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Determinants of Adoption and Labour Intensity of Stone-terraces in Eastern Highlands of Ethiopia

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Abstract

Stone-terrace construction is among the most common methods for conserving soil and water resources in the intensively cultivated highland parts of Ethiopia. Human labour is the scarcest input required for construction as stones are freely available on the farm. Consequently, adopting terraces may not be enough by itself unless adequate amount of labour is devoted for its construction. In an effort to assess factors impeding adoption of stone terraces and its labour use intensity, this study uses a household- and plot-level data collected from 211 farm households and applies a double-hurdle model for analysis. A number of variables are found to be statistically significant in affecting adoption of stone-terraces and its labour use intensity. Among important implications of this study are gradually relaxing the limited land tenure security; designing programs for enlarging parcel size and minimizing fragmentation; and launching and strengthening farm training and education activities.

Keywords: soil conservation, double-hurdle model, Ethiopia, labour use intensity, terraces

1. Introduction

Land degradation has become a global environmental threat currently drawing wide-spread attention from the international community. 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, affecting the livelihoods of about 1.5 billion people (Bai *et al*. 2008). It has multiple and complex impacts on the global environment through a broad range of direct and indirect processes. Among its direct effects is the loss of fertile soils resulting from soil erosion ultimately leading to a decline in productivity and per capita income levels. A global scale estimates of annual loss of 75 billion tons of soil costs the world about US$400 billion per year, or approximately US$70 per person per year (Eswaran *et al*. 2001).

Degradation has an abysmal effect on agricultural productivity especially in developing countries where agriculture remains one of the largest sectors in the economy both in terms of its contributions to the GDP and generating employment. Various studies, at different times, have indicated that the continent of Africa is seriously threatened by land degradation. Yield reduction in Africa due to past soil erosion averages at 8.2 percent for the continent (Eswaran *et al*. 2001). According to Thiombiano & Tourino-Soto (2007), Africa accounts for 65 percent of the total extensive cropland degradation of the world. Another study by Bai *et al*. (2008) indicated that about 494 million hectare of land in Africa, 16 percent of total land of the continent, is degraded of which soil erosion contributes about 84 percent. 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).

Ethiopia is among countries in Sub-Saharan Africa that are reported to suffer severe land degradation problem. The country, with a population that doubled from about 39.8 million in 1984 to over 79 million in 2009 just within 25 years (CSA 2008a), is now the second most populous country in Africa. 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 (Rashid *et al*. 2007) though official government reports put a two-digit figure for the past few years.

Consequently, it has become a formidable challenge for the country to feed its growing 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).

Land degradation problem mainly resulting from soil erosion and nutrient depletion, can be singled out as one of the most important environmental problems creating an unprecedented threat to food security goals of the country. 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 might be a possible reason for a very low average yield of crops in the country as compared to yields in other parts of the world.

According to World Bank (2005) estimates for the periods 2002–2004, the average yield was 1318 kg per hectare, which is less than 60 percent of that in other low-income countries and less than 40 percent of the world average. Moreover, the agricultural value-added per Ethiopian worker during the same period was about 123 dollars (in 2000 US dollars), while it was 375 dollars for low-income countries and 776 dollars for the whole world (World Bank 2005). 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. The problem of accelerating land degradation is especially serious in the intensively cultivated highland parts of the country.

In order to combat its adverse effect it is, therefore, 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. To this effect, some farmers have already made significant progress in dealing with soil erosion problems by adopting some soil conservation and fertility maintenance techniques. Among well-established methods of soil and water conservation is stone terracing. Human labour is the scarcest input required for construction of stone terraces as stones are freely available within and near the cultivated fields. Consequently, the amount of labour devoted to the construction of stone terraces can be an indicator for the intensity of terraces on the farm. That means, adopting terraces may not be enough by itself unless adequate amount of labour is devoted for its construction to the required level. Therefore, the difference among farmers in the study area with regard to terrace construction is not only in terms of adopting the measure but also in terms of the amount of labour devoted for that.

Impediments for adoption and for the intensity levels in terms of labour use can be multi-faceted including factors related to the capacity in terms of different livelihood assets, the knowledge or awareness about conservation strategies, and farm-related features. In an effort to assess factors impeding adoption of stone terraces and its labour use intensity, this study uses a household- and plot-level data collected from three districts of Eastern Highlands of Ethiopia.

