Integrated land and water management practices for rainwater harvesting: Joint estimation on the combined use of the practices in Azgo watershed, Ethiopia.

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Abstract

Rainwater harvesting (RWH) has been practiced and promoted to address the temporal and spatial variability of rainfall, thereby enhance agriculture production in rainfed systems. The practices could also address the problem of land degradation. However, there is limited practice of approaching RWH from the perspective of managing both the water and land resources. This paper analyses the various combination rainwater harvesting practices (RWHP) on a single plot using multivariate probit. The result reveals that there is a significant correlation between the RWHPs and use of the practices is interdependent, depicting either complementarities or substitutabilities between the practices. The practices are influenced differently to the set of explanatory variables considered. This implies the different RWHP would require specific entry point and promotion strategy. This study suggests that policies that enhance the integration of RWHP would be central to exploit the full value of the land and water resource for livelihood support.

JEL classification: Q01, Q16, Q18, Q24, Q25

Keywords: Rainwater harvesting, Combined use of practices, Multivariate probit, Ethiopia

1. Introduction

Today's world is changing fast as expressed in significant increase in population, economies and consumption rates. This rapid growth will intensifying demands for food, water and energy in the years to come. The pressure on land and water resource will be intense, resulting on natural resource scarcity to feed the growing population. The effect of climate change will accelerate the pressure on these challenges. It has already significantly impacted agriculture and is expected to further impact directly and indirectly food production (Lobell et al, 2011; FAO, 2013). Changes in rainfall patterns and water availability are some of the major events that have profound impact on agriculture. The impact is more important for smallholder farmers which are dependent to a large extent on rainfall for production; operate under risk of droughts, degradation of land and water resources; and affected by food insecurity and poverty.

The role of agricultural water management is required now more than ever, as a key element in strategies to reduce rural poverty thereby smallholder farmers can directly influence the management of land and water resources (CA, 2007). It is also promoted as one of the strategies for climate –smart agricultural system with more productive, efficient and stable production; and more resilient to risks, shocks and long-term climate variability (FAO, 2013). Managing water in agriculture would support the management of land (Bossio et al., 2010) and vise verse (Ringersma et al., 2003).

However, much of the earlier discussions on water resource management in agriculture focused on water in rivers, lakes and groundwater, for use in irrigation. This thinking is now challenged following the overexploitation of the river water which is only one third of the total precipitation over the continents (Falkenmark and Rockstrom, 2006). Whereas, two third of the rainfall is lost as unproductive evaporation, percolation and runoff (Falkenmark and Rockstrom, 2010), it could also reach 70-85 % depending on the land management condition (Rockstrom et al., 2002). These required the development of policies well adapted to the management of rain as the primary water source (Falkenmark and Rockström , 2006, 2010; Humphreys et al., 2008; Hoff et al., 2010).

Rain Water Harvesting (RWH) has been promoted as an approach to integrate land and water management, which could contribute to recovery of agriculture production in rainfed systems and the general water resources (Humphreys et al., 2008, Rockström et al., 2010). RWH refer to practices that make use of the runoff and surface water at farm and watershed level through integrated management of land and water resource (Amede et al., 2011). Thus, RWH practices involve a combination of different practices that enhance infiltration and/or reduce ruff, referred as *in-situ* rainwater harvesting (RWH) and those that capture, store and efficiently use runoff and surface water emerging from farms and watershed, called as *ex-situ* RWH.

Smallholder farmers in Ethiopia use different practices for the management of land and water resources since they cannot do much to influence rainfall, but do a lot to harvest it. The harvesting entails both *in-situ* and *ex-situ* rainwater harvesting measures. Farmers' practices have received policy attention following the 1973/74 drought after which several soil and water conservation program was initiated (Shiferaw and Holden, 1999; Seyoum, 2003). Despite the effort, farmers are still constrained to integrate the practices and limited to exploit the full value of the land and water resources to livelihood support (Merrey and Gebresilasie, 2011).

