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Factors Affecting Intercropping and Conservation Tillage Practices in Eeastern Ethiopia

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Abstract

In order to combat adverse effects of farmland degradation it is necessary for farmers to adopt sustainable land management and conservation strategies like intercropping and conservation tillage. However, efforts to adopt these strategies are very minimal in Ethiopia. In an attempt to address the objectives of examining factors affecting use of intercropping and conservation tillage practices, this study utilized plot- and household-level data collected from 211 farm households and employed a bivariate probit model for its analysis. The study revealed that intercropping and conservation tillage decisions are interdependent, and that they are also significantly affected by various factors. In addition, conservation tillage and intercropping practices as short-term interventions are found to augment the long-term interventions like terraces, diversion ditches, and tree plantations. The paper highlights important policy implications that are required to encourage intercropping and conservation tillage measures.

Key words

Bivariate probit, conservation tillage, farm management practices, intercropping´.

Introduction

Land degradation has become a global environmental threat currently drawing wide-spread attention from the international community. The coverage in terms of degraded area and its direct effect on the livelihood of the world population signals the severity of the threat. Globally, 24 percent of the land area has been degrading of which about one-fifth is cropland. Viewing it differently, more than 20 percent of all cultivated areas are degrading. In terms of the population being directly affected, about 1.5 billion people depend on these degrading areas for their livelihoods (Bai et al., 2008). It has an abysmal effect on agricultural productivity especially in developing countries where agriculture remains one of the largest sectors in the economy.

Various studies have indicated that the continent of Africa is seriously threatened by land degradation. In effect, countries like Zimbabwe, Ghana and Ethiopia were found to be losing five to nine percent of their agricultural output every year due to land degradation (Bojö, 1996). In such agriculture-based low-income countries, reversing the deterioration of land productivity resulting from environmental degradation, and ensuring adequate food supplies to the fast growing population is a formidable challenge.

Ethiopia, with a population that doubled from about 39.8 million in 1984 to over 79 million in 2009 just within 25 years, is now the second most populous country in Africa with a current annual growth rate of 2.6 percent (CSA, 2008). On the contrary, food gap has increased since the early 1980s, though per capita food availability has remained relatively stable over the years owing to the generous inflow of food aid; and the agricultural sector has registered a growth rate of only 1.7 percent since 1992 with more volatile production as compared to most developing countries (Rashid et al., 2007).

Hence, the country is confronted with the challenge of feeding its population, almost year in and year out. As a result, food insecurity and pervasive poverty epitomize the country as these ravage the lives of a significant portion of the population. According to FAO estimate, for instance, 44 percent of the population in Ethiopia is undernourished with 47 percent of the children suffering from malnutrition (FAO, 2009). Furthermore, the proportion of a population living below 1 US dollar a day (at PPP) is 39 percent (WHO, 2009).

The causes for food insecurity and poverty may be numerous among which land degradation problem mainly resulting from soil erosion and nutrient depletion can be singled out as causing a formidable threat. An estimate based on remote sensing tools indicated that about 26 percent of the land area in Ethiopia has been degrading over the years 1981-2003, directly affecting the livelihoods of about 29 percent of the population (Bai et al., 2008). Available estimates of economic impact of soil erosion also show that it is among the factors contributing to the country's structural food insecurity problem. Soil erosion is estimated to reduce food production by at least 2 percent annually (FAO, 1993). This definitely has a repercussion on the country's national income. In this regard, Sonneveld (2002) indicated that the cost of soil erosion to the national economy is about 1.0 billion US dollars per year. Various studies (Hurni, 1993; Zeleke, 2000; Sonneveld, 2002) have also reported land degradation as a major constraint to agricultural production and food security in Ethiopia.

The problem of accelerating land degradation is especially serious in the intensively cultivated highland parts of the country (Hurni, 1993; Bewket, 2007). Owing to the inherently good soils and relatively abundant rainfall the highlands (>1500 meters above sea level) cover about 46 percent of the land mass, account for 95 percent of the regularly cultivated lands, and support about 88 percent of the human and 75 percent of the livestock population; and these aggravate degradation problems.

