Socioeconomic Contribution of *Oxytenanthera abyssinica* (A.Rich) Munro and Determinants of Growing in Homestead Agroforestry System in Northern Ethiopia

Girmay Darcha Gebramlak, Nigussie Abadi, and Emiru Birhane Hizikias

Research

Abstract

Oxytenanthera abyssinica (A.Rich.) Munro is known to be one of the lowland perennial grass species in Ethiopia with tremendous products and ecological services. It is uncommon to find *O. abyssinica* at the homestead as it was commonly found in the study area as part of an agroforestry system. This study was conducted to assess socioeconomic benefits of *O. abyssinica* and factors that influence farmers' decision to use homestead agroforestry systems, based on a survey of 153 households in Serako **kebele,** Tselemti **woreda,** Ethiopia. This paper evaluates, using descriptive statistics, propensity score matching and logit regression analysis. The analysis demonstrates that farmers make decisions to grow *O. abyssinica* as homestead agroforestry systems based on household and field characteristics. The factors that significantly influenced growing decisions include homestead land holding size, total livestock owned, extension advice, and distance to local market. The average treatment effect (ATT) results show that the households with an *O. abyssinica* grower had significantly higher annual household income, annual expenditure, and number of months with enough food when compared to the control group. Therefore, we conclude that development of infrastructures that link producers with consumers, availability of large homestead land size, and expansion of extension facilities may enhance engagement of domestication of *O. abyssinica* at the homestead for sustainable livelihood options.

Introduction

Bamboo is one of the most commonly used natural resources by people all over the world and provides substantial benefits (Belay *et al*. 2013, Embaye 2003, Kigomo 2007, Ohrnberger 1999). According to Ohrnberger (1999), more than 1500 bamboo species are found in the world, covering more than 14 million ha of land. Africa possesses about 40 of these species on over 1.5 million ha (Kigomo 1988). Two of these species are indigenous to Ethiopia, lowland bamboo (*Oxytenanthera abyssinica* (A.Rich.) Munro) and highland bamboo (*Yushania alpina* (K. Schum) W.C.Lin.), together composing 67% of the African total (Embaye 2003, Mekonnen *et al*. 2014). Zhaohua (2001) reported that over 1500 different uses of bamboo have been documented around the world. Bamboo, generally considered to be a non-timber forest product, is a multipurpose resource and an economically viable crop. A number of studies in Asia and western countries reveal that different bamboo products show potential as outstanding substitutes for timber-produced materials, and commercial value of bamboo is elevated and growing at a substantial rate (Hogarth & Belcher 2013, Wang *et al.* 2008).

Correspondence

Girmay Darcha Gembramlak, Mekelle Agricultural Research Center, P.O. Box 258, Mekelle, ETHIOPIA. girmaydarcha@yahoo.com
Nigussie Abadi, Department of Natural Resource Economics and Management, Mekelle University, P.O. Box 231, Mekelle, ETHIOPIA. nigussieabadi@yahoo.com
Emiru Birhane Hizikias, Department of Land Resources Management and Environmental Protection, Mekelle University, P. O. Box 231, Mekelle, ETHIOPIA. emibir@yahoo.com

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In Ethiopia, in contrast to Asia, bamboo has been used traditionally as a raw material for building and making numerous household utensils, basketry, and handicrafts (Andargatchew 2008, Belay *et al*. 2013, Mekonnen *et al*. 2014). Nevertheless, recently a South African paper pulp company has invested in bamboo supply pulp fabrication ability in the country (NPSB 2013). Besides the rural income and employment opportunities, bamboo makes a significant contribution to ecological services (Belay *et al*. 2013, Krishnankutty 1998, Mekonnen *et al*. 2014, Nath *et al.* 2009). The natural bamboo forest is rapidly diminishing through indiscriminate clearing for agricultural expansion, mass flowering, and the lack of priority in its development, which together join forces to erode its numbers (Embaye 2000, Kigomo 2007, Mekonnen *et al*. 2014). This has led to reduction in *O. abyssinica* cover to make land available to agricultural expansion and overexploitation especially in the more accessible forest areas of northern Ethiopia (Embaye 2003, Gebrehiwot 2004). One of the options of increasing bamboo resources is domestication on farms as homestead agroforestry using available propagation methods (Kigomo 2007). The domestication and cultivation approach focuses on bringing planting material from the wild to farms to improve productivity, quality, and availability of targeted species (Akinnifesi *et al*. 2007). Growers decide to engage in domestic cultivation whenever there is an economic improvement relative to wild harvesting. Likewise, plant domestication is a market-led, farmer-driven process in which its importance is the incentive for management of trees (Marshall *et al.* 2006, Schippmann *et al*. 2006). Hence, in some African countries such as Sudan, Kenya, and Tanzania *O. abyssinica* is planted as agroforestry species (Kigomo 1988, LUSO-Consult 1997). According to the literature from studies within Ethiopia, *O. abyssinica* in most cases occurs in natural stands and has not been planted so far (Kelbessa *et al*. 2000). But in the study area of Tselemti **woreda,** *O. abyssinica* is planted and domesticated by some farmers as part of a homestead agroforestry system.