2. Methodology

2.1 Overview of the Study Area

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. *T'chat (Catha edulis)* is a mild narcotic perennial bush the leaves of which are chewed as stimulants. Production of *t'chat* 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. In 2008 cropping season, for instance, average landholdings in East Hararge zone was about 0.59 hectares with about 85 percent of the households owning an average area of less than one hectare. In West Hararghe zone, the average holding was 0.9 hectare with about 66 percent owning an area of less than one hectare (CSA 2008b). The indicated average holding in East Hararghe zone is fragmented into 3.15 parcels with an average size of only 0.19 ha. In West Hararghe zone, it is fragmented into 2.72 parcels with an average size of only 0.33 ha. The problem of fragmentation is very evident especially when compared to the average household size, during the same period, of 5.36 and 5.17 persons in East and West Hararghe zones, respectively. Furthermore, the severity of land degradation in the highland parts of these zones is becoming of grave concern.

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 2008c). Furthermore, investments in a long-term soil and water conservation structures are very minimal.

Construction of terraces, as a long-term soil and water conservation practices, in the study areas is becoming a common tradition especially in degradation prone highland parts. Available terraces are basically of stone-bund and soil-bund types. What is called stone-bund in the area is actually a very stable walls constructed from a combination of carefully layered stones collected from the farm and soil materials. Soil bunds, however, are made by digging or ploughing the soil and making a sort of wall. Stone terraces are very effective in preventing soil erosion and in retaining water. Soil bunds are only effective in less sloppy areas and when there is no heavy runoff. Whereas stone terraces serve for a relatively longer time period with minor maintenance activities, soil bunds will only serve one or two cropping seasons and hence require annual rebuilding. In fact, stone terraces construction requires considerably more investment of time, labour and other inputs than does building soil bunds. These conservation investments are private activities constructed by farmers on susceptible plots, sometimes assisted by the agricultural extension services. There are also public conservation structures constructed on communal steeply sloping land and marginal areas.

2.2 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* 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 perennial crops, 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.

Description and measurements of all the variables used in econometric analysis are presented in Table 1.

2.3 Analytical Framework

Conservation investments in the form of stone terraces and its labour use intensity are analyzed at plot-levels. For these, the dependent variables are adoption of stone terraces expressed as a dichotomous variable and its labour use intensity expressed as a continuous variable. The number of labour devoted to construction of terraces is considered as an indicator of the intensity of conservation structures on the farm plot. It is measured as the number of man-days devoted per hectare per year for construction and maintenance of stone terraces, by taking into consideration farmers' estimate of expected life of constructed terraces. Explanatory variables, in both cases, include market access factors, physical incentives to invest, capacity to invest, socio-institutional factors, household demographic characteristics, and farm characteristics.

Theoretically, the decisions on whether to adopt stone terraces and how much labour to devote for that can be made jointly or separately. The assumption here, however, is that the decision to adopt terraces may precede the decision on its intensity in terms of labour. In such situation, it is more suitable to apply Cragg's 'double-hurdle' as it is specified below.

If we let D_i^* as a latent variable describing the household's decision to adopt stone terraces, Y_i^* as a latent variable describing households' decision on amount of labour devoted for stone terraces, and D_i and Y_i as their observed counterparts, then based on the specification by Cragg (1971) and Moffatt (2003), the double-hurdle model essentially contains two equations as follows:

$$D_i^* = \alpha' Z_i + v_i \quad (1)$$

$$Y_i^* = \beta' X_i + \varepsilon_i \quad (2)$$

Where

$$D_i = \begin{cases} 1, & \text{if } D_i^* > 0 \\ 0, & \text{if } D_i^* \leq 0 \end{cases} \quad \text{and} \quad Y_i = \begin{cases} Y_i^*, & \text{if } Y_i^* > 0 \text{ and } D_i^* > 0 \\ 0, & \text{otherwise} \end{cases}$$

Within this framework, we can describe several different types of econometric models such as the Tobit, Cragg, Heckman, and Complete Dominance models. The differences between these models revolve around the assumptions about the farmers' decision at the two stages of the model and whether the two decisions can be made simultaneously or not. Here, in the case of farmers' adoption of stone terraces we assume a decision on adopting the practice is made first, and then decision on the intensity of use (in terms of the amount of labour devoted) follows.

Cragg's double-hurdle model is perhaps the most flexible of the other two stage models as it allows for censoring at either stage of the model (Brouhle and Khanne 2005). The advantage of the Cragg model over the Tobit model is that the former allows variables to have differing effects on the adoption and the labour use decisions (Brouhle & Khanna 2005; Burke 2009). That means, the labour intensity equation and the adoption equation are allowed to have different coefficients.

