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Resource degradation and adoption of land conservation technologies in the Ethiopian Highlands: A case study in Andit Tid, North Shewa

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Abstract

This paper reports results from a study of resource degradation and conservation behavior of peasant households in a degraded part of the Ethiopian highlands. Peasant households' choice of conservation technologies is modeled as a two-stage process: recognition of the erosion problem, and adoption and level of use of control practices. An ordinal logit model is used to explain parcel-level perception of the threat of the erosion problem and the extent of use of conservation practices. Results show the importance of perception of the threat of soil erosion, household, land and farm characteristics; perception of technology-specific attributes, and land quality differentials in shaping conservation decisions of peasants. Furthermore, where poverty is widespread and appropriate support policies are lacking, results indicate that population pressure per se is unable to encourage sustainable land use. The challenge of breaking the poverty-environment trap and initiating sustainable intensification thus require policy incentives and technologies that confer short-term benefits to the poor while conserving the resource base. © 1998 Elsevier Science B.V. All rights reserved.

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1. Introduction

In many agriculture-based developing countries, environmental degradation mainly takes the form of soil nutrient depletion and loss of food production potential. Reversal of the erosion-induced productivity decline and ensuring adequate food supplies to the fast growing populations in these countries posit a formidable challenge. The complex interlinkages between poverty, population growth, and environmental degradation (Dasgupta and Mäler, 1994; Reardon and Vosti, 1995) offer another dimension to the land degradation problem. In Ethiopia, in response to extensive degradation of the resource base, new land conservation technologies were introduced in some degrading and food deficit areas of the highlands, mainly through food-for-work incentives since the early 1980s. However, sustained adoption of new technologies has become a vital concern when peasants began to dismantle structures once the incentives were discontinued and the coercive approach was abrogated following change in economic policy in March 1990 and subsequent liberalization of the economy. Since then, peasants who seemed to be adopters in the presence of incentives and coercive pressure were found to behave differently, dismantling

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structures entirely or selectively, or retaining them in their initial state.

Several factors that condition peasants' adoption decisions have been discussed in relation to production technologies (e.g. Feder et al., 1985; Kebede et al., 1990; Bellon and Taylor, 1993; Adesina and Zinnah, 1993). Research into the determinants of conservation investments has, however, been limited. Poverty and market imperfections may create disincentives for conservation investment. Innovations that enhance or conserve the resource base may also not provide immediate benefits to land users. Thus, a different set of policies and targeting strategies may be required to promote such investments (Holden and Shanmugaratnam, 1995). Hence, research into farm household investment behavior is useful for technology development and design of policies and strategies that promote resource-conserving land use.

Investment in land conservation may be conditioned by a number of factors that may in turn depend on the nature of rural markets. A synthesis of the factors discussed in the conservation adoption literature (Ervin and Ervin, 1982; Norris and Batie, 1987; Nowak, 1987; Gould et al., 1989; Fujisaka, 1994) is depicted in a conceptual conservation decision model in Fig. 1. The decision to invest in land conservation may thus depend on perception of the erosion problem, household, technology, land and farm attributes, and exogenous conditioning factors. The effect of population pressure on resource conservation is one of the most debated issues. The opposing discourse on the issue may be denoted by the Boserupian view (Boserup, 1965), for its positive role, and the neo-Malthusian view (after Malthus, 1798), for its negative role.

The purpose of this paper is, therefore, to examine the determinants of investments in conservation based on data on voluntary choice of technologies gathered from a highly erodible area in the central highlands of Ethiopia. The rest of the paper is organized as follows. Section 2 outlines the setting and describes the study site. The analytical model of adoption behavior is developed in Section 3. Section 4 provides the empirical setup and hypothesized effects based on existing theory. Section 5 discusses the analytical results of the study and the paper ends with some policy conclusions in Section 6.

2. Resource degradation and past soil conservation in Ethiopia

The Ethiopian economy has largely remained dependent on agriculture which in any single year provides about 46% of the GDP, over 80% of the export revenue and employment for about 80% of the population. About 46% of the land mass lies in what is called the highlands (areas >1500 meters above sea level (masl)). The highlands harbor some 88% of the country's population, over 95% of the regularly cultivated lands and about 75% of the livestock population (FAO, 1986). Most of the agricultural output originates from fragmented micro-holdings cultivated by peasant households in the highlands. Oxen serve as a primary source of traction power. The peasant production system is often diversified across crops and livestock.

The use of external yield-increasing inputs is rudimentary and agricultural production relies heavily on technologies largely unchanged for centuries. Increasing demand for manure as a source of firewood and for crop residues as a source of feed for livestock, accompanied by high population pressure and a decline in land–man ratios, have made the traditional systems of regenerating soil fertility through fallowing and use of manure and crop residues increasingly difficult (FAO, 1986; Teklu, 1990). Intensification of cropping on sloping lands without suitable amendments to replenish lost nutrients has thus led to widespread degradation of land. Available estimates on the economic impact of soil erosion indicate an annual (average of estimates for three agro-ecological zones) on-site productivity loss of 2.2% from the 1985 yield level (FAO, 1986, p. 223).

Despite the increasing pace of degradation, and consistent with the old development thinking which downplayed the role of agriculture, prior to 1974, the issue of conserving agricultural land was largely neglected. Awareness of the land degradation problem was incited mainly by the formation of a new socio-economic order in 1974 and the devastating famine in Wello in 1973/74. Efforts to install conservation measures on erodible lands were initiated following the 1975 land reform and establishment of the Peasant Associations (PAs), which were instrumental in mobilizing labor and assignment of local responsibilities. This was further expanded with the involvement of

