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Agroforestry and land productivity: Evidence from rural Ethiopia

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Abstract: This study attempted to investigate the factors that substantiate the agroforestry adoption decisions of the farm households and its effect on farmland productivity. For the analysis of the agroforestry adoption incidences, the study employed probit model. The findings of the study indicated that being male-headed household, family size, vulnerability of the plot to land degradation, the comparative economic incentive of cash tree plantation and farm size have positive effect on cash tree adoption; while non-food crop farming practices and experience of cash-tree plantation had an adverse effect on the agroforestry plantation practices. Using OLS regression technique, farmland productivity was estimated, in contrast to a large body of theoretical and empirical literature, male-headed households were found to be less productive than female-headed counterparts. As projected, cash tree plantation bear out a positive impact on food crop productivity. This, in turn, empowered farm households to acquire and employ better farm technologies since cash tree plantation could enable rural Ethiopia farmers to fill the gap of rural financial market failures. Cash tree and agroforestry adoption among small farm households were also found to help farmers to improve and recover the rural farmland management system and to maximise the farm households' productivity and income.

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Geremew Worku Kassie is a fulltime lecturer in the Department of Economics at Debre Markos University, Ethiopia and currently he has been teaching several economics courses including the supervision of research projects for the students in the same department. He has owned two Masters: in Development Economics in Ethiopia and in International Cooperation Policy, in Japan. His research interests and research area are on rural livelihood diversification, agroforestry and comparative economic growth studies with particular emphasis to the East Africa and Southeast Asia regions.

PUBLIC INTEREST STATEMENT

The aim of this paper is to identify the determinant factors of cash tree adoption, and whether it has a synergy or tradeoff effect with crop productivity among farm households in rural Ethiopia. The findings entail that farm size, and the comparative economic incentive of cash tree plantation, family size, and the existence of land degradation have positive effect on agroforestry adoption. In contrast, remoteness to the proxy market and road, as well as non-food crop farming practices demonstrate negative effect on agroforestry adoption incidences. The cash tree adoption using agroforestry system illustrates the significant effect on food-crop productivity. It appears to be realistic in that, it helps out farmers to secure and employ modern farm technologies and improved seeds to reimburse the rural financial market failures. The result unveiled that agroforestry adoption, specifically cash tree farming within small farm households needs to be incentivized, supported by the government and rural developmental institutions.

Subjects: Development Studies; Gender & Development; Regional Development; Research Methods in Development Studies; Rural Development; Development Theory; Economics and Development; Environment & the Developing World

Keywords: agroforestry adoption; rural development; sustainable land management; land productivity

1. Introduction

The major challenges of agricultural development in Ethiopia, where more than 75% of the population is agrarian, include how to lift up agricultural productivity, enhance long-term investments on farmlands, and to guarantee the sustainable development of the sector. It is also argued that growth in agriculture is effective at least by reducing chronic poverty as compared to growth in other sectors (Meier, Rauch, & York, 2000).

The study area where this survey conducted, Mecha rural district, is located in Amhara National Regional State in the Northwest of Ethiopia. In this rural district, now a days farm households are adopting eucalyptus tree plantation on their farm plots to cope up with the vulnerable and volatile nature of agriculture. However, there are ongoing debates about the adoption course of fast-growing eucalyptus tree species such as *Eucalyptus globules, Eucalyptus camaldulensis, and Eucalyptus saligna* on food crop farmlands. The proponents argue that land degradation, population growth, and drought threaten food security, and thus planting of eucalyptus trees on land which is unsuitable for food crop production may substantially help farmers to raise household income and ultimately to improve food security. Besides, some ecologists argued that eucalyptus tree plantation will not have negative effects on the land conservation and food crop production and its ecological perils of plantations are limited and rather the latent ecological benefits are larger (Shiferaw & Holden, 1998).

On the other hand, opponents have argued that planting eucalyptus tree species on their farms results in depletion of soil nutrients via its long roots and high water consumption (Poore & Fries, 1985). Unlike other tree species (e.g. Lucenea, Sespania, and Acacia), eucalyptus is a non-leguminous tree, which does not fix nitrogen (N_2), which is an innermost element for soil health and sustainability (Jagger & Pender, 2003; Pender, Nkonya, Jagger, Sserunkuuma, & Ssali, 2004). Despite all these economical and ecological debates, farm households in Mecha rural district take their own choice of planting eucalyptus trees to resilience from weather prone and susceptible nature of the aged and mono-cropping food item production trends. Therefore, it is essential to analyse the determinant factors of agroforestry adoptions of farm households as well as its implications on the productivity of food crops. This ultimately will help to design and implement the informed policy for restructuring rural development packages within the sector. The result of this study will also help equally rural development policy makers and the farming communities in the process of maximising farm productivity and implement sustainable land management system.