The success of domestication can be determined by biophysical and socioeconomic factors to small-scale farmers, such as infrastructure, stipulate for the product, size of landholding, and extension contacts (Nyadzi *et al.* 2003, Oino & Mugure 2013). Thus, growing *O. abyssinica* can be motivated or discouraged by factors ranging from household characteristics to broader institutional and policy situations (Belay *et al.* 2013, Tadesse 2012).

However, little research has been conducted concerning the current condition of *O. abyssinica* domestication as part of a homestead agroforestry system and its determinant factors in the Ethiopian context. Therefore, this study aims to fill this gap by examining the determinant factors of domestication of *O. abyssinica* via homestead agroforestry and its socioeconomic significance for rural households of the study area.

Materials and Methods

Description of study site

The study area was purposively selected from the **kebele** (smallest political administration units in Ethiopia) of Tselemti **woreda,** Northern Ethiopia, based on the availability of domesticated *O. abyssinica* in their homesteads. It is located at 13°05'N and 38°08'E (Figure 1). The elevation gradient at Serako **kebele** ranges between 800 and 2872 m above sea level, and it covers a total area of 4710 ha (Hagazi *et al.* 2002).

The agro-climatic condition of the area is hot to dry semi-arid lowland plains dictated by a very hot temperature. The maximum temperature ranges from 35.6°C in May to 36.4°C in April, while the minimum temperature ranges from 15.7°C in December to 21.8°C in May (TNMA 2014, pers. comm.). The dry season occurs November–March whereas the rainy season occurs June–September, following a unimodal rainfall pattern.

The most dominant soil types of the study area are cambisols, nitosols, and vertisols. The dominant *Combretum-Terminalia* vegetation species are *Cordia africana* Lam., *Croton macrostachyus* Hochst. ex Dilile., *Acacia senegal* (L.) Willd., *Boswellia papyrifera* (Caill. ex Delile) Hochst., *Anogeissus leiocarpa* (DC.) Guill. & Perr., *Tamarindus indica* L., *Euphorbia tirucalli* L., *Faidherbia albida* (Delile) A.Chev., and *Erythrina abyssinica* Lam. as farm woodlots scattered on farms, road sides, and farm boundaries (Hagazi *et al*. 2002). *Oxytenanthera abyssinica* is dominantly occurring in these homesteads as agroforestry species (Figure 2).

Agriculture is the main livelihood of the community in the study area. Known for their mixed farming system, the rural people depend on crop and livestock production in addition to agroforestry practices for their living. The most commonly grown crops for household consumption are sorghum, maize, sesame, teff, and millet. The major livestock in the study area are cattle, goats, donkeys, and chickens (Hagazi *et al*. 2002; WARD 2014, pers. comm.). The population of Serako **kebele** has a total population of 4317 with 2197 male and 2120 female inhabitants. There are 764 households, 656 of them male-headed and 108 female-headed (CSA 2007).