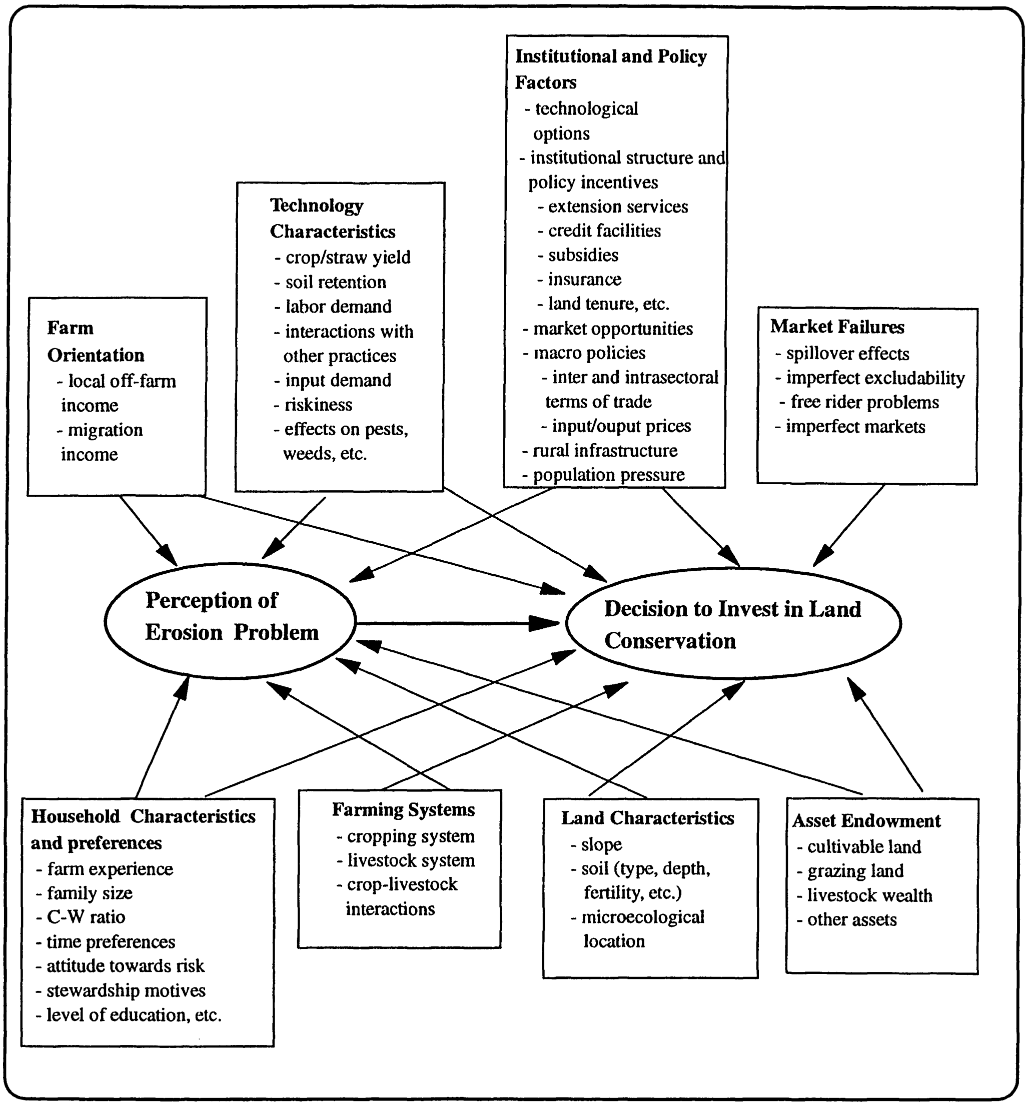

Fig. 1. Factors that influence the desire and capacity of land users to invest in land conservation.

mainly the World Food Program since the early 1980s which provided food-for-work (FFW) incentives for conservation activities. On croplands, structural measures, mainly earth and stone bunds, were built uniformly across regions with FFW incentives in food deficit areas of the highlands. Conservation activities were mainly undertaken in a campaign often without the involvement of the land user. Peasants were not allowed to remove the structures once built but maintenance was often carried out through FFW incentives. Even if considerable areas of erodible lands have been treated, maintenance of the structures has become a cause for concern to the implementing agencies (Tato, 1990). The introduction of economic reform program in 1990 and subsequent liberalization of the economy also brought more freedom and hence conservation structures may be removed if the land user so wishes.

The data for this study come from a study carried out in 1994 in a highly eroded zone of the highlands (Andit Tid) where new conservation technologies were introduced in the past with FFW incentives. The survey was carried out in cooperation with the Soil Conservation Research Project (SCRP) which maintains a field station at the site. Andit Tid lies some 180 km north-east of Addis Ababa in northern Shewa. It has a bimodal rainfall pattern averaging 315.4 mm in the *Belg* (Jan.–May), and 1056.8 mm in *Meher* (June–Dec.) seasons, with an annual average (1986/92) of 1372.2 mm (SCRP, 1995). Its topography lies between altitudes of 3000 and 3500 masl and is characterized by highly dissected and very steep terrain with over three quarters of the land area having a slope of more than 25% which makes it highly vulnerable to erosion (Gebremichael, 1989).

Two types of structural measures were introduced with FFW incentives in Andit Tid; level bunds (LB) in 1980/81 out of the SCRP catchment, and Graded Fanya-juu (GFJ) in 1982 in the catchment. Half of the 80 surveyed households owned some land within the SCRP catchment while the rest have all their parcels out of the catchment. Data collected from 452 parcels include land characteristics (slope and area), the land use type, and peasants' perceptions of the erosion problem. Land users were also asked about the kind of changes they have made on each parcel where conservation structures were built in the past. The responses generally fall into three categories: complete removal (52.8%), partial removal – every other structure in a parcel removed in a fairly consistent manner – (31%), and retention of the bunds in their initial state (16.2%).

3. Methods

Since the dependent variables of main interest, the three response levels representing the degree of adoption of introduced conservation structures, had an ordinal categorical nature, an ordinal logit model, a variant of the ordered probit (Zavoina and McElvey, 1975), was used for empirical analysis of peasants' adoption decisions. The model can be represented as:

$$Y_i^* = \beta' \boldsymbol{x}_i + \varepsilon_i \tag{1}$$

where Y_i^* is the underlying latent variable that indexes the level of use of conservation practices on a given parcel, $\boldsymbol{x}_i$ is a $(k\times 1)$ vector of explanatory variables, β is a $(k\times 1)$ vector of parameters to be estimated, and ε_i is the stochastic error term. The latent variable exhibits itself in ordinal categories, which could be coded as 0,1,2,. . .,J. Hence, we observe a response in category j when the underlying continuous response falls in the jth interval (suppressing the observation subscripts) as:

$$\begin{array}{lll} Y=0 & \text{if} & Y^* \le \delta_0 \\ Y=1 & \text{if} & \delta_0 < Y^* \le \delta_1 \\ Y=2 & \text{if} & \delta_1 < Y^* \le \delta_2 \\ \vdots & & \vdots \\ Y=J & \text{if} & \delta_{J-1} \le Y^* \end{array}$$

where $\delta_j (j = 0, 1, 2 \ldots, J-1)$ are the unobservable cutpoint (threshold) parameters that will be estimated together with other parameters in the model. When an intercept term is included in the model, δ_0 is normalized to a zero value (Greene, 1993) and hence only $J-1$ additional parameters are estimated with β_s.

The probabilities for each of the observed ordinal responses, which in our case had only three categories (0, 1, 2) for complete removal, partial removal, and retention of conservation structures, respectively, will be given as:

$$\begin{aligned} P(Y=0) &= P(Y^* \le 0) = P(\beta'\boldsymbol{x} + \varepsilon \le 0) = F(-\beta'\boldsymbol{x}) \\ P(Y=1) &= F(\delta_1 - \beta'\boldsymbol{x}) - F(-\beta'\boldsymbol{x}) \\ P(Y=2) &= 1 - F(\delta_1 - \beta'\boldsymbol{x}) \end{aligned} \tag{2}$$

where F is the cumulative distribution function (CDF) for the stochastic error term ε. As is well known, the assumptions about the functional form of F will determine whether a logit (logistic CDF), probit (standard normal CDF) or other model is used. Following Occam's razor, we use the logistic specification, but the predicted probabilities are expected to be similar to that of a probit model within the broad range of the data except at the tails (e.g. see Maddala, 1983; Aldrich and Nelson, 1984).