2. Adoption of agroforestry

Agroforestry refers to land-use systems in which trees or shrubs are grown in association with agricultural crops, pastures or livestock, whereby there are both ecological and economic interactions between the tree and other components (Alene et al., 2008; Current, Lutz, & Scherr, 1995; Mcginty & Swisher, 2008; Molua, 2005; Young, 1989). The benefit of agroforestry can be effectively alienated into two: economical and ecological. The soil and water conservation use of agroforestry is the synergy between conservation and production which is essential for sustainable land use (Young, 1989). Researchers (Rauniyar & Goode, 1992) reported three approaches of adoption of agroforestry technology. The first approach accentuates the adoption of the technology independently, the second emphasise as the adoption of the whole packages, and the third is the sequential or stepwise adoption of components of packages. For instance, (Khanna, 2001) argued that the sequential choice is a rational choice for small farmers with limited cash. There are several factors that could influence the farmers' decision whether or not to adopt a given new farm technology. For instance, as described by scholars in the field (Baptista, 2000; Baptista & Swann, 1998; Iammarino & McCann, 2006), one possible source of technology adoption is geographically rooted factors, ecological (Bo, 2011; Xepapadeas, 2005), and the social and demographic characteristics of the farm households (Browder & Pedlowski, 2000; Hayes, Roth, & Zepeda, 1997; Holden, Shiferaw, & Pender, 2004; Lee, 2005).

3. Crop productivity

Agricultural productivity is the leading component and it is a prime prerequisite for the growth of developing countries. It is a measure of the amount of agricultural output produced for a given amount of inputs. It can be defined and measured in a variety of ways, including partial measures, such as the amount of a single output per unit of a single input, or in terms of an index of multiple outputs divided by an index of multiple inputs (Assuncao & Braido, 2007; Barrett, Bellemare, & Hou, 2010; Lamb, 2003). Factors that can determine agricultural productivity and growth rates were classically studied using either a production-function approach or an index number approach. In a production-function approach, discrepancies in output or productivity across spatial units like farms or countries, and time is elucidated by differences in the level of inputs, both conventional factors of production such as land, labour, tractors, livestock, and fertiliser, and non-conventional factors like land-quality, physical infrastructure, research, and government policies. This approach usually employs partial productivity measures, such as land productivity or labour productivity (Assuncao & Braido, 2007; Carletto, Savastano, & Zezza, 2013).

Sometimes it is argued that small farms in terms of land size are more productive than large farms and it is further recommended that agricultural development strategies need to be based on the backing of small rather than large farms. In addition to this, the small farm biased agricultural development strategy simultaneously can help to overcome both growth and income distribution objectives (Ellis, 2008; Ellis & Freeman, 2005). However, in the past growth in agricultural production in Sub-Saharan Africa was achieved by spreading out the amount of cultivated land, but today there is a diminutive scope for increasing the area for cultivation. Scholars in the field (Venkatesan & Kampen, 1998) suggest that raising agricultural production in the fixed land could only be achieved by raising the yield and productivity of farm labour, yet this obliges the innovation and adoption of appropriate technologies for developing countries.

4. The model

4.1. Model for agroforestry adoption

Under imperfect markets in developing countries, the process of agricultural diversification involving non-food commodities can be impeded by shocks and costs in the food marketing system (Govereh & Jayne, 2003). Food market failures lead to non-separability of household production and consumption decisions that account for the potential breakdown of agricultural diversification strategies based on comparative advantage. In addition to production and consumption decisions, there are also non-separabilities between crop production choice and access to inputs and prospects for short or long-term investment preferences (Seo & Mendelsohn, 2008). For instance, if there is no functional credit market, farm households with limited cash income could not be able to acquire essential agricultural inputs. Subsequently, farmers take their own measures to fill this gap mainly by diversifying agricultural practices from merely food crop farming to other tree and cash crop plantations in order to maximise and diversify their incomes.

The decision made by the farm households on eucalyptus plantation enables them to acquire resources that otherwise would not be accessible, for other agricultural crop production purposes. In other words, farmers can sell tree products and will purchase fertiliser and improved seeds to boost crop yields through overcoming their capital constraints. The adoption of any agricultural technologies will be affected by economic, social, technical and physical constituents of farming practices. The theoretical model of the farm household's decision in this study was adapted from the work of (Bromley, 2009; Caviglia & Kahn, 2001; Sills & Caviglia-Harris, 2009; Toulmin, 2009). Based on the model, the agroforestry adoption first begins slowly and moves rapidly, and then reaches a maximum as the information of the practice disseminates, and finally, it slows down as the proportion of farmers that have adopted reached the ceiling. The farm household has the choice of adopting the comparatively feasible farm diversification practice, which is planting eucalyptus tree or limited to food crop farming. In this case, the farm households' plot can be allocated for food crops, other agricultural commodity production purposes, for eucalyptus tree plantation, or in the merge with other agricultural productions.

This study employed a model of the farm household utility maximisation to explain farmers' adoption behaviour since farm households in Mecha rural district are both producers and consumers of their own agricultural products. Therefore, production preferences are persuaded by consumption expenditures, and both decisions by the farm household are supposed to be made concurrently. The utility is derived from the household's consumption of goods (*C*) and a group of other factors like the accessibility of markets (*M)*. Consequently, the household utility maximisation model is rooted in the expected value of the non-observable underlying utility function that ranks the preference of the *ith* household according to the chosen agricultural practice. The non-observable underlying utility function can be represented by:

$$E[U_{it}\left(C_i\left(R_i, H_i, Y_i\right), M_i\right] \tag{1}$$

where *E* is the expectations operator, *t* stands for the technology choice and the agricultural method is chosen by the farm household (*t = 1* when eucalyptus is planted on the plot along with other agricultural crops and *t = 0* when barely food crops and other agricultural commodities are produced exclusively), and *i* stands for the individual farm household. Consumption is derived from observable farm and household characteristics, *R* (farm size, proximity to road, homestead, and market), *H* (family size, dependency ratio, age, and educational level of the household heads, and observable technology characteristics), *Y* (yield and labor), and *M* (access to credit, land tenure characteristics).

