Conservational Tree Growing by Smallholder Farm Households: Evidence from Gamo Highlands of Southern Ethiopia

Malebo Mancha Massa (malebo2004@gmail.com)
Arba Minch University https://orcid.org/0000-0002-1393-2478

Abdulaziz Abdulsemed Mosa
Wolkite University

Research

Keywords: Conservational tree growing, Smallholders’ agriculture, Gamo highlands, Ethiopia

DOI: https://doi.org/10.21203/rs.3.rs-90834/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License. Read Full License
Abstract

**Background:** Deforestation and environmental degradation were identified among the leading factors worsening risk exposure in developing countries. Conservalional tree growing was found a permissible option and an awake up policy direction to curve down the problem in Ethiopia. However, the uptake of this practice is far from complete and the art has not been made to a level that could make households self-reliant at least in tree resources, particularly in the highlands. This study was aimed at identifying the main decisive factors that potentially influence conservational tree growing behavior of smallholder farm households in Gamo highlands of Southern Ethiopia.

**Methods:** The study was based on survey data collected from 11 villages in 2011/2012. A multi-stage sampling technique was used to select 335 farm households. A structured interview schedule and observation were used to collect primary data. Descriptive and inferential statistics and Logistic regression model were used to analyze the data.

**Results:** The key findings showed that a host of factors significantly influenced smallholders’ decision to practice conservational tree growing. The study found that tree growing experience, age of the household head, farm size, and availability of suitable land area for tree growing and cash income from sales of trees were the significant factors explaining the variation in conservational tree growing behavior of households. The study also observed that indigenous social and cultural organizations and religious and old-aged funeral sites were the homes for old-aged but live indigenous tree species than private farms.

**Conclusion:** Based on the findings, the study concluded that intra-farmer experience sharing, and support to efficient indigenous institutions and rural tree markets as potential entry points for mitigating deforestation, improving forestry, and developing environmentally sustainable agriculture.

**Background**

Risk exposure identified as one of the typical features of farming in developing countries limits income generating and hence affects welfare gaining capacity of farmers (Dercon 2004). The problem is serious in the horn of Africa where the landscape of the economy is dominated by rain-fed smallholder agriculture (Fulginini et al., 2004; IPPC 2007; FAO 2011; FAO et al., 2011). Ethiopia suffers the problem seriously (FAO 2001; Di Falco and Chavas 2009) and there exist plenty of evidences that explore worse existence of such events in the highlands of the country (FAO 1984; Bishaw 2001; Pender et al., 2001; Dercon 2004; Pender and Gebremedhin 2007; Di Falco and Chavas 2009; Bekele and Mekonnen 2010; Zeleke and Bliss 2010; FDRE 2011).

Deforestation was identified among the leading factors worsening the aforementioned problems. It intensifies environmental degradation, global warming, biodiversity loss and desertification and aggravates farmers exposure to regular weather shocks, climate change, and crop failure (Bishaw 2001, 2009; Bekalo and Bangay 2002; Dercon 2004; IPCC 2007; Yesuf et al., 2008; Bekele and Mekonnen 2010). With these externalities, market prices fail to reflect resource scarcity and individual members face
insufficient incentives to adopt eco-friendly measures. This is serious in areas where people’s livelihoods heavily depend on forest resources (Tietenberg 1992) implying a key to a sustained increase in farm productivity and agricultural output in vulnerable areas such as Ethiopia in general and in the Ethiopian highlands in particular is through better and more effective use of technologies conserving land and biological resources.

Empirical studies identify variety of technologies that enhance agricultural productivity, rural income and the environment. Agro-forestry and conservational tree growing (Bishaw 2001, 2009; Abebe 2005; Deininger and Jin 2006; Zeleke and Bliss 2010), tillage and composting (Kassie et al., 2009), soil bunding (Bekele 2005), and terracing (Deininger and Jin 2006; Pender and Gebremedhin 2006; Kassie and Holden 2006) are appealing options available in Ethiopia.

Among others, tree growing founds a permissible option at least for some basic reasons. They are visible investments consistent with the notion of sustainable development set forth by the world commission on environment and development as well as can serve as a solution to the falling farm productivity and per head incomes observed in the last decades (see for example World Commission on Environment and Development (WCED) 1987; Deressa et al., 2009; Molua 2009; Pender and Gebremedhin 2007; Kassie et al., 2008; Kassie et al., 2009; Kassie et al., 2010; Melillo et al., 2011; Di Falco et al., 2011). Trees can also uphold soil moisture, maintain biodiversity balance, safeguard erosion, reverse land and biological degradation, conserve organic matter of the soil and reduce soil nutrient loss, provide shades for crops, and improve land productivity (Bishaw 2001; Kassie et al., 2010). As trees rely to a greater extent on renewable local and farm specific resources (Lee 2005), they can expand income generating opportunities for the poor, and hence resolve financial risk of buying technology inputs and food goods (Hogset 2005). Similarly, trees can support food security by either directly producing food goods or indirectly providing inputs for the production of food goods and/or supplying fuel-wood for cooking food (Belsky 1993). Based on these evidences we trust that conservational tree growing is a solution for environmental degradation, agricultural productivity, biodiversity balance, poverty reduction and hence for sustainable development.

Conservational tree growing is an awake up policy direction in a recent Ethiopia though not new. Chiefly, it is strongly promoted as part of climate resilient green economy (CRGE) strategy plan 2011 (FDRE 2011) as well as an initiative to reverse the extensive land degradation, to protect the adverse effects of environmental degradation and climate change, and to build a green economy that realize the country’s ambition of reaching middle income economy before 2025 (FDRE 2011). Being a traditional technology one can expect that trees can be adopted with less risk as traditional practices in agriculture have been perceived as less risky than modern innovations (Feder et al., 1985; Griliches 1957). Puzzling, the uptake is far from complete and the art has not been made to a level that could make households self-reliant in tree resources, particularly in the highlands.

However, large differences observe between households and villages. Some farmers and villages extensively plant and grow trees while some others do small and the rest do none (Abebe 2000; Admassie
2000; Bishaw 2001; Bekalo and Bangay 2002; Zeleke and Bliss 2010) implying that the past re-afforestation programs launched in Ethiopia were not based on clear understanding of the incentives of and constraints on growers behavior. Simply, by expecting all farmers as an agent who can plant and grow more number and species of trees as long as seedlings are available, seedling were supplied from public nurseries at least at free of charge or at subsidized prices (Zeleke and Bliss 2010). Thus, what determines conservational tree growing by households remains the central question of this study. Therefore, this study aimed to analyze and identify the main decisive factors that potentially influence conservational tree growing behavior of smallholder farm households in Gamo highlands.