In order to ease the interpretation of parameter estimates, cumulative odds ratios were computed from a cumulative logit model (Agresti, 1990). In order to extend the ordinal logit to a cumulative logit, let

$$F_j(\boldsymbol{x}) = P(Y \le j|\boldsymbol{x}) = P(Y^* \le \delta_j|\boldsymbol{x}) = F(\delta_j - \beta'\boldsymbol{x}) \quad \text{for } j = 0, 1, \ldots J-1 \tag{3}$$

where F is as defined above. The linear cumulative logits (Agresti, 1990) derived from Eq. (3) are:

$$L_j(x) = \text{Logit}[F_j(x)] = \log\left[\frac{P(Y^* \leq \delta_j)}{P(Y^* > \delta_j)}\right] = \delta_j - \beta' x \text{ for } j = 0, 1, \ldots, J-1 \quad (4)$$

Cumulative odds ratios could now be derived from Eq. (4) as a difference of the logits for two different values of the regressors,

$$L_j(x = x_1) - L_j(x = x_2) = \log\left[\frac{P(Y \leq j|x_1)/P(Y > j|x_1)}{P(Y \leq j|x_2)/P(Y > j|x_2)}\right] = \beta'(x_1 - x_2) \quad (5)$$

The cumulative odds ratio as defined in Eq. (5) is proportional to the distance between the values of the regressors, with the same proportionality constant applying to each threshold point. The interpretation is that the odds of making a response $\leq j$ are $\exp[\beta'(x_1 - x_2)]$ times higher at x=x_1 than at x=x_2 (Agresti, 1990).

4. Empirical model

4.1. Choice of explanatory variables

The choice of regressors in empirical adoption studies has often lacked a firm theoretical basis. Farm households' land use and conservation decisions are likely to be influenced by a number of factors (Fig. 1). The effect of these factors on conservation investment decisions is also conditioned by the nature of rural market imperfections (Pender and Kerr, 1996; Holden et al., 1998). When market distortions occur, the subjective price of the good may fall within the price band, and make production and consumption decisions nonseparable (Sadoulet and de Janvry, 1995). This result implies that conservation investments, competing for resources needed for current production or consumption, will also be nonseparable from production and consumption decisions. To the extent that endowments of assets and factors differ across households, market imperfections may thus lead to differences in conservation investments. As Pender and Kerr (1996) demonstrate, when perfect markets exist for all goods and services, households' factor endowments will have no effect on production and investment decisions. However, imperfections in labor markets force households to equate labor demand with family labor supply, and thus higher labor endowments may boost conservation investments. Imperfections in credit/capital markets also imply that households with higher savings or productive assets will be able to invest more in conservation. Distortions in land markets may also lead to differential investment behavior. Thus, where market imperfections are important, the theory of investment behavior suggests inclusion of household characteristics and asset endowments in explaining adoption decisions. Moreover, land attributes that influence the profitability or riskiness of technologies are important. So are household perceptions of technology attributes. Institutional innovations that help ease liquidity constraints needed for consumption and investment, or increase the flow of information on the impacts of soil erosion and available conservation options are also useful. A summary of all the variables used in this study is presented in Table 1.

Given the conservation decision model of Fig. 1, our empirical estimation attempts to capture the two-stage conservation decision process in a model of perception (in the first stage) and a model of adoption and level of use of conservation practices (in the second stage). In the second stage estimation of the adoption process, a mix of the approach used by previous researchers is employed. Similar to Ervin and Ervin (1982), the soil erosion perceptions were used directly with other regressors. Similar to Gould et al. (1989), predicted values (in our case from an OLS model)[1] of soil erosion perceptions are used as regressors in a recursive form. But, unlike the latter, due to multicollinearity, we excluded variables which were significant at 5% level in the erosion perceptions model. An ordinal logit maximum likelihood algorithm (SAS, 1990) was used to estimate Eqs. (1)–(5).

[1]The predicted values from an ordinal logit model give the probability that $Y \leq j$ for a given level of explanatory variables. This required computation of estimated probabilities for each j to calculate expected values according to $\sum_{j=0}^{2} \hat{P}_j(Y = j)$, where $\hat{P}_j$ is the estimated probability for Y=j, to obtain predicted values. Since OLS provided estimates similar to the ordinal logit model, predicted values were generated using this procedure.

Table 1
Definition of all the variables used in the perception and adoption models

Short Form	Definition
MODFIC	An ordinal dependent variable measuring the degree of use of conservation practices on a given parcel: 0 if all bunds were removed, 1 if bunds were alternately removed, and 2 if all the original bunds were maintained on a given parcel.
Perception	An ordinal variable measuring the perceived level of the parcel's exposure to soil erosion ranging from no risk of soil erosion (0) to high exposure to soil erosion (3).
Education	Number of years of formal education completed. The clergy in the Orthodox Church were considered as having equivalent of 1.5 years of formal education.
Age	Age of the household head in years.
Family size	Family size.
C–W Ratio	The consumer–worker ratio of the household.
Attitude	A dummy for the peasant's attitude towards a new technology: 1 if a desire to try new technologies on own cost is expressed, and 0 if reluctance to new techniques or a desire to wait until other land users have demonstrated its performance is indicated.
Rate of time preference	The peasant's rate of discount estimated from a survey of minimum willingness to accept an amount today instead of 100 Birr (about US $17) in a year.
Group	A dummy variable indicating whether the household has a parcel in the SCRP catchment: 1 if the household has a parcel, 0 otherwise.
Technology awareness	Awareness of the new technologies measured as the total number of new (introduced) conservation technologies known by the peasant.
Land security	An indicator variable for security of land tenure: 1 if the peasant considered he/she will be able to use the parcel at least during his/her lifetime, 0 otherwise.
Land/man ratio	Ratio of cultivable land to family size.
Farm size	The total area of the farm (cultivated land + fallow land + grazing land).
Livestock	Livestock holdings of the household (in oxen equivalents).
Type of house	An indicator variable for the type of the peasant's house: 1 if corrugated iron roof, 0 if thatched grass roof.
Slope	Slope category of the parcel measured as 1 (<10%), 2 (11–20%), 3 (21–40%), 4 (>40%). Local taxonomy of slopes was used after a random sample of 10 peasants in the village correctly identified the local slope gradients as *Meda*, *Tedafat*, *Daget* and *Areh (Gedel)* according to their level of steepness given above. This was persistently checked and clarified to the respondent, as necessary, by the enumerators at the time of the survey.
Parcel area	Area of the parcel in a local unit called *Timad* (approximately 0.25 ha).
Productivity[a]	A dummy for productivity of technology: 1 if the peasant considers output/hectare to be higher with the introduced technology than the traditional practice, and 0 otherwise.
Soil retention[a]	A dummy for the effectiveness of the technology to retain soil: 1 if the peasant considers the introduced technology to be superior, and 0 otherwise.
Sustainability[a]	A dummy for ability of the technology to sustain yields: 1 if the peasant considers the new practice to be more effective in sustaining current yields, and 0 otherwise.
Off-farm orientation	Proportion of household income (net of all variable costs) in 1993/94 from off-farm sources (other than cropping and livestock).
Location	A dummy variable for the location of a parcel in the local agroclimatic zone: 1 if located in *Dega* zone (below 3200 masl), and 0 if located in *Wurch* zone (above 3200 masl).
Land use	A dummy variable indicating the type of land use on a parcel: 1 if the parcel is a cultivable land, and 0 if it was used as a permanent grazing land.