Even though utility is unobservable, the utility derived from a specific technology is a function of the vector of the observed farm and technology characteristics incorporated. The farm household opts between $E[U_{i0}]$ and $E[U_{i1}]$ depending upon which farm technology yields the greatest expected utility. The utility ranking of the chosen technology is therefore anticipated from the vector of observable farm and technology characteristics as follows:

$$E\left[U_{it}\right] = \alpha F_i\left(X_i\right) + U_{it};\ t = 0,\ 1 \text{ and } i = 1,\ 2, \ldots n \tag{2}$$

where U_{it} is normally distributed disturbance term.

The *ith* farm household will decide to use land for food crop and other agricultural production purposes if $U_{i1} < U_{i0}$, or if the non-observable latent variable $P^* = U_{i1} - U_{i0} < 0$;

On the other hand, the farm family unit will adopt agroforestry if:

$$P^* = U_{i1} > U_{i0};\text{ or } P^* = U_{i1} - U_{i0} > 0 \tag{3}$$

$$\text{i.e. } P_i = 1 \text{ if } U_{i1} > U_{i0};\text{ cash tree will be adopted}$$

$$P_i = 0 \quad \text{if} \quad U_{i1} < U_{i0};\ \text{cash tree will not be adopted} \tag{4}$$

The probability that the farm household adopts agroforestry (the probability that P_i equals *one*) is a function of the independent variables:

$$P_i = \Pr\left(P_i = 1\right) = \Pr(U_{i1} > U_{i0})$$

$$= \Pr\left[\gamma_1 F_i(X_i) + U_{i1} > \gamma_0 F_i(X_i) + U_{i0}\right]$$

$$= [(U_{i1} - U_{i0}) > F_i(X_i)(\gamma_0 - \gamma_1)]$$

$$= [\varepsilon_i > F_i(X_i)\beta]$$

$$= F_i(X_i)\beta \quad (5)$$

where ε_i is $(U_{i1} - U_{i0})$ and β is $(\gamma_0 - \gamma_1)$. The cumulative distribution functions of *F* for *i* valued at X_i if *i* is assumed to be normal, *F* will have a cumulative normal distribution. The study employed the discrete choice model to evaluate the adoption of agroforestry in Mecha rural district, where *i* is assumed to be normally distributed.

The discrete choice model is explained briefly in (Maddala, 1988):

$$Y_i^* = \beta' X_i + \varepsilon_i \quad (6)$$

where Y_i^* is not observed and it is commonly called "latent" variable, and what one observe is a dummy variable Y_i, which is delineated as:

$$Y_i = 1 \text{ if } Y^* > 0$$

$$= 0 \text{ otherwise} \quad (7)$$

If the cumulative distribution function of ε_i in (4) is logistic, which is the cumulative distribution of the hyperbolic, we have the logit model. If the CDF of ε_i is normal, we have the probit model.

Let $Z = X\beta$,

$$\text{Then } F(Z) = P_i = \frac{1}{1 + e^{-Z}} = \frac{e^Z}{1 + e^Z} = \frac{e^{X\beta}}{1 + e^{X\beta}} \quad (8)$$

Thus, *F* needs to fulfil two conditions in that first the value of *F* must be between 0 and 1, and the second *F* needs to be non-linear.

$$\text{i.e.} \begin{cases} \lim Prob(Y/X) = 1 \\ X'\beta \to \infty^+ \end{cases} \text{and} \begin{cases} Prob(Y/X) = 0 \\ X'\beta \to \infty^- \end{cases} \quad (9)$$

This model is a non-linear model, therefore maximum likelihood estimation (MLE) method was found to be more suitable for this study instead of Ordinary Least Square technique. Likewise, as the study intended to maximise the probability of success, it could not apply the first order condition rather *iteration technique* was employed for the purpose,

Let: P_i = probability of success (agroforestry adoption or in this case cash tree plantation), and

$1 - P_i$ = probability of failure (not adopting)

Subsequently, the likelihood function (L) is:

$$\ln L = \sum_{i=1}^{n} \left[Y_i \ln \left({}^{P}/_{1-P} \right) + \ln(1 - P) \right] \quad (10)$$

However, *P* (which is probability of success) in (8) above is:

$$P = \frac{e^{X\beta}}{1 + e^{X\beta}}, \text{ and}$$

Probability of non- success is: $1 - \mathrm{P} = 1 - \frac{e^{X\beta}}{1+e^{X\beta}} = \frac{1}{1+e^{X\beta}}$

$$\text{Therefore, } \frac{P}{1-P} = \frac{\frac{e^{X\beta}}{1+e^{X\beta}}}{\frac{1}{1+e^{X\beta}}} = e^{X\beta} \tag{11}$$

$\ln\left[\frac{P}{1-P}\right] = \ln\left(e^{X\beta}\right) = X\beta$ is the log of odds ratio which is in favour of success. Conversely, the log of odds ratio which is in favour of failure is given by:

$$\ln(1-P) = \ln\left[\frac{1}{1+e^{X\beta}}\right]$$

$$= -\ln\left(1+e^{X\beta}\right) \tag{12}$$

Thus, Equation (10) turns out to be:

$$\ln\ L = \sum_{i=1}^{n}[Y_i(X\beta) - \ln(1+e^{X\beta})] \tag{13}$$

For its purpose of appraising the adoption incidences of eucalyptus tree plantation using agroforestry system, this study employed the probit model.