Double-hurdle model postulates that to observe positive level of labour use, the farmer must pass two hurdles: (i) be an adopter of the stone terraces and (ii) actually devote labour for constructing the terraces.

In the Cragg model, Equations (1) and (2) are assumed to be independent, and therefore, the error terms are randomly and independently distributed, $v_i \sim N(0, 1)$ and $\varepsilon_i \sim N(0, \sigma_\varepsilon^2)$. This means:

$$\begin{pmatrix} v_i \\ \varepsilon_i \end{pmatrix} \sim N\left[\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} 1 & 0 \\ 0 & \sigma^2 \end{pmatrix}\right]$$

In the first stage we run a probit model to capture the decision of whether the farmer uses stone terraces or not. The second stage is a Tobit model for labour use intensity conditional on use of stone terraces (i.e. for adopters).

The log-likelihood function for the version of Cragg's model that assumes the probit and truncated regressions to be uncorrelated is given as follows (Carrol *et al.* 2005):

$$L = \prod_{Y_i=0}\left[1 - \Phi(Z_i\alpha)\Phi\left(\frac{X_i\beta}{\sigma}\right)\right]\prod_{Y_i>0}\Phi(Z_i\alpha)\sigma^{-1}\phi\left(\frac{Y_i - X_i\beta}{\sigma}\right) \quad (3)$$

where Φ and ϕ are the standard normal cumulative distribution function and density function, respectively. The first portion is the log-likelihood for a probit, while the second portion is the log-likelihood for a truncated regression, with truncation at zero. Therefore, the log-likelihood from the Cragg model is the sum of the log-likelihood from a probit and a truncated regression. More useful, however, is the fact that these two component pieces are entirely separable, such that the probit and truncated regression can be estimated separately. This means the probit parameters are not included anywhere in the truncated regression, while the truncated regression parameters are not included anywhere in the probit regression.

It is also obvious that the double-hurdle model reduces to the Tobit model when the probit mechanism (i.e., $D_i^* > 0$) is absent in Equation (2). This is also seen in the likelihood function (Equation 3) when $\Phi(Z_i\alpha) = 1$. In fact, it is possible to compare the Tobit model and the Cragg's double-hurdle model. Cragg's model allows the parameters to differ in the two decisions and Tobit model allows the same parameters in these decisions. Therefore, it is appropriate to test whether or not the restriction of equal parameterization is supported by the data. The restriction requires $\beta/_\sigma = \alpha$, which is tested through the application of a Hausman-type test, as suggested by Lin & Schmidt (1984).

The estimates of the double-hurdle model might not be efficient if the error term is homoscedastic across observations. However, this problem can be further improved by allowing the standard deviation to vary across observations. Heteroskedasticity is integrated into the model by assuming that the variance of the error term is an exponential function of a set of exogenous variables, k_i, a subset of X_i (Newman *et al.* 2003). In particular, the standard deviation σ_i is parameterized as follows:

$$\sigma_i = exp(k_i'h)$$

Where h is a conformable parameter vector.

3. Empirical Results and Discussions

Results of the Cragg's double-hurdle model are presented in Table 2. The analysis reveals that there are some differences in terms of the magnitude and direction of determinants significantly affecting the decisions to adopt terraces and its intensity in terms of labour use.

The decision to adopt terraces and the decision on its intensity in terms of labour use are both positively and significantly affected by size, slope, and ownership of the parcel; training, age, and level of education of the household head; proportion of *t'chat* planted; and involvement in off-/non-farm activities.

Plot size influences conservation decision positively. This is because the proportion of the loss in area devoted to conservation structures is larger on small plots than on large plots resulting in lesser returns which may not adequately compensate for the decline in production in the former case. Thus, large plots result in better rewards to the cost of constructing terraces. A similar result has been reported in Bekele & Drake (2003). In addition, slope influences the conservation decision positively for the reason that erosion is more serious on steeper plots than on flat plots. Hence, steeper slopes increase the incentive to invest in land conservation. Similarly, investments in land conservation are greater on owned plots than on rented or shared plots as ownership implies confidence in securing long-term benefits out of conservation investments. A similar result that tenure security favours long-term investment has been reported in various other studies (Illukpitiya & Gopalakrishnan 2004; Clay *et al.* 1998; Kabubo-Mariara 2003).