[a] Most peasants in Ethiopia use traditional soil conservation methods like furrows seasonally made within the field to drain excess water and diversion ditches built up slope to prevent runoff entering cultivated fields. The effectiveness of these methods to hold the soil is generally considered low. Peasants were asked to evaluate traditional and introduced methods for these and other attributes (also see [3]).

4.2. *The perception model*

In the perception model, theory and previous research suggested the inclusion of household-specific variables (education and age), variables that condition the diffusion of information (technology awareness, and level of contact with SCRP research and outreach activities (group)), household assets (land/man ratio, livestock capital, and type of the peasant's house), land attributes (slope category), perception of technology-specific attributes (productivity and soil retention), farm orientation (proportion of income off-farm), and farming system-related variables (parcel location and land use).

We hypothesize the level of perception of the soil erosion problem to be positively correlated with the level of education and age of the household head. More experience and knowledge of the farming system associated with education and age of the peasant is expected to raise perception of the problem of soil erosion and its economic impacts. We also conjecture a positive association between perception and diffusion of information through extension and other channels. The total number of introduced conservation practices that the peasant was aware of during the survey (technology awareness) is used as a proxy for the level of information received through extension support and other routes. Moreover, we expect in-catchment households (compared to households out of catchment) who frequently meet SCRP staff and closely observe ongoing research activities to be more cognizant of the problem of soil erosion.

The effect of land–man ratios on erosion perception is ambiguous. From a Boserupian perspective (Boserup, 1965), the scarcity of land induced by population pressure would increase the impetus to invest in land quality. One may thus argue that the decrease in the soil erosion level following autonomous investment will reduce the threat of the erosion problem and its perception. From a neo-Malthusian perspective, the opposite effect may be expected. Under a land-scarce degraded environment, vulnerability to starvation (or the odds of falling below subsistence needs) increases with a decline in land–man ratios. Poverty-induced intensification of farming following the decline in land–man ratios, may thus elevate erosion to a level easily discernible by the land user. In Andit Tid, we expect the latter effect to be stronger, thus a decline in land–man ratios is expected to raise erosion perceptions. The effect of livestock wealth on conservation investment and erosion perceptions is debatable. In Andit Tid, grazing is communal and the cost of pasture degradation is unlikely to be considered by individual agents. If higher livestock wealth also indicates more specialization into this activity away from cropping, the economic significance of erosion will decline. This may lower soil erosion perceptions. Since a parcel's slope also determines erosion potential, we expect a positive effect of this variable on soil erosion perceptions.

Likewise, we expect land users to be more perceptive of the problem of soil erosion in the *Dega* zone, the major cropping zone in Andit Tid (where a variety of crops could be grown in both short and long rainy seasons) than the frost-prone *Wurch* zone (where only barley could be grown during the short rainy season). Similarly, we expect soil erosion on cropland to be more alarming than erosion on pasture land. Diversification out of agriculture is likely to reduce pressure on the land or decrease the farm orientation of the household. Thus, increased off-farm orientation is expected to lower erosion perceptions.

4.3. Adoption and level of conservation decisions model

In the study of adoption and the degree of use of conservation techniques, previous research and economic theory suggested inclusion of soil erosion perceptions, household attributes (education, age, family size, consumer–worker ratio, and attitude), institutional conditioning variables (technology awareness, group, land security), household assets (farm size, land–man ratio, livestock capital, and type of house), land characteristics (parcel area and slope), perceptions of technology attributes (productivity, soil retention, and sustainability), farm orientation, and parcel location and land use.

As recognition of the soil erosion problem is considered to be vital for soil conservation investments, the 'perception' variable is expected to be strongly associated with retention of conservation structures. As noted above, where market imperfections abound, production and consumption decisions may no longer be separable (Singh et al., 1986; Sadoulet and de Janvry, 1995). This suggests dependence of production (and conservation technology choice) on household-specific attributes, consumption choice, and asset position of the household. For example, education has been shown to be positively correlated with adoption and soil conservation effort (Ervin and Ervin, 1982; Norris and Batie, 1987; Pender and Kerr, 1996). Thus, a positive role for education is hypothesized. The effect of family size may go either way. Imperfections in labor markets imply that households with larger human capital may invest more in conservation. The combined effect of market imperfections in labor, output, and risk markets may, however, lead to a decline in investment. This may be due to several factors: (a) for a given land–man ratio, households with large families may perceive a higher risk of starvation than those with smaller families. If crops fail due to bad weather (e.g. hail storms), households with larger families will suffer more, (b) since land–man ratios do not account for land quality, similar land–man ratios may not imply similar food production potential. Similarly, where consumption smoothing constraints exist, an increase in consumer–worker ratio reduces the ability to meet subsistence needs, and may also increase the personal rate of time preference. Hence, a negative effect of the 'C–W ratio' variable is expected.

Previous research also indicates that older peasants are more likely to reject conservation practices (Norris and Batie, 1987; Gould et al., 1989) and productive practices (Bellon and Taylor, 1993). In the absence of land markets, current values of land are not capitalized into the future and land users face problems in transferring their use rights. Since labor and credit markets are imperfect, older peasants lacking the labor necessary for frequent maintenance of conservation structures may also prefer to remove them. Thus, we expect 'age' to have a negative effect on the retention of structures. Peasants with a general positive attitude towards new techniques are also considered to be keen on keeping conservation structures. Missing information about new innovations is often recognized as a deterrent to adoption. Thus, we expect in-catchment households and those with a higher level of awareness about available options to be more receptive of conservation structures (positive effects of Group and Awareness variables). In several studies, insecurity of tenure has been found to be a deterrent to conservation investment (Norris and Batie, 1987; Nowak, 1987; Reardon and Vosti, 1995). In Ethiopia, after the 1975 land reform which provided usufruct rights, land was frequently redistributed by PAs to landless peasants. This is expected to have attenuated the security of tenure, and we hypothesize 'land security' to have a positive effect on retention of structures.