Much of the earlier studies related to land and water management practices concentrated on adoption and socio-economic impact assessment on single practices (soil and water conservation, water harvesting ponds, tanks, shallow wells or supplementary irrigation), which could ignore the complementarities and/or substitutabilities of the different practices (Kassie et al., 2013). Understanding the adaptation/adoption process of multiple uses of the different types of RWH would support the design of strategies for the integrated use of the in- and ex-situ rainwater harvesting, thereby addressing the climate change induced water scarcity.

The study adds value to the growing literature on adoption of land and water management practices in the following ways. First, the study is based on a rich data that capture plot specific attributes and RWHP use decision along a landscape formed of top, middle and lower slope. Using landscape as unit of observation for studying rainwater harvesting practice use would help to avoid the problem of heterogeneity within the landscape. This implies that synergies between different RWHP within the landscape are considered to be the same within the watershed. Second, we adopt a method that consider the interdependence among the different practices and joint estimation of the combined use of traditional and introduced bunds and terraces; water harvesting pond and river diversion.

The rest of the paper is organized as follows. The next section presents the econometric framework and estimation strategy. Section 3 highlights the survey design and descriptive statistics. Estimation results will be presented and discussed in Section 4. Then the last section concludes the key findings and the policy implications.

2. Estimation procedure: Multivariate probit (MVP) model

A rich set of literature has examined the determinants of use for land and water management technologies and practices in Ethiopia and beyond. A recent extensive review of literature have been conducted over improved rainwater and land management practices use in Ethiopia and conclusion drawn as to what is known and what is to be learned from such studies (Merrey and Gebresilasie, 2011). Among the conclusion and implications for further research presented by this review is that the different land and water management practices are interrelated while research examined the performance of a single technology in a multiple sites. The decisions to use the different practices are often interrelated and appropriate econometrics procedure is required to jointly model the multiple uses of these practices. In contrast, the independently modelling the multiple use decision could ignore the potential correlation among the unobserved disturbances in the decision equations, as well as the use of the different practices. Failure to capture unobserved factors and interrelationship among the decision to use the different practices could lead to bias and inefficient estimates (Green, 2008).

This paper adopts multivariate probit (MVP) econometric techniques, which consider the possible contemporaneous correlation in the decision to use the different RWH practices (Gillespie et al., 2004). Moreover, MVP approach simultaneously model the influence of a set of explanatory variables on each of the different RWH practices , while allowing for the potential correlation between unobserved disturbance, as well as the relationship between the decisions to use the different practices. One source of correlation could be complementarities (positive correlation) and substitutabilities (negative correlation) between the different practices (Belderbos et al., 2004). In this regard, recent empirical studies of technologies adoption decisions used MVP techniques on cross-sectional multiple plot observation based on the assumption that farmers consider a set of possible technologies and choose the particular technology bundle that maximizes the expected utility accounting for interdependent and simultaneous adoption decisions (Teklewold et al., 2013; Kassie et al., 2013).

The observed outcome of RWHP use can be modeled following a random utility formulation. Consider the i^{th} farm household (i= 1, …, N) which is facing a decision to use or not to use the different RWH practice on a plot p (p=1, …, p). Let U_0 represents the farm household benefit from traditional practices (without RWHP), and U_R denotes the benefit of using the R^{th} RWHP : (R= T, B, P, D , O) representing choice of terraces (T), bunds (B), water harvesting pond (P), spring diversion(D) and other SWC (O). The i^{th} HH decided to use the R^{th} RWHP on plot p if $Y^*_{ipR} = U_R - U_0 > 0$. Y^*_{ipR} is a latent variable determined by observed household, plot and location characteristics (X_{ipR}) and unobserved characteristics (ε_{ipR}).