In order to combat the adverse effects of land degradation it is necessary for farmers to adopt sustainable land management and conservation strategies, among others, that result in increased productivity and farm income and at the same time maintain the fertility levels of land resources. Farmers' land management strategies affect land degradation level positively or negatively (Norman & Douglas, 1994), as mismanagement of land may lead to land degradation. In addition, it can directly affect productivity (Tchale et al., 2004). Generally, the measures can be long-term conservation structures like terracing, construction of diversion ditches, and tree planting; or it can be short term measures like manure application, fertilizer use, intercropping, and conservation tillage practices.

Intercropping and conservation tillage practices are common practices especially in the highland parts of Ethiopia. These tillage and cropping practices are exercised by the farmers in order to curb problems of soil nutrient depletion and degradation problems in general. Intercropping of sorghum and maize with legumes like haricot beans is a common practice. Farmers have also soil conserving tillage practices like plowing along the contour and minimizing number of tillage which are treated as conservation tillage under this study.

Despite the importance of these practices, there are also farmers who do not adopt some or all of the available techniques either because they are not aware of the increasing problem of land degradation and/or its damaging consequences or because they are trapped in various constraints impeding adoption of the available techniques. These impediments may include factors related to capacity in terms of different livelihood assets, the knowledge or awareness about conservation and land management strategies, and farm-related features.

In this regard, solid empirical analyses on the details of factors affecting use levels of intercropping and conservation tillage are very scarce in the country. This study, therefore, responds to this paucity of empirical information using data at household and plot levels collected from a total of 211 households in three districts of Eastern highlands of Ethiopia. Specifically, this study intends to address the objective of examining factors affecting use of intercropping and conservation tillage practices and how these are interrelated. The paper is organized as follows. The next section discusses about intercropping and tillage practices in the study area, the third section gives details of the analytical frameworks, third section presents the empirical results obtained, and the last section provides concluding remarks.

The study areas in relation to intercropping and conservation tillage

The study area, Eastern Highlands of Ethiopia, is found in Oromia regional state of Ethiopia. It consists of two zones, East Hararghe and West Hararghe zones. Farming systems in the East and West Hararghe zones of Ethiopia constitute complex production units involving a diversity of interdependent mixed cropping and livestock activities. The major annual crops grown in these zones include sorghum, maize, groundnuts, sweet potato, wheat, haricot beans, barley, and others. In addition, the major cash crops like t'chat and coffee have a long-standing tradition in these zones. Production of t'chat (a mild narcotic perennial bush the leaves of which are chewed as stimulants) makes the farming system in Hararghe highlands to be a cash crop-based mixed crop-livestock farming system, and not a mere grain-based mixed crop-livestock system, unlike the case in other parts of the country.

Increasing population density coupled with lack of alternative employment opportunities in rural areas has led to progressive land pressure and caused subsequent shrinking of individual land holdings, fragmentation of available holdings, and expansion into fragile and marginal areas. Despite all these problems in these zones, the technological setup has not been transformed. Farming is still traditional with limited use of yield enhancing modern inputs like improved seeds, fertilizers, irrigation, and others. Use of chemical fertilizer, for instance, was only on 16.7 percent of cereal farms in East Hararghe zone while natural fertilizer was applied on 40.6 percent constituting a total fertilized cereal area of about 57 percent in 2008 (CSA, 2008). Furthermore, investments in a long-term soil and water conservation structures are not to the adequate levels resulting in accelerated land degradation problems.

In a bid to curb a serious trend of land degradation and the resulting dwindling agricultural productivity, some farmers have already made significant progress in dealing with soil erosion problems in their farms by adopting soil conservation and fertility maintenance techniques. Among these practices are intercropping and conservation tillage practices. In the study areas, these practices are considered preferable to other measures like use of fertilizers and manures. This can be because of the fact that intercropping and conservation tillage practices are less costly in terms of the requirements of labor and financial resources, and that they are also more environmentally friendly.