As noted earlier, rural credit market imperfections imply a positive role of asset holdings of households for conservation investments. Farm size is often correlated with peasant wealth that may help ease the needed liquidity constraint. Previous research also found a positive role of this variable on conservation decisions (Ervin and Ervin, 1982; Norris and Batie, 1987; Gould et al., 1989). Similarly, we envisage a positive effect of this variable. In a land-scarce area, the per capita availability of cultivable land is also a valuable asset. Increasing population pressure and degradation of land (Grepperud, 1996), have led to extensification of highland agriculture on to marginal frontier areas previously considered unsuitable for cultivation. In many areas, possibilities to extensify have long been exhausted. Since structures occupy part of the scarce productive land,[2] often without appreciably improving yields, low land–man ratios may trigger removal of conservation structures. Thus, a positive effect of 'land/man ratio' is expected. Since grass roof houses often reflect poverty, houses with corrugated iron roofs are signs of better-off households. Thus the 'type of house' which may indicate the level of wealth (and household's rates of discount) is expected to have a positive effect on conservation.

The effect of livestock holdings on conservation decisions is difficult to hypothesize a priori. Where credit markets are imperfect, livestock wealth may (a) ease capital/cash constraints, (b) reduce the subjective rate of time preference (Holden et al., 1998), and (c) provide security (lower risk) to land users, which may enhance conservation investments. More specialization into livestock away from cropping may, however, reduce the economic impact of soil erosion, and/or increase the availability of manure needed to counter the process of nutrient depletion, and thus lower the need for soil conservation. Parcel slope has been found to positively affect adoption (Ervin and Ervin, 1982; Norris and Batie, 1987; Gould et al., 1989). The 'slope' variable is thus expected to have a positive effect on retention of structures. Peasants also expressed difficulty in turning the ox plow during cultivation of parcels where structures have been installed. Plowing with a pair of oxen is more difficult

[2] According to the soil conservation guideline's (MOA, 1986) definition of slope(%) as vertical interval – VI – (cm)/horizontal distance (m), on a hectare of land of 20% slope, with a VI of 1 m, there will be about 2 km of structures (with about 1 m width) occupying some 20% of the cultivable land.

on smaller parcels as farming will be squeezed between the structures and the parcel boundary on all sides. Hence, we expect a positive effect of 'parcel area.'

Previous research indicates the significant role of perception of technology attributes in shaping adoption decisions (Adesina and Zinnah, 1993; Adesina and Baidu-Forson, 1995). We also expect peasants' perceptions of technology attributes[3] (productivity, soil retention, and sustainability) to have a positive effect on conservation. The net effect of off-farm orientation on investments in land quality is indeterminate on theoretical grounds (Gould et al., 1989; Reardon and Vosti, 1995). Increasing dependence on non-agricultural activities may lower the economic significance of soil erosion; the reduced pressure on the land may reduce the soil erosion problem; off-farm investment may also crowd out investment resources for land quality improvement. On the contrary, off-farm income may ease the liquidity constraint needed for soil conservation investments or purchase of fertility-enhancing inputs. If structures take up productive land and decrease immediate returns, peasants are more likely to keep structures in less intensively cultivated *Wurch* zone than the main cropping (*Dega*) zone. Thus, a negative effect is expected on the 'location' variable. Since the private cost of erosion on grazing land is limited, we expect peasants to invest more on prime cultivable land than on permanent grazing lands. Hence, 'land use' is expected to have positive effect.

5. Results and discussion

5.1. The perception model

Results of an ordinal logit estimation of the perception model appear in Table 2. The signs of most of the estimated parameters conform to our expectations (exceptions are 'group,' 'productivity,' and 'type of house'). The likelihood ratio goodness of fit test shows a good fit for the model (significant at $p<0.001$ level). Physical erosion potential of the parcel (slope) seems to be the most important determinant of the perception of soil erosion. The higher the slope category of a parcel, the higher the probability that recognition of soil erosion will be above any fixed level. The odds ratio of 3.6 on the slope variable suggests that, ceteris paribus, the odds that the perception of soil erosion will be above any given level will be 3.6 times higher for parcels on higher slope categories than parcels on lower slope categories. Perceptions of technology-specific traits also seem to be highly associated with the recognition of the threat of soil erosion. Peasants who perceive the traditional technique as highly ineffective for retaining soil seem to have higher recognition of the erosion problem. For a given level of other regressors, the odds that recognition of soil erosion will be above any fixed level is 2.2 times higher for those who consider the traditional technique less effective for mitigating soil erosion. Land being a valuable asset, the ineffectiveness of farming practices to sustain productivity of the land seems to raise soil erosion perceptions.

The education variable does not significantly shape erosion perceptions. This was not very surprising since most of the households in the survey were illiterates and the average level of education was only 1.36 years, a level too low to make any significant impact. But, education and age seem to be positively associated with recognition of the soil erosion problem. Increased diffusion of information about available technological options for soil conservation had a significant effect on perception of the erosion problem. Soil erosion perceptions are negatively affected by increase in cultivable land per capita. This is consistent with our hypothesis about the relative strength of neo-Malthusian effects in the area. Households with low land–man ratios were more likely to have removed conservation structures. This suggests that in the absence of appropriate technologies and policy incentives, a decrease in land–man ratio alone is insufficient to increase land-improving or conservation investments. The probability that the level of perception of the erosion problem will be below any fixed level

[3] Peasants were also asked to compare other technology attributes. Responses for crop residue yields were left out due to high correlation with responses for grain yields. In relation to labor and cash demand, loss of productive land, and convenience for plowing, all surveyed farmers preferred their traditional methods over introduced conservation techniques.

Table 2
Ordinal logit (and OLS) results for perception of the soil erosion problem at Andit Tid

Variable (Dependent Variable: Perception)	Parameter estimates	Wald chi-squared statistic	Odds ratio	OLS parameter estimates	*T*-ratio
Household characteristics					
Education	0.066	2.286	1.069	0.037	1.740[a]
Age	0.009	1.253	1.010	0.004	1.031
Rate of time preference	−0.676	5.889[b]	0.509	−0.239	−1.849[a]
Institutional factors					
Group	−0.007	0.001	0.993	−0.012	−0.099
Technology awareness	0.546	6.887[c]	1.726	0.286	2.865[c]
Household assets					
Land/man ratio	−0.250	5.652[b]	0.779	−0.132	−2.581[c]
Livestock	−0.172	9.784[c]	0.842	−0.072	−2.112[b]
Type of house	0.002	0.000	1.002	−0.003	−0.022
Land characteristics					
Slope	1.281	132.460[d]	3.599	0.611	13.900[d]
Technology characteristics					
Productivity	−0.387	0.721	0.679	−0.323	−1.549
Soil retention	0.800	14.937[d]	2.226	0.434	4.424[d]
Off-farm orientation	−0.289	0.290	0.749	−0.239	−1.849[a]
Farming system					
Location	0.389	3.769[a]	1.475	0.179	1.861[a]
Land use	0.393	0.800	1.482	0.237	1.133
β_0	−4.870	32.920[d]			
δ_1	1.800	165.306[d]			
δ_2	2.853	272.155[d]			

−2 Log Likelihood=201.664; Model *df*=14; *N*=452.
Adj. R^2=0.347; *F*=16.68 (for OLS model).
[a,b,c,d] refer to significance at 10, 5, 1, and 0.1% level, respectively.
Wald chi-squared statistic is the square of the ratio of the parameter estimate to its estimated standard error.

also increases significantly with livestock wealth. Although lack of markets and support policies hinder emphasis on livestock, many households maintain a flock of sheep as a valuable source of income. If properly developed, emphasis on livestock may be consistent with sustainable land use since highly degraded areas as in Andit Tid are more suited to tree crops and livestock than erosive cropping activities.