$$Y_R = \begin{cases} 1 & \text{if } Y^*_{ipR} > 0 \\ 0 & \text{otherwise} \end{cases} \tag{1}$$

$$Y^*_{ipR} = X'_{ip}\beta_R + \varepsilon_{ipR} \tag{2}$$

where the error terms ε_{ipR} have a multivariate normal distribution (MVN) with mean vector 0 and covariance matrix W with diagonal elements equal to one. The off-diagonal elements represent the unobserved correlation between the random components of the RWHPs. Thus, $\varepsilon_{ipR} \sim \text{MVN}(0, \text{W})$ and the covariance matrix W is given by:

$$\text{W}= \begin{bmatrix} 1 & \rho_{TB} & \rho_{TP} & \rho_{TD} & \rho_{TO} \\ \rho_{BT} & 1 & \rho_{BP} & \rho_{BD} & \rho_{BO} \\ \rho_{PT} & \rho_{PB} & 1 & \rho_{PD} & \rho_{PO} \\ \rho_{DT} & \rho_{DB} & \rho_{DP} & 1 & \rho_{DO} \\ \rho_{OT} & \rho_{OB} & \rho_{OP} & \rho_{OD} & 1 \end{bmatrix} \tag{3}$$

MVP is based on five binary dependent variables, each takes one if the farm-household used the respective practices during interview period in the 2012 cropping season, and zero otherwise. The practices considered are terrace, bund, water harvesting pond, sprig diversion and other SWC. Definitions, description and summary statistics of the variables used in the analysis are discussed in the next section.

3. Survey design and data description

The data used for this study is based on a farm-household survey in Azgo watershed (14,049 Km^2), northeastern Ethiopia during the period June-August 2012. Stratified sampling procedure was employed to select respondents. First, the total population was stratified into users and non-users of integrated land and water management practices. Second, based on proportionate sampling, 354 farm households with 954 plots were randomly selected for face-to-face interview.

The data was collected using a pre-tested structured questionnaire by trained and experienced enumerators who are conversant of the local farming and social system. The survey is designed to collect farm-household characteristics, institutional setup, and resource endowment as potential determinants for the decision to use the RWHPs. Economic theory (de Janvry et al., 1991) and previous adoption studies in natural resource management (Pender and Gebremedhin, 2007; Shiferaw et al., 2009; Kassie et al., 2013) guided the selection of the variables considered for this study.

Farm-household characteristics that could enhance the supply of family labor supply for the construction of the different RWHP would positively influence the decision to use the practices. Access to external knowledge and input are expected to positively affect the decision to use introduced technlogies. Use of government extension services is included in the model as proxy. Plot characteristic are also included in the model. Plot distance from homestead could increase the demand for more labor, and hence negative influence the decision. Plots planted with high value crops would require a better management of water and land resources, thus positively affect the probability of use decision. Similarly, plot with steep slopes are vulnerable to erosion, and hence farmers are influenced to implement the appropriate practices. In general, the location where the plot is located influence the type of structures to implement, thus plot location in the landscape is included to capture the spatial differences.

Descriptive statistics

Farm household in the study watershed have undertaken a number of rainwater harvesting (RWH) practices on their plots (Table 1). In the meantime, there are plots that didn’t receive any of the practices. The RWH practices were implemented both in standalone and in combination. We categorized these practices into two RWH experiences based on the harvesting of the rainwater. Some of the RWH practices enhance infiltration and/or reduce runoff, referred as *in-situ* rainwater harvesting (RWH) while others capture, store and efficiently use runoff and surface water emerging from farms and watershed, called as *ex-situ* RWH.

[Table 1]

In the watershed, varieties of traditional as well as introduced *in-situ* RWH practices exist. These practices could be undertaken on and off- farmland. It includes stone terrace/check dam, soil bund, stone faced soil bund, tie ridge, trenches and eye brow. The ex-situ practices include water harvesting pond and spring diversion. The promotion of *ex-situ* water harvesting system in the watershed is only a decade practice. The system is introduced by constructing RWH tanks made of cements for demonstration purpose as part of the national food security strategy. The high cost of construction and seepage loss due to unsuitable soil type discouraged its promotion. Instead, trapezoidal shape RWH ponds are promoted, where it is now widely practiced in the watershed. The ponds are excavated into a 3 meter depth and truncated at its bottom where the upper part is 8 by 8 meter square and the bottom is 5 by 5 meter square. Farmers construct the ponds in areas where least digging or earth fill is required and hold a large volume of water, on the average 150 m^3 and can irrigate 0.25 ha of land. The structures are constructed around homesteads. The ponds use surface runoff from small catchment within and between homesteads (foot path, small grazing land, hilly areas). Moreover, water can also be collected from feeder roads, bunds, and waterways that connect a conserved cropland or hillsides. Spring development is a traditional practice in the water shed where farmers develop an earth's surface that would naturally emerge a groundwater. Thus, the availability is determined on the geology of the earth surface.