Intercropping, a type of multiple cropping systems involving simultaneous growing of two or more crops in space and time on the same land is a common practice of small-scale farmers in the study areas. In particular, cereal and legume intercropping is recognized as a cropping system with substantial benefit. The main reason for using intercropping system is the fact that it involves use of land and labor more efficiently and hence thought to offer higher benefits for small-scale farmers in terms of productivity, in fact together with the advantage of enhancing soil fertility and lowering production risks as compared to sole cropping. In intercropping, some crops (usually cereals) form relatively higher canopy and deeper root structures than others (e.g. legumes) indicating that the intercropped crops probably have differing spatial and temporal use of radiation, water and nutrient resources resulting in efficient use of these resources. Especially in areas like Hararghe highlands where there is chronic land shortage, intercropping can be among recommended strategies.

The intercropping practice considered in this study is where one annual crop is intercropped with another annual crop; a very common practice in the study area. Typically, cereal crops such as maize and sorghum are dominant crop types; whereas haricot beans, faba beans, field pea, potato, and sweet potato are the associated plant species in the intercropping system. Usually, farmers intercrop one dominant crop type with one or two other associated crop types. In addition, intercropping of maize and sorghum is also common in the area.

The other practice considered here is conservation tillage. Soil losses from water erosion recently are reported to be in excess of natural replacement rates, which in turn adversely affect farm productivity. Land preparation practices are among the most important factors contributing to the erosion problem. It has been recognized that conventional tillage aggravates soil erosion and hence degradation. Conventional tillage tends to create degradation over time by exposing soil to water and wind erosion and by weakening soil structure. This has led to the development of alternative tillage practices to reduce the loss of soil, while keeping the benefits of tilling. These methods can generally be referred to as conservation tillage.

Conservation tillage is the generic term given to soil management systems which aims to conserve natural resources with minimal use of external inputs. It is sometimes synonymously used with conservation farming and conservation agriculture (Fowler & Rockstrom, 2001). According to the glossary of soil science terms, conservation tillage is any tillage sequence, the object of which is to minimize or reduce loss of soil and water (SSSA, 2008). Minimum tillage and contour plowing, which are common in the study area, are among such practices. The critical component of conservation tillage is the minimization of soil disturbances. Reduced (minimum) tillage is a tilling practice with minimum number of plowing frequency as compared to the conventional tillage. It enables to leave some crop residues on the farm. Minimum tillage can also be in terms of depth of plowing. This practice uses minimal disturbance to prepare the seedbed for planting. Contour plowing, on the other hand, is a practice of plowing perpendicular to the slope to discourage soil and water erosion down the slope.

Methodology

Data sources and measurements

Multi-stage sampling techniques were employed to select the final sample units. Initially three districts, two from East Harerghe zone and one from West Hararghe zone, were selected purposively based on severity of degradation problems. These districts were Meta and Goro-Gutu from East Hararghe zone, and Tulo from West Hararghe zone. In the second stage, a total of 9 kebeles (the smallest administrative unit) were randomly selected using highland kebeles in the selected districts as a sampling frame. In the third stage, the survey drew a total of about 211 farm households based on probability proportional to size sampling technique. Then household-level and plot-level data were collected.

Household-level data included variables like extension contact, credit access, farm training, membership to organizations, land holding, livestock holding, number of parcels, farm equipments owned, proportion of a perennial crop t'chat, family size, dependency ratio, age, sex, education of the household head, involvement in non-/off-farm activities, and others. Plot level variables collected about all plots owned by the selected households, on the other hand, included use of different inputs, land management and conservation activities on the plot, size of the plot, slope of the plot, fertility level of the plot, ownership of the plot and others.

Since there are considerable differences in how farmers manage land depending on the characteristics of specific plots, analyses of land management practices are made at plot levels. Among the major land management strategies in the study area are use of intercropping and conservation tillage practices. As to the measurement of these dependent variables, both intercropping and conservation tillage practices are considered as dichotomous with values zero for non-users and one for users. Description and measurements of all the variables used in econometric analysis are presented in Table 1.