Moreover, the subjective rate of discount was also found to have a significant negative effect on recognition of the soil erosion problem. Consistent with the theory that poverty leads to high discount rates (Reardon and Vosti, 1995; Holden et al., 1998), we consider the rate of time preference to have an effect on conservation decisions. Its direct link with the recognition of the erosion problem is not very clear. But, it seems that where subsistence is constrained, poor rural households seem to be less concerned about current rates of erosion and their future productivity impacts.[4]

5.2. Adoption and level of conservation decisions model

The ordinal logit results for the degree of use of soil conservation practices is given in Table 3. In the first four columns, results from direct use of observed levels of the perception variable is reported. The last three columns present results from a recursive use of predicted levels of soil erosion perceptions. Although the likelihood ratio tests indicate a good fit for both models, other goodness of fit measures (the lower AIC and SC values for the non-recursive model) suggest

[4]But, the effect may be due to multicollinearity since its removal from the model affected the sign and magnitude of other estimated parameters.

Table 3
Ordinal logit results for the degree of use of conservation practices on a parcel at Andit Tid (N=452)

Variables: Dep. variable (MODFIC)	Parameter estimates	Wald Chi-square statistic	Odds ratio	Parameter estimate[e]	Wald chi-square statistic	Odds ratio
Perception						
Perception	1.053	63.651[d]	2.86	—	—	—
Predic. perception	—	—	—	1.677	92.926[d]	5.34
Household characteristics						
Education	−0.046	0.679	0.96	−0.109	3.901[b]	0.89
Age	−0.039	12.045[d]	0.96	−0.023	5.529[b]	0.98
Family size	−0.278	9.260[c]	0.76	−0.423	56.748[d]	0.73
C–W ratio	−0.182	0.396	0.83	−0.188	0.503	0.85
Attitude	0.530	4.042[b]	1.70	0.435	3.248	1.41
Institutional factors						
Group	−0.573	3.099[a]	0.56	−0.019	0.005	0.98
Technology awareness	0.855	9.449[c]	2.35	—	—	—
Land security	0.199	0.211	1.22	−0.102	0.070	0.91
Household assets						
Land/man ratio	0.629	9.269[c]	1.88	—	-	1.28
Farm size	0.067	2.047	1.07	0.135	18.219[d]	1.08
Livestock	0.005	0.003	1.01	—	—	—
Type of house	0.541	3.118[a]	1.72	0.265	1.024	1.15
Land characteristics						
Slope	0.625	23.464[d]	1.87	—	—	—
Parcel area	0.209	3.888[b]	1.23	0.210	4.240[b]	1.26
Technology characteristics						
Productivity	1.175	3.693[b]	3.24	0.996	3.385[a]	2.53
Soil retention	−0.051	0.036	0.95	—	—	—
Sustainability	−0.249	0.330	0.78	−0.044	0.013	0.927
Off-farm orientation	−0.942	1.968	0.39	−1.001	2.637[a]	3.538
Farming system						
Location	−0.768	9.752[c]	0.46	−0.729	10.201[c]	2.082
Land use	0.302	0.345	1.35	0.110	0.055	0.986
β_0	−5.55	16.42[d]		−2.31	0.609	
δ_1	2.74	152.98[d]		2.32	157.02[d]	
AIC/SC	642/736			719/793		
−2 Log L	302.9[d]			215.8[d]		
Model df	21			16		

AIC=Akaike Information Criterion=−2 Log Likelihood +2(k+s) where k is the number of explanatory variables, and s is the number of ordered values. SC=Schwartz Criterion = −2 Log Likelihood + (k+s) Log (N).
[a,b,c,d] refer to significance at 10, 5, 1, and 0.1% level, respectively.
[e]Parameter estimates using predicted values of Perception (PREDPER) from the OLS model of Table 1.

that the decision to remove or maintain conservation structures seems to be better explained in the non-recursive formulation. This may not, however, invalidate the two-stage conservation decision process since we may have missed important variables in predicting soil erosion perceptions.[5]

[5]This is evident from the low R^2 obtained from the OLS model in Table 2. A model fitted to assess the effect of the unexplained part of perceptions on conservation decisions also showed a significant effect of residual perceptions.

Most of the regressors used in this model had signs that comply with our prior expectations. The results show that peasants' decisions to retain conservation structures are positively and significantly related to soil erosion perceptions, attitude towards new technologies, exposure to new practices, per capita availability of cultivable land, parcel area and slope, and productivity of the technology. Similarly, negative significant influences for retention of conservation structures include age, family size, and location of the parcel in the main cropping zone. Some variables (education, group, soil retention, sustainability), however, carry unexpected signs, but they were all non-significant.

Older peasants are more likely to remove structures than younger ones. This indicates that although younger households may have limited experience to detect the erosion problem, they are more likely to adopt conservation practices once they perceive the problem. Family size had a significant negative effect on the decision to retain conservation structures. For a given land–man ratio, households with larger families seem to accept less risk in experimenting with new technologies. Households with positive attitude towards new ideas and techniques, however, seem more likely to retain structures. The proclivity to try new ideas and farming practices may also reflect lower risk aversion (which was not separately measured in this study) by these households.

The diffusion of information on available technological options for abating soil erosion had a significant effect on keeping conservation structures. This may indicate the positive role of extension effort on adoption. Peasants' perceptions of the security of use rights to land also seem to be associated with a higher level of use of conservation structures, but its effect was not statistically significant. This may partly be due to measurement problems as security of tenure was measured in binary units. In Ethiopia, the tenural system of use rights that prohibits land markets is likely to be a disincentive to undertake conservation investments with long payback periods (e.g. tree planting). Even for conservation structures, our results suggest a similar trend, but also indicate the presence of other more binding constraints currently limiting such investments.