Several factors might explain the variation in conservational technology adoption across households. Extension service, agro-ecology, availability of inputs, farm size, culture of people, institutions, proximity to markets, the return from the adoption, risk behavior of adopters, availability of initial capital and other socio-economic and demographic characteristics can determine technology adoption behavior, particularly in agriculture (Kassa 2003; Kebede and Yamoah 2009; Udry 2009). Factors affecting farmers’ decision to plant and grow trees in Ethiopia have also been studied in Ethiopia (see for example, Zeleke and Bliss 2010). However, the scopes are narrowly defined with no or limited emphasis to conservational tree growing behavior. Thus, applied to Gamo highlands, we estimate factors meaningfully determine the variation in the adoption behavior of smallholder households towards conservational tree growing (OFATR). OFATR in this study refers to growing a mix of both indigenous and non-indigenous trees specific to the study area else otherwise. We find some important results that suggest smallholders fail to adopt OFATR or encouraged to adopt OFATR not because of knowledge and information gaps. We also observe that cultural, religious, and old-aged funeral sites as a potential source for collecting extinct indigenous treespecies in Ethiopia.

Materials And Methods

Description of the study area

The study area, Gamo highlands, lies in a remote part of Ethiopia, within the former Gamo-Gofa province of Southern Ethiopia, some 500 kilometer to the south of Addis Ababa, the capital of Ethiopia. Gamo-Gofa is one of the ten administrative zones with total population of 1,595,570 in 2007 of which more than 90% lives in rural areas and the majority are in the highlands (CSA, 2008). The zone has a total area of 12,581.4 square kilometer and consists of 15 districts (namely, Arbaminch Zuria, Kucha, Kemba, Boreda, Chencha, Daramalo, Dita, Zala, Melakoza, Bonke, Ubadebretehay, Mirab-Abaya, Geze-Gofa, Demba-Gofa, and Oyda) and two town administrations (Arbaminch and Sawula).

Rising up from the west of twin lakes Abaya and Chamo, Gamo highlands reach an altitude of 4200 meters above sea level at mount Gughe, the highest peak in SNNPR region of Ethiopia. Gamo highlanders, who reside along the undulating chains of this mountain, form the larger proportion of the 1,595,570 population of the Gamo-Gofa province in 2007 (see also CSA 2008). The economy of people in Gamo highlands, like many other rural areas in Ethiopia, depends on agriculture, which feed and
economize almost all the people in the area. More than 90% of the populations depend on the products from this sector. Cultivation of ‘Enset’, potato and cereals (such as Barley and Wheat) form the basis of subsistence in the higher altitudes while Maize and Sorghum are important food sources on the lower slopes.

In Gamo highlands, natural resources can be considered as opportunities and threats to the lives, if unmanaged. For example, the monsoonal rains and deep aquifers streaming from top highlands continuously feed the Sago, Zage, Maze, Domba, Deme, Kulano, Gogora, Saware, Wajifo, Baso, Harre, Kullufo, Sile and Elgo rivers. These in turn wear down and provide water and eroded loam soil for the people and the fertile fields in the lowlands (Desalegn 2007). Factually, the land of Gamo highlands were believed rich and referred as land of loam soil called ‘ModhdhoBiita’ (Malebo 2005). It was used to serve as a drought season home for the nearby lowlanders. But now days, things have been reversing back. As a result, the livelihoods of people in more recent times in Gamo highlands would tend to depend on subsistent agriculture and some off-farm economic activities such as labor-intensive petty trade, traditional weaving, wage work, and collection and sale of firewood are the outshining alternatives. Associated with environmental degradation, the unsustainable use of natural resources, poor performance of the agricultural sector and few opportunities for generating income to people in the area, the traditional labor-intensive weaving, which was believed innovated by one of the Gamo tribes called ‘Dorze’ in Chencha district, as an off-farm income generating activity, has been pushing significant proportion of the highlanders (including school age children) to migrate to the urban areas in other parts of Ethiopia. The problem is aggravated by the fact that population pressure and its density are high; most farmers run small-scale agricultural production that characterizes fragmented land holding and subsistent farming and farm productivity is poor to meet an ever-increasing food and material need of the people. However, sufficient rainfall, deforestation, poor land management practices, environmental degradation, soil erosion, soil infertility, population pressure, poor agricultural productivity, crop failure, and absolute poverty are the primary challenges hindering development in the Gamo highlands (Malebo 2005).

Materials

The data used in this study sourced from five districts located in Gamo highlands (Chencha, Dita, Deramalo, Arbaminch Zuria, and Bonkie). We used detailed structured questionnaire survey for face-to-face personnel interviews with smallholder household heads who reside in eleven peasant associations or ‘kebele’ (the smallest administrative unit in Ethiopia) that were selected from the aforementioned five districts. The survey was conducted in 2011/2012. The questionnaire was developed using a lesson acquired through informal pre-survey interviews with key informants of officials and professionals. The identification strategy followed sequential stages. First, as the role of heterogeneity across agents has been recognized in the adoption literature (Feder et al., 1985), we purposively selected five districts that
characterize varying agro-ecologies and tree coverage. Second; we randomly selected representative peasant associations from each district. Lastly, 335 proportionately sampled households were selected.

Agricultural extension workers working and living in each peasant associations carried out the survey. The interviewers got training about survey questioner and data collection techniques before the survey kicked off. The focal person for the interview was the head of the household. Household heads as a manager of the household has relatively a wider availability of farm information and knowledge than anyone else in the household (Malebo 2005). Thus, they are the first line people who make almost all economic decisions refer to the household. We also conducted focused group discussions with government officials and professionals and direct personnel observation. These all enabled us to collect unfailing data that covered a broad range of socio-economic, demographic, institutional, behavioral, and farm specific characteristics.

**Methods**

**Determinants of technology adoption and the hypotheses on conservational tree growing adoption**

Traditionally, the literature on the adoption of agricultural technologies (or failure thereof) has focused on broad range of factors counting socio-economic, demographic, institutional, behavioral, and farm specific characteristics. Among others, perfection of information, availability of inputs, infrastructure, institutional constraints, and human capital found potential factors that explain variation in the adoption decisions (example, Foster and Rosenzweig 1995). Table 1 describes the determinants of conservational tree growing (OFATR) with their corresponding expected hypothesized relationships, and the significance of these factors in the adoption of conservational tree growing is exhaustively explored in latter stage of the paper.

- **Demographic and socio-economic factors**

**A. Demographic Factors**

Most empirical studies measure demographic factors either by labor availability, sex as a proxy for gender, age and family size. Planting, nursing, and growing trees are labor-intensive endeavors in the study area. We expect that labor constraints can limit the adoptions. Arguably, the larger family size (FAMS) can associate with larger number of labor force and hence with larger number and category of trees grown. Likewise, younger people have a greater chance of acquiring and applying new knowledge and skill than older people (Rogers 1995; Sidibe 2005). In contrary, across age, people can develop experience and skill of doing things. These can make the age effect on tree growing behavior dilemmatic. Thus, we were unclear to hypothesize the role of household head’s age (AGE) on the adoption of OFATR but expect a positive influence of family size on OFATR adoption behavior of smallholders (Table 1).
Gender (GEND) is another demographic factor that can influence the extent of adoptions. Being female or male-headedness proxy our gender variable. Females in the study areas play a role of household heads if and only if they were divorced or unmarried at all; if their husbands were dead; or when their son is too child to lead the household (Malebo 2005). This suggests the possibility that labor supply would tend to be short of with female-headedness. Owing larger labor force demand for OFATR adoption, we hypothesized a negative influence of female-headedness (GEND) or a positive influence of male-headedness and a positive association of active labor force (ACLF) availability to OFATR adoption (Table 1).