Analytical framework

Conservation tillage and intercropping are practices related to undertaking the existing farming activities differently, rather than using additional inputs unlike the case for fertilizer and manure applications. The purpose here is to assess determinants of these tillage and cropping practices. However, there are important assumptions to be made for this study: both decisions of using conservation tillage and intercropping are functions of same regressors (X); and conservation tillage and intercropping do not directly affect one another. However, since farmers make these decisions based on the same factors at their disposal including availability of farm resources, these decisions cannot be totally independent.

Let and be observed values for use of conservation tillage and intercropping, respectively, taking a value of 1 for using and 0 for not using; and and be the respective latent variables which are not observable. Then, the binary probit for the two choice models can be written as:

$$Y_1{}^* = \beta_1 X + U_1 \qquad (1)$$

Where $\mathbf{Y_1} = \begin{cases} \mathbf{1} & \text{if } \mathbf{Y_1^*} > \mathbf{0} \\ \mathbf{0} & \text{if } \mathbf{Y_1^*} \leq \mathbf{0} \end{cases}$

and

$$Y_2{}^* = \beta_2 X + U_2 \qquad (2)$$

Where $\mathbf{Y_2} = \begin{cases} \mathbf{1} & \text{if } \mathbf{Y_2^*} > 0 \\ \mathbf{0} & \text{if } \mathbf{Y_2^*} \leq \mathbf{0} \end{cases}$

Statistically, Equations (1) and (2) can be consistently estimated by single equation probit models. However, this is inefficient because of the possibility of correlation between the two disturbances u1 and u2 (Greene, 2003). The problem here follows a seemingly unrelated regression (SUR) model (because the regressors do not include endogenous variables and the errors may be correlated) with identical regressors.

In the situation where the disturbance terms of the two models are correlated, the bivariate probit model is employed to circumvent inadequacies of the single probit or logit models. The bivariate probit model is based on the joint distribution of two normally distributed variables (Green, 2003 for details).

The choice of conservation tillage and intercropping as land management strategies by farmers is, therefore, analyzed using a bivariate probit model.

Under bivariate probit model, it is necessary to make a test of the independence of the error terms of the two equations using the likelihood ratio test of the covariance of the error terms (**ρ**). This helps to assess whether the two models can be treated as a system of equations or as a single equation models. Putting it differently, it is to test whether the two disturbance terms are correlated or not.

Variables	Description	Obs	Mean	S.D
Intercropping	1 if intercroping is applied, 0 otherwise	489	0.738	0.440
Conserv. tillage	1 if cons. tillage is used, 0 otherwise	489	0.419	0.494
Parcel size	Parcel size (ha)	489	0.37	0.259
Slope: Flat	1 for flat slope, 0 otherwise	489	0.313	0.464
Gentle	1 for gentle slope, 0 otherwise	489	0.410	0.492
Steep	1 for steep slope, 0 otherwise	489	0.239	0.427
V. steep	1 for very steep slope, 0 otherwise	489	0.039	0.193
Fert. level: Poor	1 for poor fertility, 0 otherwise	489	0.438	0.497
Medium	1 for medium fertility, 0 otherwise	489	0.213	0.410
Good	1 for good fertility, 0 otherwise	489	0.349	0.477
Farm distance	Home-farm distance in kilometer	489	2.06	2.033
Terracing	1 if stone terraces are available, 0 otherwise	489	0.534	0.499
Ditches	1 if diversion ditches are available, 0 otherwise	489	0.425	0.495
Trees	1 if trees are available, 0 otherwise	489	0.055	0.227
Land holding	Total land holding (ha)	211	0.84	0.466
Livestock hold.	Livestock in Tropical Livestock Unit (TLU)	211	3.26	2.187
Farm equipment	Value of farm equipments (Br)	211	192.2	120.00
Fragm. (SI index)	Land fragmentation in Simpson Index (SI)*	211	0.48	0.226
Prop. of t'chat	Proportion of earnings from t'chat (Br)	489	0.25	0.247
Extension	1 if there is ext. contact, 0 otherwise	211	0.569	0.496
Membership to org.	1 if a household is a member, 0 otherwise	211	0.332	0.472
Trainings	1 if attended trainings within 5 years, 0 otherwise	211	0.251	0.435
Land ownership	1 if owned, 0 if rented-/shared-in	489	0.914	0.280
Age	Age of the household head (years)	211	40.8	9.96
Sex of HH head	1 if a household is male-headed, 0 otherwise	211	0.877	0.329
Level of educ.	Level of education of a household head			
no formal ed.	1 if no formal education, 0 otherwise	211	0.360	0.481
Primary	1 if primary level of education, 0 otherwise	211	0.450	0.499
Secondary	1 if secondary level of education, 0 otherwise	211	0.190	0.393
Adult equiv.	Family size in adult equivalents	211	4.47	1.743
Depend. ratio	'dependents' (0-14 & 64+) to 'active' members (15-64)	211	1.32	0.768
Market dist.	Distance to the nearest market in kilometers	211	6.57	4.431
Districts: Metta	1 if Metta district, 0 otherwise	211	0.304	0.021
Goro-gutu	1 if Goro-gutu district, 0 otherwise	211	0.355	0.480
Tullo	1 if Tullo district, 0 otherwise	211	0.341	0.475