Based on the purpose of the practices, the location where it is implemented and the labor requirement; the practices are categorized into five practices: bunds, terraces, water harvesting ponds, spring diversion and other SWC (soil and water conservation) practices. Other SWC practice includes hillside trench, eye brow and hillside terrace. Sampled households practiced terracing and bund on the majority of the plots covering 66 % and 57 %, respectively. Small proportion of the plots received either of water harvesting ponds, spring diversion or other SWC practice (Table 1).

It is associated that farm-household's desire to maximize RWHPs expected utility is subject to various constraints and determines the decision to use the different practices. The following observable factors are hypothesized to influence the decision to use the practices. The research considered farm-household characteristics, institutional setup, and resource endowment as potential determinants for the decision to use the RWHPs. Economic theory (de Janvry et al., 1991) and previous adoption studies in natural resource management (Pender and Gebremedhin, 2007; Shiferaw et al., 2009; Kassie et al., 2013) guided the selection of the variables considered for this study. Descriptive statistics of the dependent variables and all of the explanatory variables considered in the paper are presented on Table 2.

[Table 2]

4. Results and discussion

The result of the MVP model presents the determinants of farm-household decision to use the different RWHPs at plot level and the correlation coefficients between the errors terms of the five decision equations. The model fits the data reasonably well where the Wald test of the hypothesis that all the regression coefficients in each equation are jointly equally to zero is rejected as reported in Table 4. The likelihood ratio test (chi^2 (10) = 103.73, p= 0.0000) of the null hypothesis that the error terms are independent is strongly rejected.

The pairwise correlation coefficients across the five RWHPs use decision equations are presented in Table 3. Examination of these coefficients allows for the measurements of the correlation between the RWHP use decision considered, after the influence of the observed factors has been account for (Greene, 2008). The estimated correlation coefficients are statistically significant in seven of the ten cases, where three coefficients are positive and the rest four have negative signs. This supports the hypothesis that the error terms in the RWMP use decision equations are correlated, and the use of MVP model could be appropriate in this case. The result shows that there is significant correlation between RWHPs and use of the practices are interdependent in that the probability of using a practice is conditional by the use of the other practices considered.

[Table 3]

The positive signs of the correlation coefficients suggest that the decision to use one of the practices make it more likely that another practice is used. For example, a plot which received a water harvesting pond may also require a terrace or bund structure on the same plot. They have a complementary role where terrace/bunds trap runoff and sediments, so that the runoff is safely flowing into the ponds. In the country, water harvesting ponds constructed without integrating with other land management practices ended up with silted ponds (Rami, 2003). While, spring diversion have supplementary role to ponds and the correlation coefficient have negative sign. Spring development is much cheaper than ponds but require unique earth surface where all farmers cannot be granted. Both *ex-situ* WHPs have positive correlation coefficients with the *in-situ* practices, revealing the need for integrated RWHPs. Within the *in-situ* practices, the correlation coefficients are negative and show that the practices are substitute for each other based on the plot characteristics and rainfall pattern. For example, the other SWC practices are mostly practices on hillsides while terraces and bunds are applicable in the high-middle and lower landscapes, respectively. Kassie et al.

(2009) also presented similar result where stone bunds provide higher crop return per hectare in drier areas than in wetter areas. The interrelatedness of the different RWHP may have an important implication for the design of implementation strategies and polices in that a policy targeted on one of RWHP could have spillover effect to the other practices.