4.2. Model for measuring crop productivity

In developing countries like Ethiopia, where there is an acute capital constraint, farmers could possibly sell tree products and acquire improved farm technologies so as to boost yields. This enabled them to fill the farm technology imperfect financial markets. The production function can be estimated from a given set of data about inputs and outputs. According to (Grosskopf, 1993), there are two approaches to estimate a production function called the parametric and non-parametric approach. In the parametric approach, the coefficients of the production function are estimated statically using econometric procedure while the non-parametric approach using the mathematical programming. Similarly, (Coelli, Rao, O'Donnell, & Battese, 2005) argued that the parametric approach is commonly used in the estimation of production functions whilst the non-parametric approach is mostly used in efficiency analysis.

The typical forms of production comprise the Translog production function, the constant elasticity of substitution production function, the Zellner-Revankar production function, and the Cobb-Douglas production function. In this study, the Cobb-Douglas production function was found to be theoretically and empirically more plausible (Battese & Coelli, 2010; Coelli, Rao, & Battese, 1998; Coelli et al., 2005) to analyse the effect of agroforestry adoption on agricultural productivity. It can be depicted as:

$$Y_i = \pi\left(X_{ij}^{\beta_j} Z_{ij}^{\varphi_j}\right) e^{\alpha+\varepsilon_i} \tag{14}$$

where Y_i = yield response of the *ith* plot, X_{ij} = the use of the *ith* plot of the *jth* technological input, Z_{ij} = the use of the *ith* plot of the *jth* physical input.

To measure the effect of each physical and technological input on land productivity, Equation (14) can be specified in a logarithmic form as follows:

$$\ln\ Y_i = \alpha + \sum \beta_j \ln\ X_{ij} + \sum \varphi_j \ln\ Z_{ij} + \varepsilon_i \tag{15}$$

4.3. Data types and variables

In Mecha rural district, agriculture has been the leading economic sector for years, and it has been dominated by small-scale farmers. Recently farm households reallocate their food crop farmlands to cash trees like eucalyptus tree plantations (Figure 1).

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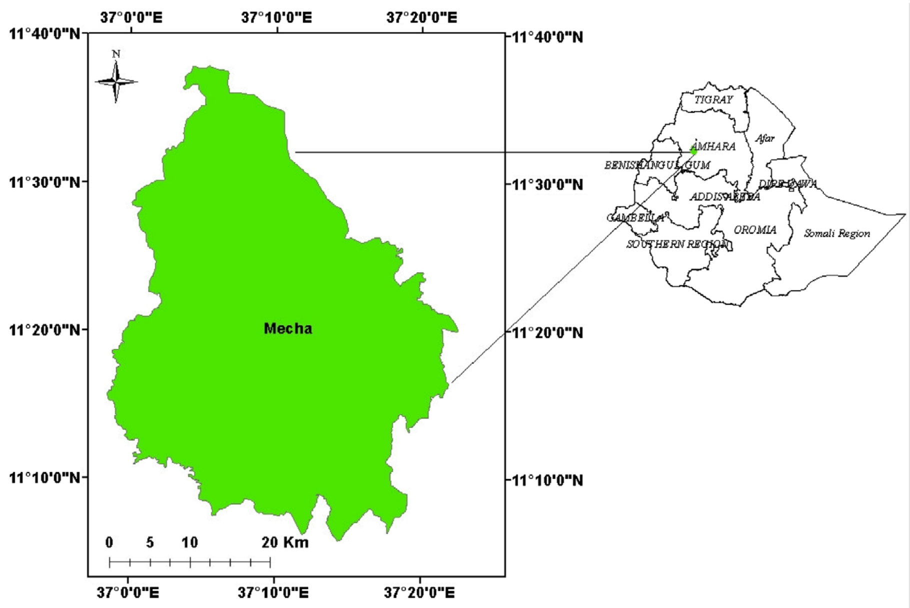
Figure 1. Map of Mecha district.



In this study, both quantitative and qualitative data were collected from 136 farm households in Mecha rural district in the year 2015. Therefore, for the intent of this study, four peasant associations namely Ambomesk, Kudmi, Bachima, and Goragot were included in the study using simple random sampling technique. Table 1 below indicates the tabular description of the survey data.

5. Regression analysis

5.1. Determinants of agroforestry adoptions

From the total sample households, 69% of them adopted eucalyptus tree cropping practices on their farmlands. To investigate the determinants of eucalyptus tree adoption incidences by the farm households in Mecha district, the probit model was employed.[1] The result of the probit regression shows that the model, in general, was significant (at $p < 0.01$). The possible multicollinearity problem was tested by the Pairwise Correlation Coefficients (Table 2).[2]

Being male-headed farm household will intensify the probability of adopting eucalyptus tree on farmlands than being female-headed. Citreous Paribas, as we move from female- to male- farm household heads, the probability of adopting agroforestry will boost by 25.3% units. This appears to be reasonable in that most female-headed households did not plough their own farm plots in the study area; rather they leased their lands for their subsistence food needs. This leads female-headed households just to concentrate on annual food crop production strategies than participating in long-term investments in their farmlands. The studies conducted in Ethiopia found out that male headed households adopted agroforestry technologies more intensively than female-headed counterparts (Abay, Berhane, Taffesse, Koru, & Abay, 2016; Mengistu, Simane, Eshete, & Workneh, 2016). In the forest zone of southwest Cameroon (Adesina, Mbila, Nkamleu, & Endamana, 2000) and other studies in various countries (Ali, Bahadur Rahut, & Behera, 2016; Angelsen et al., 2014; Augusseau, Nikiéma, & Torquebiau, 2006; Diagne & Demont, 2007; Maliki et al., 2016; Mengistu et al., 2016; Ngoc et al., 2016; Oladeji, Okoruwa, Ojehomon, Diagne, & Obasoro, 2015; Oli, Treue, & Larsen, 2015; Pandey, Bajpai, & Singh, 2016) also brought consistent results.

