.293)	0.086 (0.300)
Sigma constant	0.716*** (0.032)	0.715*** (0.051)	0.488*** (0.034)	0.488*** (0.028)	0.822*** (0.046)	0.817*** (0.072)	0.657*** (0.055)	0.656*** (0.049)	0.232*** (0.022)	0.232*** (0.015)
χ^2		67.118***		67.788***		45.284***		83.973***		71.836***
Pseudo R^2	0.058	0.060	0.104	0.105	0.051	0.055	0.141	0.142	0.531	0.531
Number of observations	976	976	366	366	673	673	290	290	179	179

Figures in parentheses are standard errors

***, **, * Denote estimated parameter is significantly different from zero at the 1, 5 and 10 % test levels, respectively

Poor fertility is base for comparison, ### Valley location is base for comparison

relatively active persons aged 44 years (43 years for non-adopters) on average with 6 years of education (5 years for non-adopters), and about 87 % of them are male. The households are composed of six persons on average, operating about one hectare of land. Over 60 % of the adopters' sampled parcels are located on hillsides, and with about 90 % of the sampled parcels perceived as either highly or moderately fertile.

3.2 Determinants of intensity of adoption of SWC technologies

Table 3[3] shows factors that influence intensity in terms of proportion of individual parcels covered by the technologies. The highly significant chi-square values for all the models indicate the existence of useful information in the estimated regressions. For purposes of comparison, the results presented in Table 3 show two models (1 and 2) for each of the regressions. Model 1 results are not controlled for selectivity bias, while model 2 results are controlled for selectivity bias. Because selectivity bias was found not to be a serious issue as indicated by the insignificant values of the control function, our subsequent discussion focuses on model 1 for all regressions, except *fanya-chini* terraces, where we focus on model 2 after controlling for selectivity bias.

Results indicate that the proportion of household members aged 15–65 years significantly ($p < 0.05$) affects intensity of adoption for grass strips. Education level of the household head is shown to positively affect intensity of adoption of agro-forestry ($p < 0.01$). In addition, intensity of adoption of agro-forestry is likely to be higher if households are headed by older farmers ($p < 0.01$). Results further indicate that households in which at least one member received SWC technologies training are more likely to have a higher intensity of adoption at parcel level for the general model and *fanya-chini* terraces ($p < 0.1$). A higher proportion of parcels is also shown as likely to be covered by agro-forestry if households are female headed than otherwise ($p < 0.1$). Households with more tropical livestock units are likely to have higher intensity ($p < 0.01$) of adoption of grass strips. Size of land operated by the household was shown to negatively influence intensity at all levels where it was significant.

Whether neighboring parcels have SWC technologies on them is shown to contribute toward increasing intensity of adoption ($p < 0.01$) for the general model. Expectation to still use a particular parcel after 5 years also positively influences intensity of adoption for the general model ($p < 0.01$), trenches, *fanya chini* ($p < 0.05$), and agro-forestry ($p < 0.01$). On the other hand, expectation to still use a particular parcel in the next 2 years had the opposite result for the general model ($p < 0.05$) and agro-forestry ($p < 0.01$). A longer period of expectation to access the parcel is related to security of tenure.

Results indicate that parcels whose fertility levels are perceived as high by the household and those with fertility levels perceived as moderate are more likely to have higher proportions covered by SWC technologies ($p < 0.01$ and $p < 0.1$, respectively), compared to parcels perceived to be of low fertility level. This means that households may not be investing in parcels whose fertility levels are perceived as very low. Specifically, *fanya-chini* terraces and grass strips seem to be used at higher intensities when parcel fertility levels are perceived as high ($p < 0.05$ and $p < 0.01$, respectively). Results further indicate that parcels located on hilltops and on hillsides are more likely ($p < 0.05$) to have higher proportions covered by grass strips, compared to those located in valleys.

[3] For purposes of comparison, and to check the robustness of the models, the same results are presented in Appendix, with the dependent variable excluding parcels without SWC technologies.

In all significant cases for distance of the parcel from the homestead, results indicate that it is associated with low adoption intensity. The intensity of adoption generally is lower as the distance between the parcel and homestead increases.

4 Discussion

Generally, results from the Tobit models indicate that depending on how and at what level intensity of adoption of SWC technologies is defined, the important determinants are likely to change, both in terms of relationships and magnitude.