Respondent sampling and data collection

An initial discussion was held with **woreda** officials, peasant association leaders, development agents, and potential respondents to explain the purpose of the study and obtain permission. The survey was done in two stages following Creswell (2009). Firstly, rapid rural appraisal (RRA) was employed to gain preliminary field observations of the study area, households, and communities. Based on this

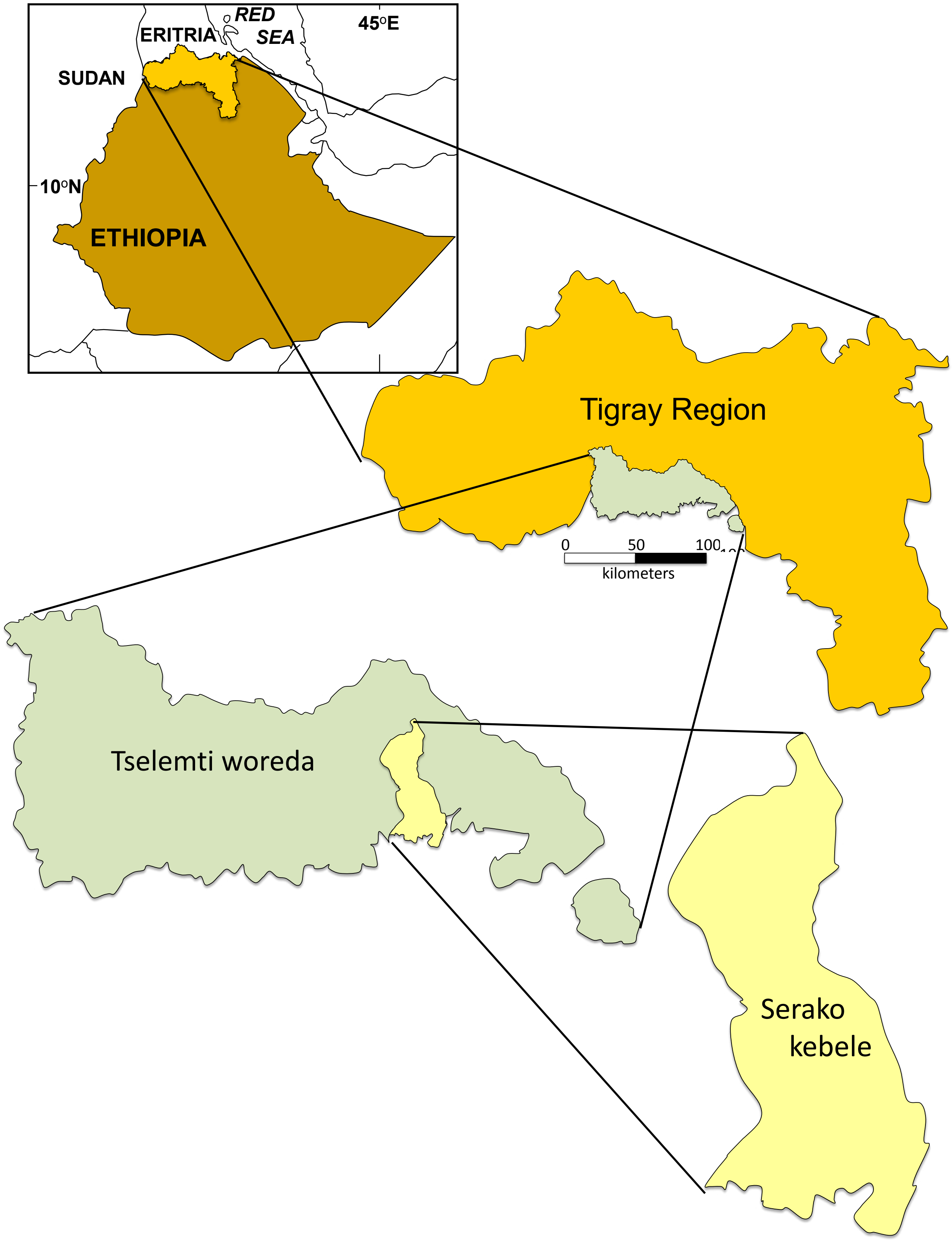

Figure 1. Location of study site in Serako **kebele,** Tselemti **woreda,** Tigray Region, Ethiopia.

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Figure 2. *Oxytenanthera abyssinica* (A.Rich.) Munro planted as homestead agroforestry system in Tselemti **woreda,** northern Ethiopia.

preliminary information, a total list of 90 households with *O. abyssinica*-based homestead agroforestry were found in the **kebele.** A total of 153 samples of households*,* 60 growers and 93 non-growers (control), were selected by systematic random sampling for questionnaire survey using resident lists where the head of the household was interviewed. Secondly, detailed household surveys were conducted between November 2013 and March 2014 using semi-structured questionnaires and focus group discussions with growers of *O. abyssinica* via homestead agroforestry and non-growers.