The MVP model also come up with the significant household, institutional and plot level factors that condition farm-households' decision to use RWHPs. The regression result is presented on Table 4. The result shows that the five RWHPs respond differently to the explanatory variables considered. This strongly indicates the heterogeneity in the decision to use the different practices and, consequently support the use of MVP model for a separate analysis instead of aggregating them into one practice.

[Table 4]

The result shows that sex of the household head significantly influence the decision to construct terraces and other SWC structure. Unlike earlier studies that indicated female headed households are constrained to invest in land management practices on theirs plots (Teklewold and Köhlin, 2011), this result shows that male-headed households are less likely to use terraces and other SWC structures. In Ethiopia, women owned land is created whenever a family falls, and thus this land would have been managed by a man before the current ownership status. Stone terraces in the watershed have a long tradition and would only require maintenance. Accordingly, the current sex of the household may not necessary influence the decision to use terracing. Similarly, other SWC structures construction is undertaken in hillsides and facilitated through cash/food for work programs, and female-headed households plots are more likely to receive the practices. The result may have an important implication in that women-owned farms should not be ignored in the promotion of RWHPs.

One of the household characteristics hypothesized to influence household farm labor supply and subsequently the decision to use the different RWHP is household participation in non-farm income sources. The result shows that participation in non-farm income activities significantly reduce the likelihood of terraces, spring diversion and other SWC structure uses. Household engaged in non-farm income sources could ignore the farm activities including the land management due to labor shortage or they do not allocate the income generated to hire farm labor for the construction of RWH practices. The result is consistent with adverse relation between farm-land management and improved access to non-farm income, disregarding the premise of reduced pressure on natural resource base due to improved access to non-farm income (Holden et al., 2004). Strengthening the existing cash for work program to focus more on sustainable land management may have an important policy recommendation than considering other non-farm income sources in rural Ethiopia.

Use of government extension service is another important variable that influence household's use of the different RWH practices. Households that used the government extension service are more likely to use water harvesting ponds. This result corroborates with most of the earlier studies that showed access to extension services is one of the most important factors either to enhance the technical capability or facilitate input for introduced technologies, thereby increase the likelihood of using the practices (Shiferaw and Holden, 1998; Paulos et al., 2004; Senait, 2005; Anley et al., 2006; Teklewold and Köhlin, 2011). In the watershed, the inputs together with the credit for water harvesting ponds are exclusively supplied by the government extension service. While, use of extension services had not a significant positive influence on the use spring diversion since it is exclusively dependent on the geology of the land.

The coefficient estimates for own cultivated land provide the role of land tenure security on the use of the different RWHPs. Consistent to earlier works (Gebremedhin and Swinton, 2003; Teklewold and Köhlin, 2011; Kassie et al., 2013), land tenure insecurity in the form of non-owner cultivated land influence the use of short-term investment like soil bunds in this case. This type of land would involve short term investment because either due to short duration of the contract/sharing arrangement or the land is already degraded and long-term investment accrue over time.

Degree of slope increased the use of stone terraces, spring development and other SWC. Farmers prefer to use terraces on gentle slopes and other SWC on steep slopes. The fact is that hilly sides are important determinant for the use of the eye brow, terraces and trenches. All these factors are consistent with the null hypothesis that physical propensity toward erosion enhances the likelihood of soil conservation adoption.

5.3 Conclusion and implications

The paper analyzed the use of multiple RWHP on a single plot using MVP. The model considered the correlation across the different RWHP and the influence of a set of explanatory variables on each of the practices. The result reveals that there is a significant correlation between the RWHPs and use of the practices is interdependent, depicting either complementarities or substitutabilities between the practices. The complementarities among the RWHPs are observed between in-situ and ex-situ, which call for the combination of the two practices.

The result also shows that the RWHPs are influenced differently to the explanatory variables considered. This implies the heterogeneity in the decision to use the different practices and, consequently support the use of MVP model for a separate analysis instead of aggregating them into one practice. The role of government extension service is important factor that influence household's use of the RWHP that demand external knowledge and/or inputs. The other important factors that influence of the user of the different practices is the location of the plots where higher slopes require stronger structure which demand more labor and material inputs.