A decrease in land–man ratio was closely related to the removal of conservation practices. This result also lends evidence to our hypotheses of the strength of the neo-Malthusian scenario in the area. As in much of the highlands, population pressure and degradation of land had led to increasing land scarcity in Andit Tid. In the major cropping zone, fallowing is rarely practised, and land scarcity has forced peasants to use hand hoes on steep slopes where oxen cannot be used for plowing. As the extensive margin disappears, land-hungry peasants strive to secure subsistence by intensifying production on ever smaller plots. Under increasing subsistence demand, the degradation of land that pursues this kind of labor-led intensification (Lele and Stone, 1989; Reardon and Vosti, 1995) often leads to a poverty–degradation trap that feeds upon each other. As Heath and Binswanger (1996) note, the effects of poverty and population on conservation investments is very much conditioned by the policy environment. Where appropriate policy incentives and technologies are lacking, population pressure per se is insufficient to encourage land conservation. As expected, peasants are also more likely to keep conservation practices on steeper slopes where they perceive higher erosion problems than on shallower slopes. The larger the area of the parcel and the steeper its slope, the higher the probability that structures will be retained.

Peasants' perception of technology attributes (productivity) was also related to increasing level of use of conservation practices. Despite the fact that only 6% of the households consider the new conservation techniques higher yielding, this attribute was found to be significant at 5%. Other things being constant, anticipation of higher productivity will enhance adoption of the new technology. Since structures take up productive land and maintenance is costly, peasants are very curious about the yield effect of the technology. Interpretation of the odds ratio is similar to the perception model. For example, the odds ratio of 2.6 for the perception variable indicates that, ceteris paribus, the probability that all conservation practices will be retained in a parcel is about 2.86 times higher at higher levels of perception than at lower level of perception of the erosion problem. Moreover, farm size and proportion of household income from off-farm sources, appear to be significant in the recursive model. While the effect of farm size was reinforced by the removal of land–man ratios in the second stage, increasing reliance on off-farm sources seems to reduce the incentive for land conservation. Similar results were obtained elsewhere (Norris and Batie, 1987; Gould et al., 1989).

The effect of some of the most important variables on the peasants' decisions to retain or remove the technology is provided in Table 4. The probabilities are computed from the estimated ordinal logit model of Eq. (2). The probability ranges are given by group of peasants and location of parcels at the extreme values of slope, perception, land–man ratios, and

Table 4
Estimated probabilities for complete removal, partial removal, or retention of conservation structures at a plot level at Andit Tid

Slope	Perception	Land–man ratio	Productivity of technology	In catchment						Out of catchment					
				Dega zone			Wurch zone			Dega zone			Wurch zone		
				J=0	*J*=1	*J*=2	*J*=0	*J*=1	*J*=2	*J*=0	*J*=1	*J*=2	*J*=0	*J*=1	*J*=2
1	0	0.4	0	0.89	0.11	0.01	0.78	0.20	0.02	0.82	0.17	0.01	0.67	0.30	0.03
1	0	0.4	1	0.71	0.27	0.03	0.53	0.42	0.05	0.58	0.38	0.05	0.39	0.52	0.09
1	0	3	0	0.60	0.36	0.04	0.41	0.50	0.08	0.46	0.47	0.07	0.29	0.58	0.14
1	0	3	1	0.32	0.56	0.12	0.18	0.59	0.23	0.21	0.60	0.19	0.11	0.55	0.34
1	3	0.4	0	0.25	0.59	0.16	0.13	0.57	0.29	0.16	0.59	0.26	0.08	0.49	0.42
1	3	0.4	1	0.09	0.52	0.39	0.05	0.38	0.57	0.05	0.42	0.53	0.03	0.27	0.71
1	3	3	0	0.06	0.44	0.50	0.03	0.29	0.68	0.04	0.33	0.64	0.02	0.19	0.79
1	3	3	1	0.02	0.22	0.76	0.01	0.12	0.87	0.01	0.14	0.85	0.01	0.07	0.92
1	**1.61**	**1.76**	**0.062**	**0.36**	**0.54**	**0.10**	**0.21**	**0.60**	**0.20**	**0.24**	**0.59**	**0.17**	**0.13**	**0.57**	**0.30**
4	**1.61**	**1.76**	**0.062**	**0.08**	**0.50**	**0.42**	**0.04**	**0.35**	**0.61**	**0.05**	**0.39**	**0.57**	**0.02**	**0.24**	**0.74**
4	0	0.4	0	0.55	0.40	0.05	0.36	0.54	0.10	0.40	0.51	0.09	0.24	0.59	0.17
4	0	0.4	1	0.27	0.58	0.15	0.15	0.58	0.27	0.17	0.59	0.24	0.09	0.51	0.40
4	0	3	0	0.19	0.59	0.22	0.10	0.53	0.37	0.12	0.56	0.33	0.06	0.43	0.51
4	0	3	1	0.07	0.46	0.47	0.03	0.31	0.66	0.04	0.35	0.61	0.02	0.21	0.77
4	3	0.4	0	0.05	0.39	0.56	0.02	0.25	0.73	0.03	0.28	0.69	0.01	0.16	0.83
4	3	0.4	1	0.02	0.18	0.80	0.01	0.09	0.90	0.01	0.11	0.88	0.00	0.06	0.94
4	3	3	0	0.01	0.12	0.87	0.00	0.06	0.93	0.01	0.07	0.92	0.00	0.04	0.96
4	3	3	1	0.00	0.04	0.95	0.00	0.02	0.98	0.00	0.02	0.97	0.00	0.01	0.99

where *J*=0, 1, 2 refer to complete removal, partial removal, or retention of conservation structures, respectively.

perceived productivity of structures at the average values of all other variables. The two rows in the middle of the table present probabilities at the average values of all other variables for the lowest and highest slope categories. For example, at the *Dega* zone, the probabilities for complete removal of structures range from 0.89 (for parcels in the lowest slope category, soil erosion is unrecognized, land–man ratio is lowest, and conservation is unproductive) to 0 (for parcels in the highest slope category, erosion is well recognized, land–man ratio is highest, and conservation is productive). This compares with 0.36 and 0.08 at the average values of the regressors at the lowest and highest slopes. Similarly, the probability of retention of structures ranges from 0.01 to 0.95 while the average values are 0.10 and 0.42. In each location, the effect of slope depends very much on the level of erosion perception, the land–man ratio, and perceived productivity of conservation. Even at shallower slopes, structures are very unlikely to be removed completely on parcels where land users perceive a significant threat of soil erosion. As one moves from the major cropping (*Dega*) zone to the less intensive cropping (*Wurch*) zone, the probabilities of complete removal decrease, while the probabilities of partial removal and retention increase. The same trend occurs as one moves from in-catchment parcels to out-of-catchment parcels within each farming zone.