The positive effect of proportion of household members aged 15–65 years on intensity of adoption can be related to the associated labor requirements of intensifying SWC technologies on a parcel. Some studies (e.g. Nkonya 2002) have used household size as a measure of labor availability. In those studies, household size has been shown to give mixed indications and has attracted different lines of argument. For example, Nkonya (2002) found that family size reduced the probability to adopt due to land fragmentation, and possible competition for land between crops and conservation technologies. Mazvimavi and Twomlow (2009) and Sidibe (2005) found that household labor availability did not limit the uptake of conservation farming for vulnerable households in Zimbabwe. Contrary to their findings, Shively (1998), Thangata et al. (2002), Anley et al.(2007) and Yila and Thapa (2008) found available agricultural labor force to be positively related with adoption of soil conservation, and out-migration (reduction of potential labor force) to have the reverse effect. Where the source of labor for intensification is not the household members only (for example, in cases where it is at communal level), the importance of household size and composition as a source of labor may diminish.

Education level of the household head has been associated with ability to process information faster, including understanding associated costs and benefits of technologies (Bett 2004). Education level has had mixed results in research, with some studies (Nkonya 2002; Bett 2004) finding that it has a negative effect on adoption and intensity of adoption of some SWC technologies. Other studies, however (e.g. Anley et al. 2007), found education to positively impact adoption intensity. Education is also associated with a higher likelihood of the household head to have other sources of income, which can lower investment in agriculture, and the intensity of adoption as a result. Where the off-farm labor market is competitive, education may negatively influence adoption intensity because of off-farm activities. In the absence of these markets, however, education can have the opposite effect due to the ability of the educated farmer to understand the dynamics and benefits of conservation technologies.

Results from other studies show mixed signs of the influence of age of the household head on the intensity of adoption of SWC technologies. Age is expected to be associated with experience and availability of the necessary resources for adoption of SWC technologies. Anley et al. (2007) and Bett (2004) found age of the household head to negatively influence adoption and intensity of adoption. Bekele and Drake (2003), Sidibe (2005) and Baidu_Forson (1999) did not find support for the influence of age on conservation decisions by farmers, yet in other studies (e.g. Amsalu and de Graaff 2007; Nkonya 2002), age affected adoption positively, with older farmers more likely to adopt land improvement technologies than younger farmers.

The positive influence of access to SWC extension services and training is in line with most previous findings. For example, Anley et al. (2007) and Tenge et al. (2004) found that extension visits were important variables increasing the probability and intensity of adoption of different conservation technologies, while Sserunkuuma (2005) found that participation in agricultural training and extension positively influenced use of land management practices. Related to conservation training, is the positive influence on intensity of adoption, when neighbors' parcels have SWC technologies. It can be argued that this factor is related to location of the parcels and therefore adoption is not entirely due to the influence of neighboring parcels. However, in the case where there is improvement in physical soil conservation and observed higher production on the parcel, this can influence some otherwise uninterested neighboring farmers to do conservation activities. Training and extension services, in addition to providing the necessary information that leads to a sustainable adoption process, also indirectly improve social capital that results in self-help groups, and positive influence among households, including adoption related influence.

Female headed households were likely to adopt more intensely at household level than the male-headed, which was unexpected especially for agro-forestry, which involves a relatively long-term investment. However, this is plausible in cases where farm level decisions are made by female members of the households, also including provision of farm labor. Contrary to these findings, Thangata et al. (2002) found that adoption of technologies has been positively associated with male-headed households, and they associated this result with ability to provide more farm labor.

Endowment in terms of land had a negative effect on intensity of adoption. This was expected given the fact that more land would require more labor, and possibly a higher number of technologies, given the diverse characteristics of the parcels. This result however, contradicts previous findings. For example, Anley et al. (2007) found that larger cultivated area positively affects use and intensity of use of improved soil bund and improved cutoff drain while Mazvimavi and Twomlow (2009) found that an increase in plot sizes was associated with adoption of more components of conservation farming in Zimbabwe.

Tropical livestock units of households are expected to reflect the asset status of the households and can be an indicator of ability to afford conservation inputs. Revenue from livestock could enable the household to cover larger areas of individual parcels with technologies.

The negative sign of expectation to access a parcel in 2 years versus access in 5 years with the latter having a positive sign was expected, especially when looked at in terms of security of tenure. Farmers are likely to invest more in conservation technologies if they are sure about benefiting from the resulting improved productivity. That is, if they are assured of still owning the land by the time of reaping the benefits of conservation. These results are similar to those of Anderson and Thampapillai (1990) and Lutz et al. (1989) who found that insecure land tenure can affect smallholder investment in SWC measures negatively by restricting planning horizons. Title to a parcel is perceived as a form of security of ownership of a parcel and assurance of future use of land and can therefore encourage investments on the land (Zirahuka 1998). FAO (2002) and Gebremedhin and Swinton (2003) argue that stakeholder commitment to land management is more likely to improve if there is clarity concerning land titles and property rights. According to Anley et al. (2007), however, the existence of well-defined and enforceable property rights to land is a necessary but not sufficient condition to use soil conservation technologies, and use of these technologies is dependent on the existence of several additional factors. In addition, Anley et al. (2007) argue that households' perception of tenure security may be more important than formal rules/documents.