Two group discussions were held in the **kebele** (Serako) with community elders and local bamboo-growers selected with the assistance of the development agents and chairman of the **kebele.** The survey questionnaires covered issues regarding basic household characteristics, major livelihood strategies, *O. abyssinica* domestication and management, total number of clumps available, total number of culms consumed and sold annually, prices and income, trade, and total expenditures of respondents.

Income and price data were also collected at local markets. Prices at the local market were collected from all interviewed households, and their averages were used in the calculation of income. Subsistence income was estimated by assigning cash income equivalents based on the average local bamboo prices per culm during the survey year and multiplying it by the estimated number of bamboo culms consumed by the household. Secondary data were obtained from available records, published and unpublished materials.

Estimation of average treatment effects based on propensity scores

One of the critical problems in non-experimental methods is the presence of selection bias which could arise mainly from nonrandom selection of participant households that makes evaluation problematic (Heckman & Ichimura 1998). As a result, differences between growers and non-growers may reflect initial differences rather than the effects of treatment in the outcome. Hence, propensity score matching (PSM) for the households' observable characteristics was used by comparing the outcomes of growers with those of matched non-growers (Heckman & Ichimura 1998). This was chosen among other non-experimental methods because it does not require baseline data, and it is considered a second-best alternative in minimizing selection biases (Baker 2000).

One can match along a single index variable given by the propensity score, P(X), which summarizes the multi-dimensional variables (Rosenbaum & Rubin 1983). This is the conditional probability that households have *O. abyssinica* growers given the conditions/variables and is written as:

$$P(X) = \Pr(B = 1|X) = E(B|X) \quad \text{……equation (1)}$$

If the propensity scores P(Xi) is known then the Average Effect of Treatment (ATT) can be estimated as follows:

$$ATT = E(Y1|P(X), B = 1) - E(Y0|P(X), B = 1) \quad \text{……equation (2)}$$

Matching estimators of ATT based on the propensity score

Propensity score is a continuous variable, and the probability of observing two units with exactly the same propensity score is, in principle, zero. The methods differ from each other with respect to the way they select the control units that are matched to the treated and with respect to the weights they attribute to the selected controls when estimating the counterfactual outcome of the treated (Caliendo & Kopeinig 2008). These were the nearest neighbor, radius, kernel, and stratification matching methods. These methods identify the closest match for *O. abyssinica* growers (i.e., with the closest propensity score) among non-growers and then compute the effect of *O. abyssinica* growers as a mean difference of household income between the two households. According to Becker and Ichino (2002) a brief description of the four matching methods used in this study is given below.

1) Nearest neighbor matching method: Each treated observation is matched with an observation in the control group that exhibits the closest propensity score. In nearest neighbor matching, it is possible that the same household in the control group can neighbor more than one household in the treated group. Therefore, after matching, the difference between their incomes was calculated as the average effect of *O. abyssinica* growers on the household income (ATT).

2) Radius matching: Each treated unit is matched only with the control units whose propensity score falls in a predefined neighborhood of the propensity score of the treated unit. If the dimension of the neighborhood (i.e., the radius) is set to be very small it is possible that some treated units are not matched because the neighborhood does not contain control units. On the other hand, the smaller the size of the neighborhood the better the quality of the matches (Becker & Ichino 2002).

3) Kernel matching method: All treated observations are matched with household in the control group based on the weighted average that is inversely proportional to the distance between the propensity scores of treated and control groups.

4) Stratification matching method: This method consists of dividing the range of variation of the propensity score in intervals such that within each interval, treated and control groups have on average the same propensity score. The ATT of interest is finally obtained as an average of the ATT of each block with weights given by the distribution of treated units across blocks.