**B. Socio-economic Factors**

Socio-economic factors are also assumed to influence the adoption decisions. We use education, occupation, and wealth of the respondents as proxy. Technology adoption literature explains an easier and well familiar adoption of agricultural technologies with higher levels of education and training than those with lower levels (Tassew 2004; Sidibe 2005). Availability of skilled labor can ease such opportunities and likely to influence current technology adoption behavior of households. Thus, we hypothesized a positive influence of education (EDUC-CAT), tree growing experience (TGEXP), and training (TRAIN) on the adoption of OFATR. However, as labor demand in agriculture varies across seasons (peak during planting and harvesting and off-peak otherwise) the occupation variable (OCCUP) might dually influence on OFATR adoption (Table 1).

On the one hand, sufficient availability of off-farm economic occupation can minimize work avoidance during off-peak periods. This might help to generate more income for those who supply more labor hours away from the household. Accordingly, one can expect positive income effect of off-farm occupation for the adoption of farm technologies as it can build farmers ability to invest in productive technologies and other high pay-off inputs and avert risks associate with the adoption. Yet, there are evidences that report negative role of off-farm economic occupation for the adoption of on-farm soil conservation measures. Abera’s (2003) study in Ethiopia estimates that off-farm economic occupations constrain household labor supply to on-farm economic activities. However, we expect that a household’s sole dependence on on-farm incomes and generation of cash income from tree (YTR) can force them to plant more trees. Consequently, we hypothesized positive link between YTR and OFATR and remained unclear to hypothesize the association between off-farm occupations (OCCUP) and OFATR adoption (Table 1).
### Table 1
Determinants of OFATR with expected hypothesized relationships

| Acronym | Description of variables | Measurement | Expected sign |
|---------|---------------------------|-------------|---------------|
| **Dependent variable** | | | |
| OFATR  | Whether a household adopted conservational tree growing or not | Dummy (1 if grows ecological trees including a mix of indigenous species, 0 otherwise) | |
| **Independent variables** | | | |
| **1. Demographic and socio-economic factors** | | | |
| FAMS   | Family size of the household | Number of people in the household | + |
| AGE    | Age of the household head | Formal age in number of years | ? |
| GEND   | Sex of the household head | Dummy (1 if female, 0 if male) | |
| EDUC   | Formal educational background of the household head | Categorical variable (Cannot read and write or no schooling = 1, grades 1–4 = 2, grades 5–8 = 3, grades 9–12 = 4, and grades above 12 = 5) | + |
| OCCUP  | Occupation background of the household head | Dummy (1 if farming only, 0 if both farming and others) | ? |
| YTR    | Source of household’s income | Dummy (1 if collects cash income from trees, 0 otherwise) | + |
| ACLF   | Active labor force in the household | Number of active labor members | + |
| TRAIN  | Training received about the role of tree growing in environmental conservation | Dummy (1 if yes, 0 if no) | + |
| TGEXP  | Tree growing experience in the past | Dummy (1 if yes, 0 if no) | + |
| **2. Agro-ecological and farm specific factors** | | | |
| SULNTR | Availability of suitable land area for tree growing | Hectares of land area owned by the household and located on sloppy mountainous areas | + |
| FARMS  | Farm size of the household | Total hectares of land owned by the households (in hectares) | + |
| AVATR  | Sufficient availability of seedlings | Dummy (1 if yes, 0 if no) | + |

Source: Authors’ compilation
Agro-ecological And Farm Specific Factors

Farm size, land suitability, and proximity of farms to the nearest input and output markets are among the agro-ecological and farm specific factors assumed to determine technology adoption behavior. Agro-ecological factors were proxies by agro-ecological zones of the respondents. The agro-ecological zones of Ethiopian highlands were classified into three broad major categories: (i) the high potential perennial (HPP) zone, (ii) the high potential cereal (HPC) zone, and (iii) the low potential cereal (LPC) zone (Table 2). These often were defined in terms of temperature, stored soil moisture and number of days in a year that plants grow without irrigation (Bishaw 2009).

We included these agro-ecological variables to control for all the unobserved agro-ecology specific factors associate with the adoption OFATR of in the smallholder farmers. We expect larger adoption of conservational trees in LPC zone than the other two as it characterizes high variability of climate and occasional occurrence of droughts (Bishaw 2009).

| Acronym | Description of variables | Measurement | Expected sign |
|---------|---------------------------|-------------|---------------|
| HPP     | High potential perennial agro-ecological zone | Dummy (1 if the respondent belongs to HPP zone, 0 otherwise) |               |
| HPC     | High potential cereal agro-ecological zone   | Dummy (1 if the respondent belongs to HPC zone, 0 otherwise) |               |
| LPC     | Low potential cereal agro-ecological zone    | Dummy (1 if the respondent belongs to LPC zone, 0 otherwise) |               |

Source: Authors’ compilation

Table 2
Major Agro-Ecological Zones of the Ethiopian Highlands

| Agro-ecological zones | Climate                  | Growing period in number of days |
|-----------------------|--------------------------|---------------------------------|
| HPP zone              | Warm and more humid      | Mainly > 240                    |
| HPC zone              | Intermediate rainfall    | Usually > 180                  |
| LPC zone              | High variability and occasional drought | Mainly 90–150                  |

Source: Bishaw (2009)
As far as farm specific factors are concerned, we use farm size, land suitability for tree growing and sufficient availability of seedling sources. A basic possible hypothesis on-farm size is that the adoption of an innovation will tend to take place earlier on larger farms than on smaller farms. This can be largely due to cost issues. For instance, Feder and O’Mara (1981) demonstrate that fixed transaction costs associated with the adoption innovations prevents small farms from adopting technologies. Land ownership can also influence land related investments by many other ways. The larger the farm size (FARMS) a farm household owns the more land area can be accessed for planting and growing trees. Land suitability for tree growing (SULNTR) is another farm specific factor that might influence farmers’ technology adoptions; the availability of more mountains land area, the greater the likelihood of adopting conservational investments. Sufficient availability of seedling sources (AVATR) is also basic as investors use factor inputs for production. We thus expect that OFATR is positively associated with SULNTR, AVATR, and FARMS (Table 1).

**Model Specifications**

The analysis and presentation of the study was quantitative. To this end, the data were quantized to scores as shown in Table 1 and the analysis employed a mix of both descriptive statistics and econometric tools. Initially, the inter-relation between the potential predictors was analyzed by spearman correlation and then regression analysis was utilized principally. Since our observations take limited categories with zero values on the dependent variable the orthodox Ordinary Least Squares (OLS) regression models cannot properly accommodate the data. This failure directed us to utilize estimators built on the principle of maximum likelihood (MLE) estimators. The most common of these models used in the adoption literature are the logit and the probit. As Anemiya (1985), Wooldridge (2000) and Verbeek (2004) conclude that the choice of which model to use cannot be justified theoretically. They estimate almost similar results. However, there are empirical suggestions that force us to prioritize between them. Arguably, logistic regression analysis provides response probability estimates that are asymptotically consistent and computationally easier to use than probit (Pindyck and Rubinfeld 1981).