* Simpson Index (SI) is computed as $SI = 1 - \frac{\sum_1^n A_i^2}{(\sum_1^n A_i)^2}$ where Ai is area of i^{th} parcel and n is number of parcels; SI lies between zero and one; and a higher SI means a higher degree of fragmentation.

Table 1: Description and summary Statistics of explanatory variables.

Furthermore, the possible non-independence of error terms across plots within a household need to be corrected; that means robust standard errors have to be generated.

Just like the case for univariate probit models, it is also necessary to calculate marginal effects in bivariate probit models. Marginal effects are the sum of the direct and indirect effects (through the relationship between the residuals of the two models) of the independent variables on dependent variable. Since separating the total marginal effect into direct and indirect components is a tedious work as described in Greene (1996), only total marginal effects are reported in this study.

Variables	Intercropping			Conservation tillage		
	Coef.	Rob. S.E.	Marg. Pr♣	Coef.	Rob. S.E	Marg. Pr♣
Parcel size	3.902***	0.546	0. 866	0.179	0.277	0.058
Slope (cf. flat)						
Gentle	0.278	0.188	0.067	0.332**	0.151	0.110
Steep	0.123	0.216	0.030	0.469**	0.203	0.162
Very steep	0.259	0.340	0.057	0.788*	0.452	0.180
Fertility level (cf. poor)						
Good	0.429**	0.176	0.109	0.072	0.161	0.023
Medium	0.699***	0.243	0.205	-0.123	0.211	-0.041
Farm distance	0.071*	0.042	0.108	-0.068	0.056	-0.022
Terracing	-0.116	0.195	-0.029	0.377**	0.158	0.121
Ditches	0.321*	0.169	0.077	-0.53***	0.167	-0.166
Trees	0.617*	0.377	0.114	-7.88***	0.545	-0.419
Land holding	-0.61***	0.224	-0.150	-0.150	0.225	-0.049
Livestock holding (TLU)	-0.005	0.044	-0.001	-0.087	0.059	-0.028
Farm equipments	-0.001	0.001	-0.000	0.003***	0.001	0.001
Land fragmentation (SI index)	0.419	0.522	0.104	0.054	0.475	0.018
Proportion of t'chat	-0.780**	0.343	-0.193	-0.527	0.365	-0.071
Extension	0.588**	0.258	0.119	0.695**	0.276	0.189
Organization member	0.220	0.188	0.052	0.221	0.210	0.073
Training	0.219	0.185	0.057	0.891***	0.220	0.316
Land ownership	0.755***	0.232	0.238	0.047	0.244	0.015
Age	0.009	0.011	0.002	-0.022*	0.013	-0.107
Gender	-0.415	0.348	-0.086	-0.128	0.271	-0.043
Educ. (cf. no formal ed.)						
Primary	0.125	0.221	0.031	0.742***	0.256	0.236
Secondary	0.292	0.333	0.066	1.059***	0.356	0.269
Adult equivalents	0.040	0.049	0.010	-0.068	0.054	-0.022
Dependency ratio	0.209*	0.122	0.106	-0.153	0.130	-0.050
Market distance	-0.025	0.019	-0.006	-0.027	0.021	-0.009
District (cf. Metta)						
Goro-gutu	1.203***	0.222	0.257	-0.519**	0.233	-0.160
Tullo	0.858***	0.199	0.179	-0.868***	0.253	-0.246
Constant	-1.384*	0.799		2.225**	0.904	
Rho (ρ)	-0.302***					
Log likelihood function	-442.099					
Wald χ^2(significance)	1627.26 (P<0.0000)					
Number of observations	489					