Definition of variables and working hypothesis

After having appropriate analytical tools it was possible to identify, define, and describe the independent variables with their appropriate symbols and measurements in a working way. The dependent variable for *O. abyssinica* domestication as homestead agroforestry is dichotomous one, where *O. abyssinica* domestication takes the value 1 if the household is grower and 0 otherwise. The independent variables that were expected to influence farmers' decision to grow the plant and their hypothesized influence are described as follows:

- **Age of the household head (Age_HH):** a continuous independent variable that indicates the age of the household head in years. This variable is also used as a proxy for measuring farming experiences. Experiences of the household, as indicated by age of the household head, are likely to have a range of influences on the domestication of *O. abyssinica* via homestead agroforestry system. The effect of farmer's age is taken as a composite effect of farming experience and planning horizon. While longer experience has a positive effect, older people are more risk averse and less willing to take on new innovations. Thus age of the household head may have either a positive or negative effect on domestication of *O. abyssinica.*
- **Gender of household head (Ge_HH):** takes a value of 1 if the household head is male and 0 otherwise. It is mainly women who take care of cooking-related needs at home rather than collecting plants from the natural forest, and therefore they are expected to negatively influence *O. abyssinica* domestication. As a result the influence of gender on domestication of *O. abyssinica* via homestead agroforestry system is hypothesized to be indeterminate.
- **Family size (Numb_H):** measured as a continuous variable. It is expected that a household head with a large family size has sufficient labor, and thus family size is positively related with intensive use of *O. abyssinica.* The success or failures to collect from the wild and plant and manage in the homesteads are determined by the involvement of family members. Those who have larger family sizes are positively influencing the domestication of *O. abyssinica* via homestead agroforestry as they can provide sufficient labor.
- **Education level of household head (Edu_HH)**: a dummy variable (1 = illiterate, 2 = religious, 3 = formal, 4 = adult). Educated farmers are more likely to decide to domesticate *O. abyssinica* than are educated farmers. Therefore, education is hypothesized to have a positive influence on farmers' decisions to domesticate *O. abyssinica* in their homesteads.
- **Homestead size (Lnd_H):** variable measured by the size of homestead owned by the household measured in **tsimdi** (0.25 ha). Given the space requirements in terms of area for plantation of *O. abyssinica,* the size of land owned as homestead by the household becomes the crucial factor in the adoption of planting this crop. Therefore, it is hypothesized that households with large size of homestead are more likely to adopt domestication of *O. abyssinica* via homestead agroforestry system.
- **Tropical livestock unit (TLU):** the total number of livestock holdings of the farmer measured in livestock units. Livestock is a source of livelihood to the community, and households tend to rely on their livestock more than agroforestry as source of income. Thus it is hypothesized that an increase in the number of livestock owned by a household would either decrease or increase the likelihood of a household domesticating *O. abyssinica* due to the potential of the plant as a source of income and feed value.

- **Distance to communal bamboo forest (Dis_bam):** measured by the length of time it takes the household to travel to the nearest communal bamboo forest measured in minutes. Longer distances to the forest imply scarcity of available naturally grown *O. abyssinica*. As a result it is hypothesized that long distances either negatively or positively influence adoption of domestication of *O. abyssinica* as homestead agroforestry system.
- **Distance to local market (Dis_Lm):** measured by the time spent in minutes needed to reach the nearest local market. Farmers nearest to the local market could experience benefits from better pricing information and lower transportation costs required to sell their products. Distance to local market is therefore hypothesized to negatively influence the adoption of *O. abyssinica* via homestead agroforestry.
- **Distance to major market (Dis_Mm):** measured by the time spent in minutes needed to reach the nearest major market. Similar to local markets, farmers nearest to the major market could experience benefits from better pricing information and lower transportation costs required to sell their products. Distance to major market is therefore hypothesized to negatively influence the adoption of *O. abyssinica* homestead agroforestry.
- **Extension service (Exte_Ad):** a dummy variable (equal to 2 if the household had contact with an extension agent, 1 if with farmer to farmer, 0 otherwise). Feder *et al.* (1985) noted that extension efforts increase the probability of adopting new technology by increasing the stock of information pertaining to modern production investment. It is therefore hypothesized that access to extension services positively influence adoption of *O. abyssinica* as homestead agroforestry system.

Data analysis

Data were analyzed with SPSS ver.16.0 (Statistical Package for Social Science) and Stata version10 using a combination of descriptive statistics, propensity score matching (PSM), and regression analysis. Data collected through group discussions, observations, and qualitative interviews were analyzed qualitatively. Determinants of *O. abyssinica* domestication were analyzed using regression analysis where domestication via homestead agroforestry (taking the value 1 if the household includes a grower and 0 otherwise) was taken as the dependent variable.

Results

Demographic and socioeconomic characteristics of respondents

The results presented in Table 1 show that the difference in the means of the variables used in the matching analyses along with their significance levels. The significance levels suggest that there are some differences between homestead *O. abyssinica* growers and non-growers with respect to household and outcome variables.