Following this framework, logistic modeling approach founds customary in empirical studies that examine factors determining technology adoption, particularly in agriculture (Green and Ng'ong'o 1993; Chaves and Riley 2001; Tadesse and Belay 2004; Asfawa and Admassie 2004; Mercer, et. al., 2005; Iqbal et al., 2006; Zeleke and Bliss, 2010). Evidently, the assessment of factors influencing the adoption of integrated pest management for coffee in Colombia (Chaves and Riley, 2001), the adoption of fertilizer use in Africa (Green and Ng'ong'o, 1993) and the assessment of factors determining rubber–tea intercropping by the smallholder farmers in Sri Lanka (Iqbal, et., 2006) are worth mentioning. Consistently, we apply the logit model to estimate factors influencing household’s decision to grow conservational trees.

A common starting point for logit model is a ‘random utility framework’, in which the utility of each alternative is a linear function of observed characteristics and the error term of the model (Verbeek 2004,
see also Asfawa and Admassie 2004). Following the context we assumed individuals choose to adopt or not to adopt OFATR depending on their utility maximizing behavior. That is, an individual household can decide to adopt or not to adopt OFATR if he/she expects the adoption will generate him/her the highest possible benefit or utility than else.

Therefore, relying on the frameworks developed by the past studies and following the notation of Wooldridge (2000), the general specification of the logit identifying the probability, \( P_i \), of the \( i^{th} \) household's behavior towards the adoption of ecological tree growing technology is given by:

\[
P_i = \frac{e^{Z_i}}{1 + e^{Z_i}}
\]

1.1

Where \( Z_i \) is an indirect utility derived from the adoption decision or random variable that predicts the probability of the \( i^{th} \) farmer adopting OFATR. \( Z_i \) is also referred to as the log of the odds ratio in favor of the adoption. The odds ratio is defined as the ratio of the probability that a farm household adopts OFATR \( (P_i) \) to the probability of non-adoption of OFATR \( (1 - P_i) \).

For an individual farm household, we construct \( Z_i \) as a linear function of explanatory variables \( (X_i) \), where \( \beta_i \) is an unknown parameter; \( X_i \) is set parameters which influence the \( i^{th} \) farm household's adoption decision to grow ecological trees (OFATR). The unknown parameter \( \beta_i \) associated with each \( X_i \) is determined by an iterative process that makes use of a maximum likelihood estimate (Wooldridge 2002).

\[
Z_i = \ln \left[ \frac{P_i}{1 - P_i} \right] = \ln \text{Odds} = \beta_0 + \sum \beta_i X_i
\]

1.2

Taking natural log in both sides of (1.2), the final standard form of the logistic model estimating the likelihood of adopting OFATR by smallholder households becomes Eq. (1.3). In the Eq. 1.3, \( i \) refers to the \( i^{th} \) observation in the sample, \( k \) refers to number of explanatory variables, \( \beta_0 \) refers to the intercept term, and \( \beta_1, \beta_2, .., \beta_k \) refer coefficients associated with explanatory variables \( X_1, X_2, ..., X_k \) respectively.

\[
Z_i = \ln \left[ \frac{P_i}{1 - P_i} \right] = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \cdots + \beta_k X_{ki}
\]

1.3

Since the parameters \( \beta_i \)s are unbiased and normally distributed, we used an analogue of student’s t-test to test the significance of the regression. Throughout the estimation, we use t statistics based on standard errors that are robust to heteroskedasticity. The significances of the coefficients of the variables presented in the logistic model were tested using a log-likelihood ratio assuming a chi-square (\( \chi^2 \)) data distribution (see also Pindyck and Rubinfeld 1981). All the analyses were run using a mix of STATA and Microsoft offices excel program software packages.
Results And Discussions

Characteristics of the respondents

Descriptive statistics of all the variables used in the study are shown in the Table 3. The dependent variable OFATR is a dummy variable that takes the value of 1 if the respondent grows a mix of indigenous species of trees and 0 otherwise. The results for this variable show that about 39.4% (132) of the households surveyed grow conservational trees while 60.6% do not. The study used availability of active labor force (ACLF), gender (GEND), family size (FAMS), and age (AGE) as proxies for demographic characteristics. The size of ACLF in the respondent’s family system is a discrete variable representing number of adults who are member of the respondent’s household, aged between 15 and 64 years and available for work. The average number of ACLF is about 3.2 adult people with the minimum of 1 and the maximum of 13 implying the ACLF of the majority of the households is less than 4. This might be due to the fact that majority of the younger adults are devoted to traditional weaving and/or migrate to urban areas.
The gender (GEND) status of the respondents is either male or female. It is included to observe the implications of gender differences on conservational decision-makings. From the sampled households 11.3% are female and 88.7% are male. Family size (FAMS) is a discrete variable representing number of people in the household. The average family size is 6.9 people with the minimum of 1 and the maximum of 17. The study proxies human capital of the households by their head’s age (AGE), education level (EDUC-CAT) and tree growing experience (TGEXP). The respondent’s tree growing experience in the past (TGEXP) is a dummy variable attains a value of 1 for those who have experience and 0 otherwise. Among the respondents, 72.2% have tree growing experience while the rest 27.8% do not. The respondent’s age (AGE) is a continuous variable representing age in number of years. The average age of the sample household heads is nearly 43.8 years with the minimum of 20 years to the maximum of 75 year old.
Thus, majority of the household heads are aged on the high side of ages above 40 years. This might be because of the fact that some parents co-reside with son and daughter-in-law and because of age-selective migration of the younger male to urban areas.

The education variable is represented in categorical orders ranging from 1 to 5 with the average of 2.5, which is equivalent to primary school level below grade 8. Average education levels are low because older generations are relatively uneducated than younger generations. As Table 3 indicated, about 25.9% of surveyed households generate liquid cash income through sale of trees while the rest 74.1% do not. Moreover, as a component of socio-economic indicator, the study proxies occupation status of the households by a dummy variable that assume the value of 1 if the respondent household’s head work solely on-farms and 0 if work on on-farm and off-farm activities. Accordingly, 20.6% of farm households have an off-farm job while 79.4% exclusively work on-farms. Farm size (FARMS) is a continuous variable with the size of farms in hectares. This variable represents the land owned by household. As shown in the Table 3, the average size of farm or landholding is 1.02 hectares of land and there appears to be a wide range of variability in farmland ownership ranging from 0.01 hectares farm possession at the minimum to owning 7.82 hectares of farmland at the maximum.