Notes: ***, **, and * indicate significance at 1%, 5%, and 10% levels, respectively; The indicated marginal probabilities include both the direct and indirect effects of the variables; for dummy variables, a discrete change from 0 to 1 is considered; and the reference probabilities (at mean levels of continuous variables and modal levels of dummy variables) are 0.836 for intercropping and 0.261 for conservation tillage.

Table 2: A Bivariate Probit Estimates for Intercropping and Conservation Tillage.

The marginal effects, in this case, show the effect of a given change in the independent variable on one dependent variable by keeping all other continuous variables at their mean levels and categorical variables at their modal value.

Results and discussions

Table 2 presents the results of the maximum likelihood bivariate probit estimates of the equations explaining the probabilities of farmers' decision to use intercropping technique and conservation tillage practices in order to manage the fertility of their farm plots. The marginal effects of the regressors on the probability of practicing intercropping and conservation tillage are also reported as marginal probabilities in the same table.

The likelihood ratio test of the covariance of the error terms (ρ=-0.302) that maximized the bivariate probit likelihood is used to make a test of the independence of the error terms of the equation in the bivariate probit system of equations. The significance of rho (ρ) suggests that the random disturbances in the two decisions are affected (in opposite direction) by random shocks and that the two decisions are not statistically independent. It indicates that the error terms of the two equations are interdependent and hence treating the two equations as a bivariate probit model, rather than two univariate probit, is more appropriate. The bivariate probit model fits the data well ($\chi2$= 1627.26; P<0.0000), suggesting that the independent variables taken together influence the two decisions.

Several variables are found to influence farmers' decisions of managing their farm in terms of intercropping and plowing strategies. For most of the variables the estimated coefficients for the two decisions differ either in terms of sign or in terms of their significance. Discussions on variables significantly affecting intercropping practice, and that on variables significantly affecting conservation tillage are separately presented in the following sub-sections.

Determinants of intercropping

The result from bivariate probit model reveals that parcel size has a positive and significant effect on the decision to use intercropping. When combining direct and indirect effects, for a unit (1 ha) increase in parcel size the predicted probability of using intercropping technique increases by 86.6 percent, holding all other variables constant at their reference points (at mean levels for continuous and modal level for dummies). This is the highest marginal effect among all other explanatory variables. That means as farm plots are fragmented into small pieces, the probability of maintaining its fertility through intercropping decreases. Furthermore, the probability of using intercropping increases on fertile plots as compared to less fertile ones. This is probably because the technique is more of maintaining the available fertility rather than making additions to the fertility statuses. In addition, less fertile lands may not provide adequate nutrients required for two or more crops and hence crop intensification may not be paying on such farms.

Intercropping techniques are more likely practiced by households with higher dependency ratio. It is probably because of a lesser labor requirement for intercropping practices than other measures like manure application and construction of terraces; as higher dependency ratio implies less availability of active labor force in the family relative to 'inactive' members. The probability to practice intercropping technique increases on owned plots as compared to shared/rented ones. Putting it specifically, ownership increases the probability of practicing intercropping by 23.8 percent. This implies that ownership boosts the incentives to invest not only on long-term conservation measures but also on short-term fertility maintenance techniques.