The data set contains 153 observations. About 40% (60) of the sample households were growing *O. abyssinica* at their homestead while the remaining households did not grow *O. abyssinica* at their homesteads. The survey also collected extensive information on several factors, including household characteristics, asset endowments, income and expenditure, household food security, and access to infrastructure and institutions. In many of the variables, we observed that households growing *O. abyssinica* to be in a better position than the non-growers. For example, growers had a larger annual income, expenditure, and available food stock than non-growers. This difference in the outcome variables is statistically significant at 1%, 10%, and 10%, respectively (Table 1).

With regard to the independent variables we also found a significant difference between *O. abyssinica* growers and non-growers. The median size of household members for was eight for growers and seven for non-growers. Over half of the growers reported that they obtained technical information on the importance of the species from development agents (DA) and 43% from farmer to farmer information exchange. Only 38% of non-growers were aware of *O. abyssinica* technical information. The average size of homestead land holding for growers is 2.26 **tsimdi** and 1.82 **tsimdi** for non-growers. The livestock holdings average is six tropical livestock units for growers and nine units for non-growers.

Propensity score estimation results

The findings above suggest that growers of *O. abyssinica* were generally better off than non-growers in terms of various livelihood indicators. Given that the comparisons of mean differences do not account for the effect of other characteristics of farm households, they may confound the impact of *O. abyssinica* on the livelihood of the house-

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Table 1. Basic descriptive statistics for growers and non-growers of *Oxytenanthera abyssinica* (A.Rich.) Munro. SD = standard deviation. HH = head of household. DA = development agent. *Significant at α = 0.05. **Significant at α = 0.02. *** Significant at α = 0.01.

Variables	Growers (N = 60)		Non-growers (N = 93)		P-value
	Mean	SD	Mean	SD	
Outcome Variables					
Annual household income (birr)	12789.35	598.63	8798.7	354.46	0.0000***
Total household expenditure	7147.34	3574.82	5743.2	3741.25	0.0225*
Number of months with enough food available per year	11.28	1.15	10.92	0.99	0.0422*
Independent variables					
HH gender (1 if male, 0 otherwise)	0.85	0.36	0.92	0.27	0.2200
HH age	49.47	12.83	44.26	12.83	0.0160**
HH education level	1.63	0.11	1.65	0.09	0.7700
Family size	7.75	2.16	6.76	2.33	0.0170**
Distance to DA office in minutes	58.02	29.08	48.69	29.72	0.0578
Homestead land holding size (**tsimdi**)	2.26	1.1	1.82	1.1	0.0170**
Livestock owned (TLU)	6.41	4.66	8.94	7.85	0.0120**
Land size excluding homestead	2.47	1.56	3.09	1.95	0.0423*
Extension advice (2 if DA, 1 if farmer-to-farmer, 0 otherwise)	1.87	0.99	1.62	0.48	0.0466*
Distance to local market in minutes	59.88	32.36	89.73	35.74	0.0000***

holds with influence of other characteristics. To this end we use the propensity score matching to control for bias and predict the determinants of *O. abyssinica*-growing and thereby estimate the average treatment effect. The independent variables used in the logit regression models to predict the propensity scores were based on past research on determinants of agroforestry adoption. Table 2 presents the variables used to create propensity scores for the matching algorithm. The control variables chosen include household demographics (gender, education, and family size), assets (size of homestead owned and livestock ownership), and access to institutional services and markets.

Average treatment effect of O. abyssinica on household welfare

The outcome variables used in this study was total annual household income, total household expenditure, and number of months in a year that the household had enough food available. The average treatment effects (ATT) results from the different matching algorithms of these outcome variables are presented in Table 3.

The ATT of *O. abyssinica* on household income was found to be 3382 Ethiopian birr ($176 USD) and 4743 ($247 USD) for the nearest neighbor and radius matching algorithms, respectively ($p < 0.01$ for both). In the same way, the ATT for annual expenditure per capita was 2012.74 ($105 USD) and 1859 ($97 USD) for both the nearest neighbor and stratification matching, respectively ($p < 0.01$ for both).

In addition to that, number of months with enough food available per year among treatment households were significantly different ($p < 0.01$) based on radius and stratification matching by 0.333 months. This robust result indicates that the mean income of households has significantly increased due to *O. abyssinica* growing.