The coefficients for the educational and training dummies imply that the probability of investing in land conservation increases with the level of education and trainings obtained. Public investments in education and farmers' training promote conservation activities. The knowledge farmers gained through education and training enables them to be equipped with the technical knowhow required for constructing conservation structures. Furthermore, it makes them far-sighted to look for long-term benefits through sustainable production and land management practices rather than immediate benefits obtained at the expense of soil quality. This is in line with the results reported by several studies (Illukpitiya & Gopalakrishnan 2004; Kabubo-Mariara 2003).

The positive effect of involvement in off-/non-farm activities is contrary to some research results that indicate the possibility of reduced time available for farm work because of involvement in off-farm activities (Holden *et al*. 2004; Mbaga-Semgalawe & Folmer 2000; Amsalu & de Graaff 2007). Here, the result implies involvement in non-farm income sources is an incentive to invest in conservation structures, as also supported by a result reported in Marenya & Barrett (2007). Non-farm income, especially where credit markets are underdeveloped, is important for households in order to buy materials and labour required in constructing terraces. Similarly, the major cash crop in the area, *t'chat*, is especially important in enhancing conservation investment. It provides farmers with the incentive and capacity to make substantial investments as the proportion of *t'chat* farm indicates the economic status of households in the study areas.

The two decisions, adoption and labour use, are both negatively and significantly affected by fertility status of the plot and the proportion of female members in the farm household. This implies that the way households rank the soil fertility status are important determinants of adoption and the level of resources devoted to its conservation. That means households tend to adopt and devote resources for conservation structure on less fertile soils as compared to more fertile plots. These results are in line with some earlier studies (Mbaga-Semgalawe & Folmer 2000; Amsalu & de Graaff 2007). In addition, as conservation measures are relatively labourious activity usually requiring strong male labours, the proportion of female members has a negative effect on conservation efforts.

There are also variables whose effects are only reflected in one decision and not in the other. The decision to adopt terraces is affected negatively and significantly by land fragmentation, distance of the plot and membership to organizations and positively and significantly by extension contact and market distance. A possible explanation for the negative influence of land fragmentation, the geographical dispersion of plots measured in terms of Simpson index, can be because of a lesser returns to conservation investment from small pieces of dispersed plots than that from large-sized plots as related with economies of scale, a result which is consistent with the finding revealed in Clay *et al*. (1998). Moreover, the decision to adopt conservation structure is negatively influenced by farm distance, as home-farm distance detracts the propensity to construct stone terraces. Another possible reason can be because distant parcels are often found where soil erosion is less severe and where lands have been brought into production more recently, as compared to nearby parcels. The negative effect of membership to organizations, which is against other empirical results, is rather puzzling and a bit difficult to justify. A possible explanation can be based on the type of information obtained from available organizations in the study area. Available organizations, as sources of information to farmers, might not encourage farmers to invest on long-term measures if their major focus is on some other issues or if they favour short-term land management strategies like use of fertilizer.

On the contrary, extension contact results in increased probability of adopting conservation measures as extension agents are important sources of technical information in the study areas. A similar effect of distance to the market can be explained by the availability of alternative activities on which farmers can devote their labour, other than land conservation, for farmers living nearer to market centres as compared to those in distant areas.

On the other hand, the amount of labour invested for terracing increases with an increase in value of farm equipment, and decreases with an increase in the size of total land holding. The negative relationship between total land holding and intensity of conservation investment indicates that farmers with relatively larger landholdings may have more land under fallow and thus may feel less pressured to protect their land, or larger farmers are not compelled to take conservation measures to meet daily food and cash needs because of the adequacy of production from available lands as compared to those with small landholdings. In addition, owners of large farms tend to have less household labour available per hectare for building and maintaining conservation structures. A similar finding is revealed by Bekele & Drake (2003), Clay *et al*. (1998), and Kabubo-Mariara (2003). On the other hand, a positive effect of value of farm tools indicates that higher investment in physical capital favour long-term conservation activities.

4. Conclusions

A number of variables are found to be statistically significant in affecting adoption of conservation decisions and its intensity. Positive and significant effects of variables like size, slope, and ownership of the parcel; age, level of education, and training of the household head; proportion of perennial cash crop (*t'chat*); and involvement in off-/non-farm activities in affecting terrace adoption and its labour use intensity are revealed in this study. The two decisions are both negatively and significantly affected by fertility status of the plot and the proportion of female members in the farm household. In addition, variables whose effects are only reflected in one decision and not in the other are also discussed. This implies that land and soil moisture conservation through use of long-term investments like terracing can be promoted by paying attention to all these factors.

It is a fact that tenure insecurity provides little incentive for innovation, better land management, and increased use of farm inputs. This implies that there is a need for a more secure land tenure policy than currently prevailing in the country. The limited security needs to be gradually relaxed so as to facilitate investment in the land. This may initially take a form of use rights granted over sufficiently long periods of time followed by complete privatization.