The agro-ecological origin of the respondents shows that 28.1% are from HPP zone, 53.7% are from HPC zone, and the rest 18.2% are from LPC zone. Availability of seedling (AVATR) variable suggests that about 32.8% of the respondents have sufficient access to sources of seedlings while the rest 67.2% do lack. The study proxied land suitability for tree growing by number of hectares of the household’s land located on sloppy mountains. If the household owns larger hectares of land area on mountainous slopes, the owner has very suitable land area for tree growing than cropping. About 43.9% of the respondents have more than 10% of their own land area on sloppy mountains. Training variable of the study indicate that about 60% of the respondents are either consulted information or received training on land and soil conservation measures while the other 40% do not.

In general, majority of the households surveyed averagely fail to adopt OFATR. Most of those households who did not grow trees are male headed with more than 43 years of age, host more than six people per household, and have less than four working age people in the household. Furthermore, these households on average hold than 1.02 hectares of land area, attained education status below grade 8, work solely on small-scaled and fragmented farmlands, and have poor access to off-farm economic opportunities. On the other hand, the data also reveal that a household who plant and grow trees have acquired tree growing experiences in the past, use trees mainly for home consumption with low sales for cash, were informed about the importance of trees and owns land area that can primarily be used for tree growing than for crop production and animal grazing. We also observed that there exist old-aged trees in traditionally protected areas of Gamo highlands; funeral and mystical sites are worth mentioning (Fig. 1)

The summaries of descriptive statistics for household who adopt OFATR and household who do not adopt OFATR are separately reported in Appendix 2 and Appendix 3, respectively.
Factors determining the adoption of OFATR by smallholder farm households in the Gamo highland of Southern Ethiopia

In this section, we outline the partial correlation and main results exploring the determinants of conservational tree growing behavior of households specific to Gamo highlands of Southern Ethiopia. Initially partial correlation analysis was performed. This was to assess the inter-relation of the factors that potentially affect the farmer’s decision to adopt OFATR. Appendix 1 summarizes partial and semi-partial correlation coefficients of the main factors associated with the decision to adopt conservational tree growing (OFATR) by smallholder farmers in Gamo highlands. Of the factors, six variables are significantly correlated (P < 0.1) with the decision to adopt conservational tree growing and results consistent with the logit estimations. These factors are (i) age of the household head (AGE) measured in years, (ii) age-squared of the respondent (AGE\(^2\)), (iii) farm size of the household measured in hectares of land area (FARMS), (iv) cash income that households generate through sales of trees or tree goods measured in units of ‘birr’ value of the sales (YTR), (v) past experience of growing trees proxies by dummy values of existence or non-existence (TGEXP), and (vi) land suitability (SULNTR) for growing trees measured in hectares of land area on mountains or very sloppy location.

Likewise, to assess the relative contribution of significant factors we principally used a multivariate logistic regression analysis. Logistic estimates predicting the maximum likelihood for the factors that determine the adoption of conservational tree growing behavior of farm households are presented in Table 4. The estimates were made with and without controlling for agro-ecological dummies in order for capturing the unobserved factors specific to varying agro-ecologies. The logit estimation also founds significant at 1% level of significance; i.e., the log-likelihood ratio (regression deviance) is significant (P < 0.01) throughout the estimations, indicating that the model is statistically valid.
Table 4
Summary of the factors associated with OFATR adoption: The logit estimates

| Variables | Coefficients | Robust standard errors | P > /Z/ | Coefficients | Robust standard errors | P > /Z/ |
|-----------|--------------|------------------------|--------|--------------|------------------------|--------|
|           | Estimation 1 (Appendix 4) |                        |        | Estimation 2 (Appendix 5) |                       |        |
| GEND      | -0.769       | 0.503                  | 0.147  | -0.749       | 0.541                  | 0.166  |
| FAMS      | 0.026        | 0.064                  | 0.687  | 0.004        | 0.066                  | 0.946  |
| AGE       | 0.209**      | 0.103                  | 0.044  | 0.218**      | 0.106                  | 0.039  |
| EDUC-CAT  | 0.050        | 0.209                  | 0.810  | 0.042        | 0.212                  | 0.845  |
| OCCUP     | 0.239        | 0.346                  | 0.489  | 0.284        | 0.356                  | 0.423  |
| ACLF      | 0.025        | 0.103                  | 0.810  | 0.043        | 0.107                  | 0.688  |
| FARMS     | -0.392***    | 0.160                  | 0.014  | -0.473***    | 0.175                  | 0.007  |
| YTR       | 0.612**      | 0.305                  | 0.045  | 0.599*       | 0.308                  | 0.052  |
| TGEXP     | 4.346***     | 1.049                  | 0.000  | 4.507***     | 1.092                  | 0.000  |
| AVATR     | 0.169        | 0.305                  | 0.578  | 0.146        | 0.307                  | 0.633  |
| TRAIN     | 0.403        | 0.298                  | 0.177  | 0.349        | 0.304                  | 0.249  |
| SULNTR    | 1.785**      | 0.814                  | 0.028  | 1.962**      | 0.895                  | 0.028  |
| AGE\(^2\) | -0.002**     | 0.001                  | 0.052  | -0.002*      | 0.001                  | 0.050  |
| HPP       |              |                        |        | -0.642       | 0.428                  | 0.134  |
| HPC       |              |                        |        | -0.726       | 0.413                  | 0.079  |
| Constant  | -9.849***    | 2.403                  | 0.000  | -9.515***    | 2.470                  | 0.000  |
| Pseudo R\(^2\) | 0.286 |                        |        |              | 0.292                  |        |
| Log likelihood | -160.337 |                        |        |              | -158.978               |        |

* P < 0.1, ** P < 0.05, and *** P < 0.01

Source: Authors’ computation based on field survey

Based on t-probability values, smallholders’ OFATR adoption behavior is positively and significantly associated to household’s age (AGE), the existence of tree growing experience (TGEXP), household’s capacity to generate cash income from trees (YTR) and the availability of suitable land area for tree growing (SULNTR). However, smallholderOFATR adoption decision is negatively related to the age-squared variable (AGE\(^2\)) and the farm size available to the households (FARMS).
Among others, past tree-growing experience is the most significant factor associated with tree-growing behavior of smallholder farmers in the current Gamo highlands. In other words, households with past tree-growing experience are more likely to adopt OFATR relative to households without such experience. Evidently, we demonstrate that a significant number of farmers who grow trees in the past also plant and grow more number and species of trees in their present farms. This is consistent with the hypothesis we made so far and with the predictions that producers primarily specialize in the agricultural system in which they have past experiences.