An increase in the family size of the household leads to a rise in the likelihood of adopting eucalyptus trees on the farmlands. In this study, when the family size increased by one percent, the likelihood of agroforestry adoption would rise by 7.8% units. It is due to as family size raised, the

Table 1. Definition of variables and their expected signs

Variable Name	Definition of variables	Expected sign	
		Model I	Model II
Dependent variables			
Model I:AGROECUDUM	A dummy whether the household adopted cash tree farming or not		+
Model II: LNYIELD (crop productivity)	Farm yield per hectare (Gross value of food crop output per farm size)		
Independent variables:			
DMALE	A dummy for Sex of the household head (1 = male; 0 = female)	+	+
LNAGE	Age of the household head	+	+
FSIZE	Family size of the household	−	
DEPRATIO	Proportion of dependent family members whose age is ≤15 and ≥65 to total family size	−	−
PROPOSTUDENT	Proportion of family members who are students	+	+(−)
DUEDU1	A dummy for household head level of education (=1 illiterate; =0 otherwise)	+(−)	+(−)
DUEDU2	A dummy for household head level of education (=1 elementary; =0 otherwise)	+	−
DUEDU3	A dummy for household head level of education (=1 secondary and above; =0 otherwise)	+	−
FARMSIZE	Total farm size of the household	+	−
NONCROPFARM	Farm land allocated for non-food crop farming (like chat, vegetable…)	−	
DLANDEGRA	A dummy for land degradation (=1 if the farm land is degraded; =0 otherwise)	+(−)	
DULANDRIGHT	A dummy for land right (=1 if the household perceives moderately secured; =0 otherwise)	+	+
DECONINCENT	A dummy for economic incentive (=1 if economic incentive of agroforestry and non-farm activity is perceived better than food cropping; =0 otherwise)	+	
LNTOTAGRICOST	Total agricultural input cost (in 2007/2008 current market price, in log form)		+(−)
NUMCATT	Number of cattle the household has	+	+
LNTOT-LIVESTOKVAL	Estimated livestock value (in 2007/2008 current market price, in log form)	+	+(−)
LNEQUEXPER	Number of years the household adopts agroforestry in his/her farmlands (in log form)	+	
AVHOMEDISTA	Average home distance from the farm plot (in Min.)	−	
AVMARKETDISTA	Average home distance from the proxy market (in Min.)	−	
AVROADISTA	Average home distance from the main road (in Min.)	-	
EXTSERVICE	A dummy for extension service (=1 if households use extension service; =0 otherwise)		+(−)
FERTPERHA	Fertiliser per hectare(in kg) the household used in 2006/07		+(−)
LABMANDAY	Total labour man-day the household applied on food crop farming in 2006/07		+(−)
DAMBOMESK	Location of farm household is in Ambomesk (1 = yes; 0 = no) dummy	+(−)	+(−)
DKUDMI	Location of farm household is in Kudmi (1 = yes; 0 = no) dummy	+(−)	+(−)
DBACHIMA	Location of farm household is in Bachima (1 = yes; 0 = no) dummy	+(−)	+(−)
DGORAGOT	Location of farm household is in Goragot (1 = yes; 0 = no) dummy	+(−)	+(−)

Notes: OLS and the Maximum Likelihood Estimation techniques estimate the above models, and the analyses of the models carried out using the statistical package of STATA version 12.

Table 2. Determinants of agroforestry adoption in Mecha District

Variables	Coefficients	Std. err.	Marginal effects
Dependent			
AGROECUDUM			
Explanatory			
DMALE	3.378**	1.417	0.253
LNAGE	−0.837	0.918	−0.086
FSIZE	0 .834**	0.390	0.078
DEPRATIO	4.358	3.739	0.499
PROPOSTUDENT	2.429	1.651	0.123
DUEDU2	−1.598	1.248	−0.026
DUEDU3	−0.160	1.129	−0.004
FARMSIZE	12.843***	4.679	0.282
NONCROPFARM	−14.873***	5.586	−0.134
DLANDEGRA	4.086**	1.755	0.234
DULANDRIGHT	0.025	0.763	0.223
DECONINCENT	6.174***	2.305	0.050
NUMCATT	2.191**	1.047	0.276
LNTOTLIVESTOKVAL	0.173	1.401	0.563
LNEQUEXPER	−3.113**	1.301	−0.352
LNAVHOMEDIST	−5.190	2.021	−0.062
LNAVMRKTDIST	−3.645**	1.437	−0.210
LNROADISTA	−2.099***	1.332	−0.032
DKUDMI	−0. 548	1.498	−0.339
DBACHIMA	−9.304***	3.465	−0.236
DGORAGOT	−3.715**	1.789	−0.066
_CONS	0.438	17.694	–
Number of obs.	136		
LR $\chi^2(26)$	134.32		
Prob. > χ^2	0.0000		
Pseudo R^2	0.7989		

Source: Computed from survey data.
*Significant level at 10%.
**Significant level at 5%.
***Significant level at 1%.

subsistence need of that household would increase and some of the household members would employ themselves in non-farming activities and migrate out by cropping their farm plots with cash trees. Conversely, as the family size of the household raised the demand for fuel wood and construction materials would also be increased, and this could, in turn, reinforce the reduction of natural forests, and that might shove the households to apportion food crop plot lands for agroforestry production purposes. Studies in Ethiopia (Abay et al., 2016; Gessesse, Bewket, & Bräuning, 2015; Kassa, 2015) and studies in various countries, including in southern Malawi, Benin, Nigeria, and Pakistan respectively by (Thangata & Alavalapati, 2003), (Maliki et al., 2016), (Owombo, Idumah, Akinola, & Ayodele, 2015), and (Ali et al., 2016) also found out similar results.