These results would help policy makers and development actors in the design appropriate entry strategy for the promotion of RWHPs. The different RWHP would require specific entry point and promotion strategy before generalizing that smallholder farmers are reluctant or not willing to accept RWHP and relate the low rainwater harvesting as a farmer's problem. The full potential of the land and water resources could be exploited by combing the *in-situ* and *ex-situ* water harvesting practices. It will also have implication to address climate change induced water scarcity as well as the land degradation problem faced by the smallholder farmers in Ethiopia and beyond.

In addition, it is important to note that the research has not included soil fertility management practices, improved seed and crop selection , which are the most important component of land management practices, but not common in the study area. Future research is needed to better understand the joint adoption decision of these land management practices with the water management practices.

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Table 1. Rainwater Harvesting (RWH) Practices in *Azgo* watershed

RWH Practices	N	% of the practices	% of the plot
No structure	79	5.13	8.11
In-situ			
Soil bund **(Bunds)**	250	16.23	25.67
Stone faced soil bund**(Bunds)**	281	18.25	28.85
Stone terrace **(Terrace)**	660	42.86	67.76
Contour trench **(Other SWC Practice)**	42	2.73	4.31
Tie ridge **(Other SWC Practice)**	18	1.17	1.85
Planting trees**(Other SWC Practice)**	14	0.91	1.44
Hillside trench**(Other SWC Practice)**	18	1.17	1.85
Eye brow**(Other SWC Practice)**	12	0.78	1.23
Hillside terrace **(Other SWC Practice)**	24	1.56	2.46
Ex-situ			
Water harvesting pond (**WHPond**)	93	6.04	9.55
Spring diversion (**Diversion**)	44	2.86	4.52

Table 2. Variable definitions, description and descriptive statistics for the sample

Variable	Description	Mean	Std. dev
Dependent variables			
Terrace	1= Plot received terrace	0.66	
Bund	1= Plot received bund	0.57	
Water harvesting pond	1= Plot received water harvesting pond	0.10	
Spring diversion	1= Plot served by spring diversion	0.05	
Other SWC	1= Plot received other SWC practices	0.07	
Explanatory variables			
Household characteristics			
Household head Age	Age of the household head (HHH) (years)	48.66	12.6
Household head Sex	1= if sex of the HHH is male	0.88	
Household head Edu.	1= If HHH is enrolled in formal school	0.08	
Non-farm income source	1= if household earns other income and transfers	0.27	
Family size	Household family size	4.93	1.80
Institutional factors			
Membership in farmer based organization	1= if household is member of any farmers based organizations in the kebele	0.85	
Use of government extension service	1= if household used government extension service	0.72	
Resource endowment			
Farm size	Ln of household total farm size	0.85	0.42
Own cultivated land	1= Plot is cultivated by the land owner	0.93	
Plot characteristics			
Plot size	Plot farm size in ha	0.29	0.23
Top landscape	1= Plot is located in the top landscape	0.60	
Middle landscape	1= Plot is located in the middle landscape	0.25	
Lower landscape	1= Plot is located in the lower landscape	0.15	
Cash crop plot	1= Plot produce cash crop	0.42	
Food crop plot	1= Plot produce food crop	0.48	
Grazing/fallow plot	1= Grazing/fallow plot	0.10	
Homestead plot	1= Plot is located within 5 minute walk from homestead	0.28	
Plain slope plot	1= Farmers' perception that plot has plain slope	0.52	
Gentle slope plot	1= Farmers' perception that plot has gentle slope	0.33	
Steep slope plot	1= Farmers' perception that plot has steep slope	0.16	