The age variable is differently resulted as it was unclearly hypothesized. The estimates indicate that age and age-squared variables remain noteworthy to explain adoption behavior of households. The age-squared variable was included to assess whether the likelihood of adoption behavior diminishes at some threshold level of age or not. The estimates for this variable suggest that the likelihood of OFATR adoption diminishes meaningfully (P < 0.1) as age of the household heads increases, particularly in the Gamo highlands. Thus, on average, conservational tree-growing behavior of farm households is positively related to age of household heads but can diminish across age as the $AGE^2$ variable is negatively related to OFATR (P < 0.05). Therefore, there can have some threshold level of age on which household head’s tree-growing behavior can change from rising trend to diminishing trend. This is consistent with Rogers’s (1995) and Sidibe’s (2005) estimates of the age influence on the technology adoption behavior of the adopters but inconsistent to justify their conclusions. Rogers (1995) and Sidibe (2005) demonstrate that younger people have a greater chance of acquiring and applying knowledge and skill than older people. This does mean that people can develop experience and skill of doing things across age. However, unlike their argument, the estimates of the TGEXP variable in this study prove strong positive association to OFATR, which is evidently significant.

The availability of suitable land area for tree growing (SULNTR) is positively and significantly (P < 0.05) influences OFATR adoption decision of households. Farm household who owns more hectares of land in mountainous area that is suitable for tree growing more likely adopt OFATR relative to households who possess less mountainous land area that is consistent to support our hypothesis. However, the estimates for farm size variable founds paradoxical. It disproves the fixed transaction costs hypothesis that ‘the adoption of an innovation will tend to take place earlier and larger on large farms than on small farms’ (Feder and O’Mara 1981). The variable also finds inconsistent to our hypothesis that the larger the farm size (FARMS) a farm household owns the more land area can be accessed for planting and growing trees and the more number and species of trees can be planted. We estimate strong negative association between FARMS and OFATR. This supports the conclusion by Bekalo and Banguy (2002) –‘environmentally friendly investment decisions are a luxury for rich but a necessity for poor’.

In contrast, estimates for gender of heading households (GEND), family size of the household (FAMS), and education status of the household head (EDUC-CAT) are inconsistent to support the hypotheses made so far, not significantly influence the variation in OFATR adoption and hence less likely affect OFATR adoption decision of households. Likewise, the estimates for occupation category of the household (OCCUP), access to training and information (TRAIN), availability of seedlings (AVATR), availability of
active working age labor force in the household (ACLF), and agro-ecological differences in the Gamo highlands all showed statistically insignificant associated to OFATR. Thus, these factors are less likely to affect conservational tree growing behavior of smallholder farm households in Gamo highlands.

Specifically, we assumed farmers with formal education (EDUC-CAT) can have greater agricultural awareness than others and this variable is assumed to have positive link to the adoption of OFATR. Unlike the hypothesis, the estimates shows that EDUC-CAT is positively but insignificantly associated with OFATR, this reveal that education is less likely influence conservational tree growing behavior of households in the study area. This is inconsistent with the conclusions by Tassew (2004) and Sidibe (2005). We also observe that households headed by educated people have relatively more number of educated labor forces in their family system than the uneducated one. In view of these, one can expect that more number of skilled labor forces in the family might pave the way for tree growing opportunities. However, the coefficient for EDUC-CAT variable does suggest the reverse. This reminds us the narration by an old man in Chencha – “I don't want my child will farm ... as I lived poor because of my farms”. If this continues to hold and educated people leave farms before agricultural transformation, the future of rural Ethiopia, mainly for the highlanders, might become dark. These suggest some cautious intervention and necessitate further analysis of the events in the smallholders’ agriculture in Gamo highlands.

We expected that female-headedness can negatively influence OFATR adoption because of labor shortages and hypothesized that labor constraints of the family can limit the adoption of conservational tree growing (OFATR). Even if, the estimation results indicate female-headed household are negatively affect OFATR adoption but it is statistically insignificant and hence gender of the household cannot make a big difference in the adoption behavior of households. Similarly, even though the estimation result supports the hypothesis that household with larger number of family size (FAMS) and larger number of working age people (ACLF) in the family system tend to adopt OFATR than households with less family size and less number of active labor in Gamo highlands but these results are also statistically insignificant.

The variations in agro-ecological zones (for example, HPP, HPC and LPC) do not result any significant difference in the OFATR adoption behavior of household. In other words, irrespective of their agro-ecological location, similar factors influence farm households’ OFATR adoption decisions. Although we hypothesized that availability of off-farm economic occupation (OCCUP) and OFATR adoption behavior are ambiguous, the model result indicate that having an off-farm job positively affects the likelihood of a farmer’s OFATR adoption behavior but it is statistically insignificant and hence we find weak evidence that support the strong association between OCCUP and OFATR adoption.

On the contrary, the cash income that households generate from sales of trees from farms (YTR) meaningfully links to their OFATR adoption behavior. On the one hand, occupational differences that might cause variation on per head income of households founds insignificant to explain difference in the OFATR adoption behavior of households. On the other hand, income that can allow ease access to inputs finds insignificant to explain the variation in OFATR adoption. Therefore, though our estimates for the
YTR variable do support Abera’s (2003) study that he reports negative role of off-farm income in the adoption of soil conservation measures in Ethiopia, the path way through which income variable (YTR) links to tree growing behavior of farm households necessitates further scrutiny. This is soundly that availability of seedlings (inputs) also founds less likely to explain OFATR adoption behavior of smallholders in Gamo highlands.

**Conclusion And Policy Implications**

The study has intended to estimate factors determining the adoption behavior of smallholder farm households towards conservational tree growing specific to Gamo highlands. The results indicated that as age of household heads rise and households get involved in tree growing experiences they tend to plant and grow more number and species of trees, harvest more tree goods, earn more cash income from sales of trees and further adopt planting and growing of more number and species of trees, though it diminishes with age of household heads.

Paradoxically, households with larger resource base (mainly land) do not grow larger number and species of trees compared to households with smaller resource base. Likewise, smallholder households fail to plant and grow conservational trees or encouraged to plant and grow conservational trees not because of knowledge and information gaps or its perfections, not because of being male or female-headedness, not because of excess or shortage availability of working age people in the household, and not because of insufficient availability or unavailability of seedling inputs but they characterize varying experiences of tree growing in the past, ages of the household head, hectares of land area available to the households and suitability for growing trees than cropping, and cash income generates from sales of trees and tree products.

We also observe that conflicts with adjacent farm household others might influence tree growing behavior of smallholders in Gamo highlands. In addition, we witness that cultural, religious, and old-aged funeral sites can be taken as potential sources for collecting becoming extinct tree species mainly in Gamo highlands of Southern Ethiopia. Thus, indigenous social organizations can serve as potential sources for collecting becoming extinct tree species in the smallholders’ agriculture, mainly in Gamo highlands of Southern Ethiopia. These also suggest positive role of indigenous institutions for forestry development, poverty reduction and sustainable development in rural Ethiopia in general and in Gamo highlands in particular. Therefore, we recommend some important respects: (i) revival of shock resilient green economy is timely though late, (ii) except fattening history, dinosaurs can contribute nothing for future, and (iii) resources must regenerate by many as development needs participation of developers and beneficiaries, but still (iv) further inspection must be done for evidence-based interventions.