As expected, farm size has a positive and significant effect on the probability of adopting eucalyptus trees. That is, as it increased by one hectare, the probability of adopting agroforestry of that household would rise by 28.2% units. The result coincided with the theoretical and empirical literature. This meant that, where there is surfeit farmland, the household can be motivated to allocate the excess farmland for cash tree crop plantation purposes. In Ethiopia, previously conducted studies (Abay et al., 2016; Gessesse et al., 2015; Kassa, 2015; Kifle, Teferi, Kebedom, & Legesse, 2016) indicated that farm size has a positive and significant effect on agricultural technology adoption. Similar results also reported in the studies of (Marenya & Barrett, 2007) in western Kenya, (Oli et al., 2015) in Nepal, (Oladeji et al., 2015) in Northern Nigeria and (Feder, Just, & Zilberman, 1985) in developing countries.

In contrast, when non-food crops, such as vegetables and other plant productions expanded; the probability of adopting eucalyptus trees will be declined. It is certain that non-food crop productions and agroforestry cropping may substitute to each other. Since, once farmers allocate their fixed-scarce resource, i.e. farmland, for non-food crop plantation purposes; they face a shortage of land to apportion for further cash tree plantation.

The auxiliary plot characteristics that push farmers to adopt cash tree cropping on their farmlands are the scale of land degradation and soil erosion. That is, as land degradation and soil erosion of the farm plot increased by one percent, the probability of agroforestry adoption on that specific plot would be intensified by 23.4% units. This is because as the farmland becomes obsolete for food crop production due to the excessive continuation of soil erosion, then farmers prefer to allocate their farmlands for eucalyptus tree cropping purpose which can protect the land from further soil erosion and degradation. Studies in Uzbekistan, in Sub-Saharan Africa, and Ethiopia (Djalilov, Khamzina, Hornidge, & Lamers, 2016), (Meijer, Catacutan, Ajayi, Sileshi, & Nieuwenhuis, 2015) and (Gessesse et al., 2015) respectively found out that the existence of degraded croplands on farms legitimatized agroforestry plantations.

Adoption of agroforestry on farmlands is also motivated by its comparative economic returns relative to other agricultural crops. As the economic return of eucalyptus tree products compared to food crop products increased by one percent, the likelihood of adopting eucalyptus tree would be increased by five percentage units. Except for the cost at its initial stage and the opportunity cost of replacing the food crops, tree cropping requires a small investment and monitoring costs, compared to its economic return following the growing demands of tree products in the study area. Furthermore, tree cropping is less vulnerable to weather distress than food crops, and farmers could get expected returns from the former diversification strategy. The population growth and urbanisation also channel to a lift up in the demand for fuel woods and construction materials that lead for the raise of its product prices. Similarly, the demand for eucalyptus products of this district has increased in Ethiopia (mainly in Bahir Dar, Gonder, Tigray) and in Sudan. Other studies (Ali et al., 2016; Mengistu et al., 2016; Ngoc et al., 2016) also showed similar results. In western Kenya (Scherr, 1995)'s study about economic factors in farmer adoption of agroforestry and in Uzbekistan (Djalilov et al., 2016)'s study about incentives for the adoption of agroforestry practices on degraded cropland reached that the potential profitability emerged as farmers priorities when considering the agroforestry adoption.

In this study, the numbers of cattle the households own demonstrate the significant effect on the adoption of cash tree plantation on the farmlands. The study in Ethiopia (Abay et al., 2016) also showed a similar result. On the contrary, farmers' experience in tree cropping has a negative effect on the prospect of agroforestry adoption. That is, as the experience of the farm household in planting eucalyptus tree increases by 1 year, the probability of adopting additional eucalyptus tree on the remaining plot lands will be declined by 35% units. These can be due to first, it may be a subsistence motive and a non-separability in production and consumption decision of the farm household in that farmers need to continue in food crop production rather than concentrating just on tree crop plantations and farmland is a fixed factor of production that could not be expanded indefinitely. Second, it may be an ecological rationale in that, as opponents argued, farmers who have experience in adopting eucalyptus trees on their lands may find out, through experience, the negative environmental impact on soil nutrients of their farmlands, and they may further desist from expanding it in their farmlands. Contrarily, a study (Adesina & Chianu, 2002) found out that experience of the farm household showed a significantly positive effect on agroforestry adoption.