Not surprisingly, as access to extension increases the probability to practice intercropping also increases (by 11.9%) implying that the technical information provided to farmers through extension agents incorporate intercropping techniques, among others. In addition, the probability to adopt intercropping is higher on distant farms as compared to that on nearby plots. The probable reason is the difficulty to use labor intensive techniques like manure application on distant farms making farmers to opt for alternatives like intercropping which does not require more labor input. Tree plantations and diversion ditches on the farm also increases the probability to adopt intercropping indicating that intercropping can be applied in conjunction with structural measures.

Although larger parcel sizes encourage intercropping, larger farm size does not. Intercropping is negatively related to total land holding depicting that at present it is a small farm, rather than large one, that contributes to improvement in soil-fertility status. Furthermore, an increase in the proportion of t'chat crop on the field reduces the probability of practicing intercropping measures due to various probable reasons. First, the canopy of t'chat crop may not allow two or more annual crops to be efficiently intercropped on the field. In addition, as an important cash crop in the study area, t'chat increases the financial position enabling the owner to pay for expensive chemical fertilizer input or for long-term structural measures like terraces instead of short-term intercropping activities. In terms of differences in location, farmers in Goro-Gutu and Tulo districts are more likely to use intercropping strategies than those in Meta district.

Determinants of conservation tillage

Based on the results of the Bivariate Probit Model indicated in Table 2, use of conservation tillage practice is significantly affected by many important variables. As the slope of the plot increases, the probability to practice conservation tillage increases. The possible reason is that degradation problem is severe on steep slopes as compared to flat fields. In addition, steeper slopes are associated with higher probabilities of using plowing techniques rather than applying other short-term measures like fertilizer because of the farmers' concern that fertilizers are more likely to be washed away if applied on steeper slopes.

Availability of terraces on the plot also increases the probability of using conservation tillage by 12.1% implying that terracing as a long-term investment complements the short-term strategy of adopting plowing techniques. In addition, due to the obvious reason of the requirement of farm implements for applying conservation tillage, value of farm equipments also influence conservation tillage positively and significantly.

The probability to use conservation tillage also increases with an increase in the level of education of the household head, with involvement in farm trainings, and with access to extension services, a result supported by many research reports (Jansen et al., 2006). These reveal that the technical knowhow required to implement conservation tillage can be acquired through education, farm trainings, and extension services. Use of plowing techniques has a negative relationship with age of the household head as also depicted from Savadogo et al. (1998) indicating that conservation tillage is practiced more among younger farmers than among older ones. Prior investments in the form of trees and diversion ditches which were indicated to affect intercropping techniques positively are found to affect conservation tillage negatively, as these are more effective measures by their own in preventing soil erosion. In terms of geographical differences, using plowing strategies for soil conservation is very common in Meta district as compared to Goro-Gutu and Tulo districts.

Conclusions

Though there are opportunities to apply short-term low-external input investments like intercropping and conservation tillage, adoption levels of these practices are not to the adequate extent owing to various impeding factors. The complexity of these factors in affecting land management strategies calls for making careful decisions for enhancing adoption and use levels and thereby increasing or maintaining fertility status of the soil.

The results from a Bivariate Probit model, for intercropping and conservation tillage decisions, showed that the two decisions are not independent. Furthermore, parcel size, fertility level of the soil, farm distance, diversion ditches, tree plantations, extension contact, land ownership, and dependency ratio are found to positively and significantly affect the probability to practice intercropping techniques while land holding and proportion of t'chat affected the same technique in a negative way. On the other hand, the probability to practice conservation tillage is positively and significantly affected by slope, terraces, farm equipments, extension contact, trainings, and levels of education while it is negatively and significantly affected by ditches, tree plantations, and age of the household head. Notably, short-term interventions in preventing the problem of fertility depletion like conservation tillage and intercropping are found to augment the long-term structural interventions like terraces, diversion ditches, and tree plantations.

The overall results of the study lead to make the following important implications. The significances of parcel size and land ownership call for the need to revisit the existing land tenure structure and to gradually relax it so as to allow land markets (buying, selling, renting) which are not currently available in the country. It is also very essential to strengthen and support both long-term and short-term land management and conservation strategies. Furthermore, it is necessary to provide institutional support to farmers in terms of creating access to extension, farm trainings, and rural education programs.

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