**Abbreviations**

*CRGE: climate resilient green economy, OFATR: conservational tree growing, FAMS: family size, AGE: household head's age, GEND: Gender, ACLF: active labor force, EDUC-CAT: education, TGEXP: tree*
growing experience, TRAIN: training, OCCUP: occupation variable, YTR: cash income from tree, OCCUP: off-farm occupations, SULNTR: land suitability for tree growing, FARMS: farm size, AVATR: availability of seedling sources, HPP: high potential perennial agro-ecological zone, HPC: high potential cereal agro-ecological zone, LPC: low potential cereal agro-ecological zone.

**Declarations**

**Ethics approval and consent to participate**

Not applicable.

**Consent for publication**

Not applicable.

**Availability of data and materials**

The data used for this study can be obtained from the corresponding author up on request.

**Competing interests**

The authors declare that they have no competing interests.

**Funding**

This study is financed by Arba Minch University. However, the views expressed in this manuscript do not represent the position of Arba Minch University. Thus, the authors are solely responsible for any errors or omissions of this manuscript.

**Authors’ Contributions**

The corresponding author is the major contributor from administering the data collection to writing the draft manuscript, the co-author contributed by administering the survey and editing the manuscript.

**Acknowledgements**

The Authors are grateful to the research and community development service division of Arba Minch University for its material and financial support of this research. We are also grateful to data collectors and respondents for their support in successfully conducting the survey.

**Authors’ Information**

1Department of Economics, Arba Minch University, P.O.Box 21, Arba Minch, Ethiopia. 2Department of Economics, Wolkite University, P.O.Box 07, Wolkite, Ethiopia.
References

1. Abebe SW (2000) Farmers’ Private Tree Growing Traditions and Management at Wondo-Genet. MSc Thesis, Wageningen University, the Netherlands
2. Abebe T (2005) Diversity in Home-Garden Agroforestry Systems of Southern Ethiopia. Tropical Resource Management Papers, Number 59
3. Abera BD (2003) Factors Influencing the Adoption of Soil Conservation Practices in Northwestern Ethiopia. Discussion Paper 37. Institute of Rural Development. University Of Gottingen, Gottingen, Germany
4. Admassie Y (2000) Twenty Years to Nowhere: Property Rights, Land Management and Conservation in Ethiopia. Asmara, Eritrea. The red sea press
5. Amemiya T (1985) Advanced Econometrics. Harvarde University Press, Cambridge
6. Asfaw A, Admassie A (2004) The Role of Education in the Adoption of Chemical Fertilizer under Different Socio-Economic Environments in Kenya. Agric Econ 30:215–228
7. Bekalo S, Bangay C (2002) Towards Effective Environmental Education in Ethiopia: Problems and Prospects in Responding to the Environment - Poverty Challenge. International Journal of Educational Development 22:35–46
8. Bekele W (2003) Economics of Soil and Water Conservation: Theory and Empirical Application to Subsistence Farming in the Eastern Ethiopian Highlands. Doctoral Thesis, Swedish University of Agricultural Sciences
9. Bekele W (2005) Stochastic dominance analysis of soil and water conservation in subsistence crop production in the Eastern Ethiopian highlands: The case of the Hunde-Lafto area. Environmental Resource Economics 32:533–550
10. Bekele G, Mekonnen A (2010) Investments in Land Conservation in the Ethiopian Highlands: A Household Plot-Level Analysis of the Roles of Poverty, Tenure Security, and Market Incentives. Environment for Development, Discussion Paper Series, 10 – 09
11. Belsky JM (1993) Household Food Security, Farm Trees, and Agro-Forestry: A Comparative Study in Indonesia and the Philippines. Human Organization 52(2):130–141
12. Bishaw B (2001) Deforestation and Land Degradation in the Ethiopian Highlands: A Strategy for Physical Recovery. Northeast African Studies, 8(1), New Series, 7–26
13. Bishaw B (2009) Deforestation and Land Degradation in the Ethiopian Highlands: A Strategy for Physical Recovery. Ethiopian e-Journal for Research and Innovation foresight, 1 (1), Inaugural Issue, 5–18
14. Central Statistical Authority (CSA) of Ethiopia (2003) Ethiopian Agricultural Sample Enumeration: Statistical Report on Farm Management Practices Livestock and Farm Implements. Addis Ababa Ethiopia
15. Central Statistical Authority (CSA) of Ethiopia (2008) Summary and Statistical Report of the 2007 Population and Housing Census. CSA, Addis Ababa Ethiopia
16. Chaves B, Riley J (2001) Determination of Factors Influencing Integrated Pest Management Adoption in Coffee Berry Borer in Colombian Farms. Agriculture Ecosystems Environment 87:159–177
17. Green DA, Ng’ong’ola G (1993) Factors Affecting Fertilizer Adoption in Less Developed Countries: An Application of Multivariate Logistic Analysis in Malawi. J Agric Econ 44(1):99–109
18. Deininger K, Jin S (2006) Tenure Security and Land-Related Investment: Evidence from Ethiopia. Eur Econ Rev 50:1245–1277
19. Dercon S (2004) Growth and shocks: Evidence from rural Ethiopia. J Dev Econ 74(2):309–329
20. Deressa TT (2007) Measuring the Economic Impact of Climate Change on Ethiopian Agriculture: Ricardian Approach. Policy Research Working Paper 4342. The World Bank, Development Research Group. Sustainable Rural and Urban Development Team
21. Deressa TT, Hassan R, Ringler C, Alemu T, Yesuf M (2009) Determinants of Farmers’ Choice of Adaptation Methods to Climate Change in the Nile Basin of Ethiopia. Glob Environ Change 19:248–255
22. Desalegn D (2007) The Bio cultural Diversity of Living Indigenous Sacred Landscape in the Gamo-Highlands of Ethiopia.” Ethiopian Wildlife and Natural History Society
23. Di Falco S, Chavas J (2009) On Crop Biodiversity, Risk Exposure, and Food Security in the Highlands of Ethiopia. Am J Agr Econ 91(3):599–611
24. Di Falco S, Veronesi M, Yesuf M (2011) Does Adaptation to Climate Change Provide Food Security? A Micro Perspective from Ethiopia. American Journal of Agricultural Economics. In Press
25. FAO, IFAD, WFP (2011) The State of Food Insecurity in the World: How Does International Price Volatility Affect Domestic Economies and Food Security? FAO, Rome Italy
26. FDRE CSA (2008) Summary and Statistical report of the 2007 population and housing census. CSA Addis Ababa, Ethiopia
27. Federal Democratic Republic of Ethiopia (FDRE) (2011) Ethiopia’s Climate-Resilient Green Economy. Green Economy Strategy, Addis Ababa, Ethiopia
28. Feder GRE, Zilberman D (1985) Adoption of Agricultural Innovations in Developing Countries: A Survey. Econ Dev Cult Change 33(2):255–298
29. Feder G, O’Mara GT (1981) Farm Size and the Adoption of Green Revolution Technology, Economic Development and Cultural Change, 30, 59–76
30. Food and Agricultural Organization of the United Nations (FAO) (2011) The State of Food and Agriculture 2010–2011: Women In Agriculture: Closing The Gender Gap For Development. FAO, Rome
31. Food and Agriculture Organization of the United Nations (FAO) (1984) “Ethiopian Highlands Reclamation Study (EHRS)”. Final Report, Volumes 1–2, Rome
32. Food and Agriculture Organization of the United Nations (FAO) (2001) The Economics of Soil Productivity in Sub-Saharan Africa. Rome
33. Foster AD, Rosenzweig MR (1995) Learning by doing and learning from others: human capital and technical change in agriculture. J Polit Econ 103:1176–1209
34. Fulginiti LE, Perrin RK, Yu B (2004) Institutions and agricultural productivity in Sub-Saharan Africa. Agric Econ 31:169–180
35. Green DA, Ng'ong'oala G (1993) Factors Affecting Fertilizer Adoption in Less Developed Countries: An Application of Multivariate Logistic Analysis in Malawi. J Agric Econ 44(1):99–109
36. Griliches Z (1957) Hybrid Corn: An Exploration in the Economics of Technological Change. Econometrica 25(4):501–522
37. Hogset H (2005) Social Networks and Technology Adoption. Selected Paper prepared for presentation at the American Agricultural Economics Association Annual Meeting
38. Intergovernmental Panel on Climate Change (IPCC) (2007) Summary for Policymakers, Climate Change 2007: The Physical Science Basis. Working Group I Contribution to IPCC Fourth Assessment Report. Geneva
39. Iqbal SMM, Ireland CR, Rodrigo VHL (2006) A Logistic Analysis of the Factors Determining the Decision of Smallholder Farmers to Intercrop: A Case Study Involving Rubber–Tea Intercropping in Sri Lanka. Agric Syst 87:296–312
40. Kassa G (2003) GIS-Based Analysis of Land Use/Land Cover, Land Degradation And Population Changes - A Study Of BoruMetero Area Of South Wello, Amhara Region. Unpublished Msc Thesis, School of Graduate Studies, Addis Ababa University
41. Kassie M, Zikhali P, Pender J, Köhlin G (2008) Sustainable Agricultural Practices and Agricultural Productivity in Ethiopia: Does Agroecology Matter? RFF and Environment for Development Initiative Working Paper
42. Kassie M, Zikhali P, Manjur K, Edwards S (2009) Adoption of Sustainable Agriculture Practices: Evidence from a Semi-Arid Region of Ethiopia. Natural Resources Forum 33:189–198
43. Kassie M, Zikhali P, Pender J, Kohlin G (2010) The Economics of Sustainable Land Management Practices in the Ethiopian Highlands. J Agric Econ 61:605–627
44. Kassie M, Holden ST (2006) Sharecropping Efficiency in Ethiopia: Threats of Eviction and Kinship. Agricultural Economics, 37, 179–188
45. Kebede F, Yamoah C (2009) Soil Fertility Status and Numass Fertilizer Recommendation of TypicHapluustertes in the Northern Highlands of Ethiopia. World Applied Sciences 6(11):1473–1480
46. Lee DR (2005) Agricultural Sustainability and Technology Adoption: Issues and Policies for Developing Countries. Am J Agr Econ 87(5):1325–1334
47. Malebo M (2005) Determinants of Household Income Poverty in the Rural Areas of Chencha District: A Cross-Sectional Data Analysis. A Thesis Submitted for the requirements of BA Degree in Economics. Ethiopian Civil Service College, Addis Ababa Ethiopia
48. Melillo J, Butler S, Johnson J, Mohana J, Steudler P, Luxa H, Burrows E, Bowles F, Smith R, Scott L, Vario C, Hill T, Burtoni A, Zhouj Y, J Tang (2011) Soil Warming, Carbon–Nitrogen Interactions and Forest Carbon Budgets. Proc Natl Acad Sci USA 108:9508–9512
49. Mercer DE, Haggar J, Snook A, Sosa M (2005) Agroforestry Adoption in the Calakmul Biosphere Reserve, Campeche, Mexico. Small-scale Forest Economics. Management Policy 4(2):163–183