Accessibility of proximal markets, Merawi and Bikolo, and the proximity of the district to the main-road, which is stretched from Bahir Dar to Addis Ababa, have the positive and significant impact on agroforestry adoption preferences of the households. That is, as the distance of the farm household from the proximal market areas increased by one percent, the probability of agroforestry adoption would be declined by 21% units. It would be attributable to farmers' migration to the mentioned-towns, and the population pressure, both coerced to lift up the demand for fuel woods and construction materials in the towns might induce the proximate farm-households to adopt agroforestry on their farmlands. Correspondingly, as the distance of the household from the main road stretched by one percent, the probability of adopting agroforestry plantation would decrease by 3.2% units. This is because, as farm households are located far from the main road, the transaction costs, mainly time and transportation costs, of eucalyptus tree product will be raised. This again would lead to the shrink in adoption extents. Besides, as farm households are far from markets and roads, they would impede from accessing market information. On the adoption of improved technologies in Ethiopia (Admassie & Ayele, 2011) using probit model reported that distance of the farmer from the market centre had a negative effect on the adoption decision. Similar studies in Kenya and Ethiopia found out an adverse relation between technology adoption and distance to the proximate markets (Aura, 2016; Kifle et al., 2016).

Geographical location has an effect on eucalyptus tree adoption, i.e. when we move from Ambomesk to Bachima and from Ambomesk to Goragot farm villages; the probability of agroforestry adoption by the respective farm households declined by 23.6 and 6.6% units respectively. This is due to Ambomesk households might have ample awareness about agroforestry adoption activities than households' of Bachima and Goragot farm villages. It can also be justified by differences in ecology and soil nutrients among farm villages.

5.2. Determinants of land productivity (yield)

The productivity of land can be determined by farm household characteristics, the resource endowments of the farm household, plot characteristics, farm technology, and the market characteristics and structure. Ordinary Least Square method is found to be consistent estimator[3] to analyse the productivity of farmlands. In order to inspect the heteroskedasticity problem, the Breusch-Pagan-Godfrey test was employed for the model in effect, and there was no detected problem of heteroscedasticity. The result obtained indicates that the model, in general, is significant at $p < 0.01$. The adjusted $R^2 = 0.8370$ tells all the explanatory variables together explain 83.70% of variations in the farmers' land productivity (Table 3).

Farm size demonstrates a negative effect on land productivity. That is, as farm size of the household increased by one hectare, the yield would be declined on average by 43.40% units. This is because when farm size expands without a proportional increase in the variable factors (i.e. labour and other farm inputs) the productivity of the plot will be diminished. Moreover, as large farms seek to hire more labour to maximise output and yield, this may lead to inefficiency which results from the increase in the monitoring and transaction costs of labour. There are mixed empirical findings on the impact of farm size on land productivity. Using Data Envolvement Analysis method, researchers found a strong inverse relationship between farm size and productivity of farmlands (Helfand & Levine, 2004). Likewise, previous studies (Aguilar, Carranza, Goldstein, Kilic, & Oseni, 2015; Alene et al., 2008; Assuncao & Braido, 2007; Bardhan, 1973; Deininger, Jin, Liu, & Singh, 2016; Govereh & Jayne, 2003; Hayes et al., 1997; Pender et al., 2004; Sen, 1962) indicated that farm size had a negative effect on yield. They further justified that inefficiency would arise in the production of larger farms. Other scholarly studies also indicated that labour is subject to increasing marginal cost of supervision, thus the optimal land-to-labour ratio is found to be higher for large landowners (Bardhan, 1973; Eswaran & Kotwal, 1986; Feder et al., 1985).

Table 3. Determinants of land productivity in Mecha district

Variables	OLS estimation of yield	
	Coefficients	**Std. err.**
Dependent variable		
LNYIELD		
Explanatory variables		
LNFARMSIZ	−0.434***	0.116
DUEDU2	0.031	0.064
DUEDU3	0.082	0.068
LNPROPOSTUDENT	0.001	0.051
LNDEPRATIO	0.050	0.051
LNAGE	0.084*	0.066
DMALE	−0.119*	0.072
LNTOTAGRICOST	−0.287**	0.110
LNNUMCATT	−0.110	0.084
LNTOTLIVESTOKVAL	0.032	0.030
EXTSERVICE	−0.002	0.054
DULANDRIGHT	0.091*	0.048
LNFERTPERHA	0.362***	0.102
LNLABMANDAY	0.312***	0 .115
DKUDMI	0.063	0.077
DBACHIMA	0.219**	0.085
DGORAGOT	−0.006	0.076
AGROECUDUM	0.166**	0.072
_CONS	5.519***	0.453
Number of observations	136	
F(23, 112)	31.14	
Prob. > F	0.0000	
R^2	0.8648	
Adj. R^2	0.8370	
Root MSE	0.25859	

Source: Computed from own survey data.

*Significant level at 10%.

**Significant level at 5%.

***Significant level at 1%.

In contrast, a study conducted (Weiner, Moyo, Munslow, & O'Keefe, 1985) reported that the productivity of maize per hectare for large commercial farms is between 4–5 tones while it is less than one tonne per hectare for small farms. They also argued that land use and capital intensity are found to be intrinsically and positively linked with farm productivity. Their evidence suggests that capital is substituting labour as the size of the farm unit gets grown. Similarly, a study was done in China (Ma & Abdulai, 2016) pointed out that farm size owned by the household resulted in the positive effect on crop yield.