Table 3: Correlation coefficients of RWHP decisions: MVP model result

	$\rho_{Terrace}$	ρ_{Bund}	ρ_{WHPond}	$\rho_{Diversion}$
ρ_{WHPond}	- 0.394***(0.048)			
ρ_{Bund}	0.349*** (0.101)	0.192**(0.097)		
$\rho_{Diversion}$	0.334*** (0.126)	-0.1637 (0.109)	-0.436***(0.166)	
$\rho_{OtherSWC}$	- 0.261***(0.099)	-0.085 (0.111)	-0.331** (0.157)	-0.022 (0.151)
Likelihood ratio test of $\rho_{TB} = \rho_{TP} = \rho_{TB} = \rho_{TD} = \rho_{TO} = \rho_{BP} = \rho_{BD} = \rho_{BO} = \rho_{PD} = \rho_{DO} = 0$ chi2(10) = 103.73 Prob > chi2 = 0.000				

Note: Standard errors in parenthesis; *, **, and *** denotes significance level at 10, 5, and 1%.

Table 4: Factors influencing the decision to use RWHPs: MVP model result

Independent variables	Terrace		Bund		WH Pond		Spring Diversion		Other SWC	
Household head Age	0.000	(0.005)	-0.005	(0.005)	-0.005	(0.009)	0.008	(0.011)	-0.013	(0.010)
Household head Sex	-0.253*	(0.144)	0.102	(0.146)	-0.353	(0.354)	-0.391	(0.339)	-0.706*	(0.387)
Household head Edu.	0.225	(0.166)	0.187	(0.159)	-0.408	(0.335)	-0.068	(0.350)	0.050	(0.264)
HH non-farm income source	-0.191*	(0.109)	-0.020	(0.107)	-0.303	(0.211)	-1.113***	(0.389)	-0.420*	(0.226)
Family size	-0.002	(0.027)	-0.003	(0.026)	0.069	(0.052)	0.079	(0.066)	0.052	(0.052)
Membership in FBO	-0.071	(0.169)	-0.358**	(0.166)	-0.374	(0.304)	0.633	(0.442)	-0.043	(0.355)
Use of government extension service	0.024	(0.103)	0.089	(0.100)	0.485**	(0.198)	-0.391*	(0.218)	-0.050	(0.192)
Own cultivated land	-0.134	(0.179)	-0.302*	(0.176)	-4.580	(524.9)	-1.939	(2669.4)	-4.443	(1509.9)
Plot size	0.394**	(0.232)	0.917***	(0.239)	3.108***	(0.531)	-1.137*	(0.666)	0.614	(0.441)
Total Farm size	-0.304***	(0.110)	-0.115	(0.105)	-0.485**	(0.190)	-0.204	(0.245)	0.219	(0.213)
Upper landscape	-0.230**	(0.111)	-0.127	(0.104)	-1.004***	(0.174)	4.857	(284.9)	0.588***	(0.250)
Lower landscape	-0.457***	(0.154)	-0.001	(0.156)	1.151**	(0.492)	-0.412	(1833.7)	1.125***	(0.299)
Cash crop plot	1.375***	(0.163)	1.784***	(0.099)	7.098	(336.5)	4.562	(372.2)	-1.753***	(0.224)
Food crop plot	0.983***	(0.164)	1.878***	(0.236)	-3.355	(419.1)	-0.509	(524.8)	-1.992***	(0.255)
Homestead plot	-0.091	(0.105)	0.033	(0.100)	0.701***	(0.169)	0.067	(0.197)	0.459**	(0.189)
Gentle slope plot	0.222**	(0.102)	0.059	(0.098)	-0.094	(0.184)	0.921****	(0.221)	0.114	(0.210)
Steep slope plot	0.184	(0.137)	-0.139	(0.135)	0.255	(0.243)	-0.159	(0.384)	0.839***	(0.211)
Constant	-0.274	(0.439)	-1.371***	(0.456)	-8.263	(336.5)	-11.261	(468.8)	0.072	(0.876)
Wald statistics	Wald chi^2(85) = 478.49, Prob > chi^2 = 0.000									
No of observation	974									
No of household	354									

Note: Standard errors in parenthesis; *, **, and *** denotes significance level at 10, 5, and 1%.