50. Molua E (2009) An Empirical Assessment of the Impact of Climate Change on Smallholder Agriculture in Cameroon. Global Planet Change 67:205–208

51. Pender J (2001) Rural Population Growth, Agricultural Change and Natural Resource Management in Developing Countries: A Review of Hypotheses and Some Evidence from Honduras

52. Pender J, Desta L, Kassie M, Sn B(2001) Land degradation in the highlands of Amhara region and strategies for sustainable land management. International Livestock Research Institute, Livestock Policy Analysis Program, Addis Ababa. Working Paper No. 32

53. Pender J, Gebremedhin B, Benin S, Ehui S (2001) Strategies for Sustainable Development in the Ethiopian Highlands. Am J Agr Econ 83(5):1231–1240

54. Pender J, Gebremedhin B (2006) Land Management, Crop Production and Household Income in the Highlands Of Tigray. An Econometric Analysis, Northern Ethiopia

55. Pender J, Gebremedhin B (2007) Determinants of agricultural and land management practices and impacts on crop production and household income in the highlands of Tigray, Ethiopia’. Journal of African Economies 17:395–450

56. Pindyck RS, Rubinfeld DL (eds) (1981) Econometric Models and Economic Forecasts. McGraw-Hill Book Company, New York

57. Rogers EM (1995) Diffusion of Innovations (4th edition). The Free Press, New York

58. Sidibe M (2005) Farm-Level Adoption of Soil and Water Conservation Techniques in Northern Burkina Faso. Agriculture Water Management 71:211–224

59. Tadesse M, Belay K (2004) Factors Influencing Adoption for Soil Conservation Measures in Southern Ethiopia: The Case of Gununo Area. Journal of agriculture rural development in the tropics sub-tropics 105(1):49–62

60. Tassew W (2004) The Role of Schooling in the Alleviation of Rural Poverty in Ethiopia, Proceedings of 25th International Conference of Agricultural Economists (IAAE).761–770

61. Tietenberg T (1992) “Environmental and Natural Resource Economics”.3rd edition. Harper Collins Publishers, New York

62. Udry CR (2009) Networks, Local Institutions and Agriculture in Africa: Notes Toward a Research Program, Yale University, Department of Economics

63. Verbeek M (2004) A Guide to Modern Econometrics, 2nd edn. John Wiley and Sons Ltd, England

64. WCED (World Commission on Environment and Development) (1987) Our Common Future: The Brundtland Commission Report. Oxford University Press, Oxford

65. Wooldridge JM (2000) Econometric Analysis of Cross Section and Panel data. MIT Press, Cambridge

66. Wooldridge J (2002) Econometric Analysis of Cross Section and Panel Data. The MIT Press, Cambridge
67. Yesuf M, Di Falco S, Deressa T, Ringler C, Kohlin G (2008) The Impact of Climate Change and Adaptation on Food Production in Low-Income Countries. Evidence from the Nile Basin, Ethiopia

68. Zeleke E, Bliss JC (2010) Tree Growing by Smallholder Farmers in the Ethiopian Highlands. Proceedings of the IUFRO Conference. Slovenian Forestry Institute, Slovenian Forest Service, 166–187