Parcels perceived as fertile seemed likely to be more intensely adopted on than those perceived as not fertile. This has implications for policies that target overall improvement of general agricultural land. It would mean that the fertile and fairly fertile parcels may improve, while the less productive parcels may get even less attention, and thus not improve in the long run. Contrary to these results, a FAO (2008) study noted that a number of environmental conditions including erosive rainfall, degraded and eroded soils, and hilly topography, might speed up the successful promotion of conservation agriculture, since the results from adoption of better land management technologies under these conditions are clearer.

5 Conclusions and recommendations

Sustainable adoption of SWC technologies is key in reduction of land degradation trends. However, the decision to adopt becomes meaningful if the levels (intensity) of adoption are sustainable, in terms of conserving agricultural land successfully.

The current agricultural policy in many developing countries emphasizes improving agricultural productivity in sustainable ways. Some of the efforts put in place to achieve this end have included extension services and training of farmers. This study concurs that intensity of adoption can be improved through improvement of access to training and extension services. However, in addition, approaches that are geared toward dissemination of SWC technologies should also fully sensitize households on the nature (long term) and extent of benefits from adopting SWC technologies including taking up all the components of particular technologies in order to fully benefit.

Key infrastructure such as feeder roads would reduce the average time taken to access parcels, and ease transfer of outputs and inputs. Further, for parcels that have longer distances from homesteads, voluntary exchange of parcels among farmers would ensure that farmers have better access to parcels that are nearer to homesteads. Voluntary transfer of parcels, however, is affected by tenure security, whereby farmers can only exchange parcels to which they have got/perceive assured future ownership. In addition, farmers are not likely to invest heavily in those parcels to which they are not assured of possession in future. Even though processes toward formalizing land ownership including registration and documentation would increase expectations of security and thereby favor conservation efforts, the most important aspect is that property rights are guaranteed.

The role played by fellow farmers in technology adoption and intensity of adoption decisions is apparent, in terms of the influence on neighboring parcels if a farmer invests in conservation on a given parcel. This implies that technologies that target key farmers first, due to their influential role, and those that target farmer groups and organized community clusters are likely to be more successful.

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Appendix

See Table 4.

Table 4 Estimated parcel level Tobit model results for factors that influence proportion of the parcel area covered by SWC technologies (Without parcels that are not adopted on)