In addition, fragmentation of farm lands into small-sized parcels is widespread in the country. Fragmentation as measured in terms of Simpson index resulted in lesser probability of adopting conservation structures. This implies that it is necessary to have large-sized parcels and to minimize fragmentation. This can be through implementing programs of consolidation that leads to the creation of viable-sized farms, enlargement of fragmented holdings, reduction of production costs and costs per unit for constructing conservation structures.

Furthermore, both trainings and education level of household heads are found to be important determinants in enhancing use of conservation structures. Therefore, farm training activities focusing on the benefits of conservation and technicalities in designing and constructing conservation structures like terraces, and in managing other measures; and rural education programs in general need to be launched and strengthened.

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Table 1. Detailed description and summary statistics of major variables

Variables	**Description**	**Obs**	**Mean**	**S.D**
Terracing	1 if stone terraces are available, 0 otherwise	489		
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
Fertil. 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 kilometre	489	2.06	2.033
Land size	Total land holding (ha)	211	0.84	0.466
Livestock holding	Livestock in Tropical Livestock Unit (TLU)	211	3.26	2.187
Farm equipment	Value of farm equipments (Br)	211	192.2	120.0
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 extension contact, 0 otherwise	211	0.569	0.496
Membership to org.	1 if member of organization, 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	1 if a household is male-headed, 0 otherwise	211	0.877	0.329
Educ: 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
Dependency ratio	'dependents' (0-14 & 64+) to 'active' members (15-64)	211	1.32	0.768
Female prop.	Proportion of female members in the family	211	0.46	0.127
Market dist.	Distance to the nearest market in kilometres	211	6.57	4.431
Off-/non-farm	1 if involved in off-/non-farm activ., 0 otherwise	211	0.332	0.472
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 $\boldsymbol{SI} = \mathbf{1} - \frac{\sum_1^n A_i^2}{(\sum_1^n A_i)^2}$ where A_i is area of i^{th} parcel and $\boldsymbol{n}$ is number of parcels; $\boldsymbol{SI}$ lies between zero and one; and a higher SI means a higher degree of fragmentation.

Table 2. Estimates of Cragg's double-hurdle model for adoption of terraces and its labour use intensity

Variables	adoption model (pobit)		Labor intensity model (Truncated)	
	Coef.	S.E.	Coef.	S.E.
Parcel size	0.481*	0.275	2.055*	1.155
Slope (cf. flat) Gentle	0.529***	0.154	3.643***	1.241
Steep	0.866***	0.191	5.381***	1.325
Very steep	1.176***	0.381	8.431***	2.113
Fertility level (cf. poor) Good	-0.612***	0.150	-4.594***	1.154
Medium	-0.703***	0.191	-4.306***	1.315
Farm distance	-0.081**	0.035	-0.312	0.341
Land holding	0.075	0.176	-2.582**	1.206
Livestock holding (TLU)	-0.017	0.040	-0.081	0.333
Farm equipments	0.001	0.001	0.015***	0.005
Land fragmentation (SI index)	-0.250*	0.137	-2.055	3.196
Proportion of *t'chat*	0.817***	0.303	4.845*	2.766
Extension	0.355*	0.189	0.815	1.568
Organization member	-0.277*	0.163	-2.205	1.544
Trainings	0.608***	0.161	3.469**	1.576
Land ownership	0.411*	0.235	3.028*	1.684
Age	0.020**	0.009	0.161**	0.068
Gender	0.076	0.260	1.567	1.751
Level of educ. (cf. no formal educ.)				
Primary	0.250	0.171	2.532*	1.548
Secondary	0.562**	0.233	3.015*	1.711
Adult equivalent	-0.059	0.040	-0.336	0.362
Dependency ratio	0.039	0.093	-0.056	0.778
Proportion of female	-0.866*	0.530	-8.026*	4.407
Market distance	0.031*	0.0167	0.109	0.134
Off-/non-farm activities	0.355**	0.158	2.412*	1.247
District (cf. Metta) Goro-gutu	-0.098	0.171	-0.081	1.641
Tullo	-0.074	0.181	-0.068	1.572
Constant	-2.869***	0.736	-15.352***	5.816
No. of observations	489		253	
Chi-square	104.50***		57.32***	
Log likelihood	-268.209		-699.805	
Sigma			5.114***	

Notes: ***, **, and * indicate significance at 1%, 5%, and 10% levels, respectively.