The land productivity of cash tree plantation adopters is greater than that of non-adopters significantly by 16.60% units, which is attributable to farmers to sell eucalyptus tree products and purchase adequate improved seeds and fertilisers and could apply these farm technologies intensively on their farm plots. Furthermore, as farm households adopt agroforestry, the proportion of land that was used previously for food crop production declines. This may create surplus labour hour in the family (being agroforestry is relatively labour saving technology) and then this excess labour may be allocated by the farm household intensively to maximise food crop production. Therefore, wedding and ploughing frequencies would be intensified, on the reduced food crop farmlands, which could lead to the increase in yield of farm plots. In addition, the subsistence food requirement for agroforestry adopters, due to the reduced farmlands, would also further force them to apply their resources intensively on the diminished plot land than those of non-adopters. In connection with, long-term investments on farmlands, (Govereh & Jayne, 2003; Neupane & Thapa, 2001) pointed out that households engaging intensively in cotton production could gain better foodgrain yields than non-cotton and marginal cotton producers in Zimbabwe. On the other hand, it was argued that the presence of trees on a plot would significantly decrease the food crop yield (Hayes et al., 1997).

Age is another household characteristic that affects farm productivity positively. As the age of household head increase by 1 year; the land productivity will be boosted by 8.4% units. This illustrates the experience of farming has a significant impact on increasing farm productivity. The study conducted (Ma & Abdulai, 2016) in China also showed that age of the household implied a positive effect on farm yield. Likewise, in Ethiopia, (Urgessa, 2015)'s study about the determinants of agricultural productivity and rural household income found out that age of the farm household had a positive impact on productivity. On the other hand, the productivity of male-headed households is less than those of female-headed households by 12%. This seems reasonable in that, in the study area female-headed households add more compost and crop byproducts on their farmlands to augment the nutrient content of the soil than male-headed households do.

Agricultural input cost has a negative effect on the productivity of farm households. When agricultural input cost (in Birr) increased by 1%, this would lead to a significant shrink in farm productivity by 28.7% units. This is because being farm households are rational economic agents and the agricultural inputs are normal goods then as the input costs increased, the farmers' inputs demand would decline. This leads to the reduction of input use intensity per hectare by the household; this definitely will have an adverse impact on the productivity of farm plots.

On the other hand, the land property right perception of the household has remarkable effect on land productivity. Farm households who feel moderately secured land ownership rights raise land productivity by more than nine percent than who do not feel fairly protected. This may be due to the theoretical and empirical ground that land tenure security motivates farmers to protect the quality of their lands through long-term land management systems such as counter ploughing, fallowing, which will help further to increase the productivity of their plots.

The other vital variables that affect the productivity of land include fertiliser and labour inputs employed on the farmlands. As anticipated, when fertiliser per hectare increased by 1% the productivity of land would be increased by 36.26% units. Likewise, as labour man-days intensity increased by 1%, the productivity of land would increase by 31.2% units. Consistently, some studies demonstrated that household labour endowments reveal the positive and significant effect on crop yield (Aguilar et al., 2015; Hayes et al., 1997; Ma & Abdulai, 2016).

Finally, the location of farm households has its own effect on the production. The farm households that dwell in Bachima village have greater farm productivity than households located in Ambomesk by 21.9% units. This is due to the existence of soil fertility and ecological divergences between locations.

6. Conclusion and implication

As production and consumption decisions, there is also non-separability between crop choice decisions in production and access to inputs for short or long-term investment by the farm household. In developing countries, like Ethiopia, farm households with limited cash income may not afford to acquire essential agricultural inputs due to flawed and imperfect credit markets. Consequently, farmers usually try to fill this gap by diversifying agriculture from merely food crop farming to other tree and cash crop planting practices. In this study, the sex of the farm household, farm size, the economic incentive, plantation experience of agroforestry and number of cattle the households own were found to be the positive determinants of cash tree adoption. Contrarily, the location of the household to the proximal market and main road, and non-agricultural practices indicated a negative effect.

Correspondingly, the age of the farm household, land right, the amount of fertiliser and labour input employed, and agroforestry that is cash tree adoption incidences could have a positive and significant effect on food crop productivity. Farmers prefer to produce and sell eucalyptus tree products and purchase improved farm technologies, and the revenue generated from selling tree products could help them to bridge rural financial market failures. On the other hand, farm size, sex and an agricultural input cost demonstrate negative impact on farm productivity. Likewise, this empirical study reached the same conclusion as the previous studies made with respect to farm size and productivity inverse relationship puzzle. Therefore, land redistribution would increase the agricultural productivity. However, one needs to be conscious in that some studies indicated the inverse relation was caused by market failures in the farm technology, labour and credit markets, which is inevitable in most developing nations. Therefore, alternative policies would be required that could correct rural financial market failures.

The rural development policy in the least developed countries needs to motivate cash tree adoption among small farm households. In addition, small farm households in developing countries, specifically in rural Ethiopia need to be stimulated to use modern farm technologies, cash tree adoption and intensive labour on farm plots so as to simultaneously maximise productivity and enhance better farmland management system. As a result, correcting the agricultural market failures, and enhancing the farm technology and farm labour skill will help to advance the rural livelihoods.

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Notes
1. For comparison purposes the logit regression results have also indicated in appendix one.
2. One can suspect multicollinearity problems if the Pair-wise Correlation Coefficients were greater than 0.8.
3. By considering agroforestry adoption as an endogenous variable, the study supposed to use two stages least square (2SLS) estimation technique than Ordinary Least Square (OLS) technique. But, when we employ the endogeneity test using Durbin-Wu-Hausman, we could not reject H_0 that says agroforestry adoption is an exogenous factor for determining land productivity. Therefore, OLS is found to be a consistent estimator, and only OLS results are analysed.

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