Variables	General		Trenches		*Fanya Chini*		Grass strips		Agro-forestry	
	Model 1	Model 2	Model 1	Model 2	Model 1	Model 1	Model 2	Model 1	Model 2	Model 1
Coefficients (Robust SE)										
Proportion of household members aged 15–65 years	0.211** (0.083)	0.176** (0.080)	−0.083 (0.104)	−0.087 (0.104)	0.251** (0.121)	0.293*** (0.110)	0.264 (0.211)	0.173 (0.192)	0.069 (0.067)	0.082 (0.066)
Education of the household head (years in school.)	0.021*** (0.006)	0.021*** (0.006)	0.025*** (0.008)	0.027*** (0.008)	0.023*** (0.008)	0.024*** (0.008)	−0.006 (0.012)	−0.004 (0.012)	0.015*** (0.005)	0.014*** (0.005)
Age of the household head (Years)	0.005*** (0.002)	0.005*** (0.002)	0.013*** (0.003)	0.013*** (0.003)	0.005** (0.002)	0.005** (0.002)	0.002 (0.004)	0.003 (0.004)	0.002 (0.002)	0.001 (0.002)
Household accessed SWC training (1 = yes)	−0.060 (0.102)	0.074 (0.048)	−0.051 (0.144)	0.066 (0.067)	0.080 (0.158)	−0.036 (0.080)	−0.501* (0.285)	−0.238** (0.114)	0.223** (0.096)	0.147*** (0.049)
Gender of the household head (1 = Male)	−0.047 (0.061)	−0.065 (0.060)	−0.019 (0.075)	−0.040 (0.072)	−0.056 (0.074)	−0.046 (0.074)	−0.067 (0.105)	−0.104 (0.099)	−0.258*** (0.083)	−0.232*** (0.079)
Land operated (Ha)	−0.270*** (0.029)	−0.250*** (0.025)	−0.379*** (0.036)	−0.362*** (0.031)	−0.310*** (0.038)	−0.325*** (0.034)	−0.213*** (0.050)	−0.191*** (0.045)	−0.007 (0.033)	−0.029 (0.023)
Proportion of land operated that has a title	−0.225*** (0.080)	−0.170** (0.071)	−0.240* (0.134)	−0.161 (0.102)	−0.308** (0.147)	−0.325** (0.146)	−0.299 (0.292)	−0.287 (0.293)	−0.016 (0.067)	−0.065 (0.040)
Tropical livestock units (TLU)	0.039** (0.019)	0.053*** (0.016)	−0.011 (0.025)	0.003 (0.020)	0.069*** (0.025)	0.061*** (0.022)	0.140*** (0.031)	0.150*** (0.030)	0.012 (0.018)	−0.002 (0.010)
Distance of the parcel from the homestead (Km)	−0.001 (0.015)	−0.001 (0.015)	0.033** (0.016)	0.032* (0.016)	0.023 (0.020)	0.023 (0.021)	−0.018 (0.031)	−0.016 (0.031)	0.036*** (0.011)	0.035*** (0.011)
Neighbors' parcels have SWC technologies (1 = yes, 0 = No)	−0.117*** (0.043)	−0.113*** (0.043)	−0.244*** (0.068)	−0.239*** (0.068)	−0.142** (0.064)	−0.146** (0.064)	−0.038 (0.083)	−0.046 (0.083)	−0.001 (0.035)	0.007 (0.034)
Expectation to access the parcel in 2 years (1 = yes, 0 = No)	−0.111 (0.133)	−0.102 (0.134)	−0.234 (0.176)	−0.238 (0.176)	−0.139 (0.186)	−0.148 (0.186)	0.241 (0.241)	0.220 (0.242)	−0.316* (0.176)	−0.358** (0.171)
Expectation to access the parcel in 5 years (1 = yes, 0 = No)	0.165 (0.124)	0.159 (0.125)	0.360** (0.159)	0.372** (0.159)	0.272 (0.169)	0.275 (0.169)	−0.313 (0.209)	−0.299 (0.209)	0.241 (0.174)	0.279 (0.170)
Fertility of the parcel is perceived as high##	0.339*** (0.079)	0.338*** (0.079)	0.147* (0.088)	0.138 (0.088)	0.292*** (0.095)	0.293*** (0.095)	0.345*** (0.126)	0.352*** (0.126)	−0.135 (0.097)	−0.133 (0.097)

Table 4 continued

Variables	General		Trenches		*Fanya Chini*		Grass strips		Agro-forestry	
	Model 1	Model 2	Model 1	Model 2	Model 1	Model 1	Model 2	Model 1	Model 2	Model 1
Fertility of the parcel is perceived as Moderate##	0.029 (0.079)	0.030 (0.079)	−0.006 (0.087)	−0.010 (0.087)	0.026 (0.094)	0.025 (0.094)	0.092 (0.123)	0.089 (0.123)	−0.372*** (0.097)	−0.375*** (0.097)
The parcel is located on a hillside###	0.010 (0.041)	0.012 (0.041)	0.086* (0.048)	0.086* (0.048)	0.064 (0.053)	0.061 (0.053)	0.088 (0.078)	0.098 (0.077)	−0.033 (0.048)	−0.026 (0.048)
The parcel is located on a hilltop###	0.081 (0.068)	0.082 (0.068)	0.014 (0.123)	0.014 (0.124)	−0.036 (0.085)	−0.032 (0.085)	0.093 (0.108)	0.106 (0.108)	−0.165* (0.098)	−0.147 (0.097)
Control function	−0.130 (0.088)		−0.112 (0.122)		0.126 (0.148)		−0.251 (0.248)		0.073 (0.079)	
Constant	0.436** (0.184)	0.275* (0.149)	0.223 (0.260)	0.053 (0.183)	0.147 (0.262)	0.288 (0.203)	0.906** (0.405)	0.605** (0.275)	0.624*** (0.214)	0.740*** (0.174)
Sigma constant	0.404*** (0.015)	0.405*** (0.015)	0.295*** (0.016)	0.296*** (0.016)	0.439*** (0.021)	0.439*** (0.021)	0.384*** (0.026)	0.385*** (0.026)	0.150*** (0.009)	0.151*** (0.009)
χ^2	265.312***	263.122***	157.497***	156.661***	146.372***	145.657***	88.286***	87.265***	136.832***	135.972***
Pseudo R^2	0.246	0.244	0.478	0.475	0.200	0.199	0.295	0.292	5.116	5.084
Number of observations	652	652	247	247	432	432	182	182	151	151

Figures in parentheses are standard errors

***, **, * Denote estimated parameter is significantly different from zero at the 1, 5 and 10 % test levels, respectively

Poor fertility is base for comparison, ### Valley location is base for comparison

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