6. Conclusions

We may conclude that, first, peasant households' conservation decisions are shaped by a host of factors. Adoption of conservation technologies is likely to increase, among other things, with recognition of the erosion problem, slope and area of the parcel, availability and diffusion of information about conservation needs and options, increase in land–man ratios, and anticipation of higher returns with conservation. In our case, adoption is also likely to be lower with increase in age of the land user and family size. The significance of household attributes, preferences, and capital assets in conservation technology choice provide evidence for nonseparability between production and consumption decisions. This is an effect of rural market imperfections. Second, in degraded areas with widespread poverty, autonomous intensification of land use as a response to increasing population pressure may not always lead to increased investments in land conservation. Although households may invest in land quality with increasing scarcity of land, their abilities to cope with increasing population pressure will eventually be exceeded unless appropriate policies and technical change help ease the pressure. In the absence of such interventions, poor rural households can be caught up in a poverty–population–environment trap that may feed upon each other and lead to worsening poverty and resource degradation. Third, there is a strong need to develop conservation technologies that also provide immediate benefits to impoverished households by improving yields. This is one of the most important challenges for soil conservation policy in the future.

The majority of peasants in Ethiopia do not have access to credit facilities and soil amendments like inorganic fertilizers. Institution of incentive structures to promote conservation effort may include, linking farm subsidies and credit facilities with conservation, provision of secure land rights, and integrated extension services whereby conservation remains an integral part of all forms of land use. In the long term, the need to ease subsistence pressure requires, among other things, technical change, development of the non-farming sector, and curbing population growth. This suggests that the current laissez faire approach to conservation, which primarily relies on market forces and voluntary choices of land users, is unlikely to induce sufficient investment in land conservation. Specific policies addressing the constraints and limitations of peasants through technical change, development of rural markets, and provision of appropriate incentives are required. More research is, however, needed to identify the most efficient ways of promoting land conservation.

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References

Adesina, A.A., Baidu-Forson, J., 1995. Farmers' perceptions and adoption of new agricultural technology: Evidence from analysis in Burkina Faso and Guinea, West Africa. Agricultural Economics 13, 1–9.

Adesina, A.A., Zinnah, M., 1993. Technology characteristics, farmers' perceptions and adoption decisions: A Tobit model application in Sierra Leone. Agricultural Economics 9, 297–311.

Agresti, A., 1990. Categorical Data Analysis, John Wiley .

Aldrich, J.H., Nelson, N.D., 1984. Linear Probability, Logit and Probit Models, Sage Publications.

Bellon, M.R., Taylor, J.E., 1993. 'Folk' soil taxonomy and the partial adoption of new seed varieties. Economic Development and Cultural Change 41, 763–786.

Boserup, E., 1965. The Conditions of Agricultural Growth. The Economics of Agrarian Change under Population Pressure, Earthscan Publications, London.

Dasgupta, P., Mäler, K.-G., 1994. Poverty, institutions and the environmental – Resource base. World Bank Environment Paper 9, Washington, DC.

Ervin, C.A., Ervin, E.D., 1982. Factors affecting the use of soil conservation practices: Hypotheses, evidence, and policy implications. Land Economics 58(3), 277–292.

FAO, 1986. Ethiopian Highlands reclamation study. Final Report, vols. 1 and 2, Food and Agriculture Organization of the United Nations (FAO), Rome.

Feder, G., Just, R.E., Zilberman, D., 1985. Adoption of agricultural innovations in developing countries. Economic Development and Cultural Change 33, 255–298.

Fujisaka, S., 1994. Learning from six reasons why farmers do not adopt innovations intended to improve sustainability of upland agriculture. Agricultural Systems 46, 409–425.

Gebremichael, Y., 1989. Land-use, agricultural production and soil conservation methods in the Andit Tid Area, Shewa Region, Research Report 17. Soil Conservation Research Project, Addis Ababa, Ethiopia.

Gould, B.W., Saupe, W.E., Klemme, R.M., 1989. Conservation tillage: The role of operator characteristics and perception of soil erosion. Land Economics 65, 167–182.

Greene, W.H., 1993. Econometric Analysis, 2nd edn., Macmillan, New York.

Grepperud, S., 1996. Population pressure and land degradation: The case of Ethiopia. Journal of Environmental Economics and Management 30, 18–33.

Heath, J., Binswanger, H., 1996. Natural resource degradation effects of poverty and population growth are largely policy-induced: The case of Columbia. Environment and Development Economics 1, 65–83.

Holden, S.T., Shanmugaratnam, N., 1995. Structural adjustment, production subsidies and sustainable land use. Forum for Development Studies 2, 247–266.

Holden, S.T., Shiferaw, B., Wik, M., 1998. Poverty, market imperfections and time preferences: Of relevance for environmental policy?. Environment and Development Economics 3, 105–130.

Kebede, Y., Gunjal, K., Coffin, G., 1990. Adoption of new technologies in Ethiopian agriculture: The case of Tegulet-Bulga district, Shoa Province. Agricultural Economics 4, 27–43.

Lele, U., Stone, S.W., 1989. Population pressure, the environment and agricultural intensification. Variations on the Boserup hypothesis. MADIA Discussion Paper 4, The World Bank, Washington, DC.

Maddala, G.S., 1983, Limited-dependent and Qualitative Variables in Econometrics, Cambridge University Press, Cambridge.

Malthus, T., 1798, An Essay on the Principles of Population.

MOA, 1986. Guideline for Development Agents on Soil Conservation in Ethiopia, Ministry of Agriculture (MOA), Addis Ababa, Ethiopia.

Norris, P.E., Batie, S.S., 1987. Virginia farmers' soil conservation decisions: An application of Tobit analysis. Southern Journal of Agricultural Economics 19, 79–90.

Nowak, P.J., 1987. The adoption of agricultural conservation technologies: Economic and diffusion explanations. Rural Sociology 52(2), 208–220.

Pender, J., Kerr, J., 1996. Determinants of farmers' indigenous soil and water conservation investments in India's semi-arid tropics. EPTD Discussion Paper #17, International Food Policy Research Institute, Washington DC.

Reardon, T., Vosti, S.A., 1995. Links between rural poverty and the environment in developing countries: Asset categories and investment poverty. World Development 23(9), 1495–1506.

Sadoulet, E., de Janvry, A., 1995. Quantitative Development Policy Analysis, The Johns Hopkins University Press, Baltimore, MD, pp. 140–175.

SAS, 1990. SAS/STAT User's Guide, vol. 2, 4th edn., SAS Institute, Cary, NC.

SCRP, 1995. Unpublished data received from SCRP, Addis Ababa, Ethiopia.

Singh, I., Squire, L., Strauss, J., 1986. Methodological issues. In: Singh, I., Squire, L., Strauss J. (Eds.), Agricultural Household Models. Extension, Application and Policy, The Johns Hopkins University Press, Baltimore, MD, pp. 48–70.

Tato, K., 1990. Ethiopia's experience including policy: Ethiopian soil conservation programme and its future trends. A paper presented at the Conference on Conservation Strategy for Ethiopia, 22–25 May 1990, Addis Ababa, Ethiopia.

Teklu, Y., 1990. Rural energy requirements. A paper presented at the Conference on Conservation Strategy for Ethiopia, 22–25 May 1990, Addis Ababa, Ethiopia.

Zavoina, R., McElvey, W., 1975. A statistical model for analysis of ordinal level dependent variables. Journal of Mathematical Sociology, pp. 103–120.