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Table 2. Logit model of *Oxytenanthera abyssinica* (A.Rich.) Munro growers (N = 153). ***Significance at 99% confidence level. SE = standard error.

Variable	Coefficient	SE	P-value
Gender of household	-0.83	0.80	0.290
Education level of household	0.22	0.33	0.500
Age of household	-0.05	0.06	0.390
Homestead land holding size	1.31	0.33	0.000***
Distance to local market	-0.05	0.01	0.000***
Farming experience of the household head	0.04	0.07	0.580
Total family size of the household head	0.16	0.14	0.230
Extension advice to the household head	1.11	0.38	0.002***
Total livestock of the household head	-0.13	0.05	0.002***
Pseudo R-Squared	0.42		

Table 3. Average treatment results. ns = not significant. 10% (*), 5% (**) and 1% (***) errors are bootstrapped. SE = standard error.

Outcome variable	Matching method	(ATT) (birr)	SE	t-stat
Annual household income	Nearest neighbor matching	3382.00	1373.924	2.460**
	Radius matching	4742.68	1015.870	4.670***
Annual expenditure per head	Kernel matching	2012.74	1246.230	1.620^{ns}
	Stratification matching	1859.18	891.670	2.090**
Number of months with enough food available per year	Stratification matching	0.334	0.199	1.681*
	Radius matching	0.333	0.263	1.270^{ns}

Discussion and Recommendations

The study revealed that farmers growing *O. abyssinica* as homestead agroforestry are influenced by the interacting farm household socioeconomic characteristics such as homestead land size, distance to local market, extension contacts, and livestock holdings.

The results indicated that homestead farm size is positively associated with growing *O. abyssinica* ($p < 0.01$; Table 2). A possible explanation for this finding is that farmers with large homesteads might be more likely to plant *O. abyssinica* and to use the land intensively than farmers with small homesteads. Our study supports the findings of Nyadzi *et al*. (2003) and Oino and Mugure (2013) who reported that farmers with smaller plots are less likely to adopt agroforestry technologies because they fear trees might compete with the food crops. The results also show that distance from local market negatively influenced growing *O. abyssinica*, findings in line with the studies of Belay *et al.* (2013) and Tadesse (2012) who confirmed that distance to local market had negative impact on adopting of agroforestry systems. The possible explanation may be that farmers nearest to the local market could gain better knowledge of market pricing and have reduced product transportation costs.

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Contact with extension was positively related between growers and non-growers, showing that the growers who frequently visit extension agents and other knowledgeable farmers get more acquainted with technology and tend to decide in favor of adoption of the technology. This finding is in agreement with the studies of Adesina *et al.* (2000), Buyinza *et al*. (2008), and Feder *et al.* (1985) who implied farmers that have contacts with extension and development agencies working on agroforestry were more likely to grow *O. abyssinica* as a homestead agroforestry system. The negative relationship of tropical livestock unit (TLU) holdings between growers and non-growers might be explained by the fact that farmers with more livestock might give high management priority to their livestock rather than introducing *O. abyssinica* as homestead agroforestry. Other studies have found that the number of livestock kept by households was found to be the most important determinant of agroforestry adoption. This is because those with higher number of livestock are severely constrained by the shortage of fodder (Neupane *et al*. 2002).

Overall, we found a robust indication of positive effects of *O. abyssinica* on economic conditions of the households of the study area. This is in line with the findings of Andargatchew (2008) who found that highland bamboo positively affected the income of rural households in **shedem,** Bale Province, Ethiopia. This is also strengthened by Krishnankutty (1998) who revealed that the estimated average income returns from *Bambusa bambos* (L.) Voss collected from home-gardens of Kerala, India, are relatively modest.

This study concludes that *O. abyssinica*-based homestead agroforestry systems can be considered as a means to improve livelihood in the study area. *Oxytenanthera abyssinica* can be used as an additional income source and could improve households' income security. The results indicate that distance to local market and total livestock holdings were negatively related to growing *O. abyssinica*. However, extension advice and homestead farm size were positively related. Average income gain due to *O. abyssinica*-growing ranged from 3382 (USD $176) to 4743 birr (USD $247*)*, indicating that the mean income and number of months with enough food available per year has significantly increased due to *O. abyssinica*-growing.

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