# *Spatial Patterns and Determinants of Smallholder Tree Planting in Northwest Highlands of Ethiopia*

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*ABSTRACT:*

Trees outside forest have immense benefits for people's welfare in rural Ethiopia. Understanding and characterizing the incentives and constraints of smallholder tree growers is essential to hasten efforts in rural transformation. This study has investigated the most important tree species grown by smallholder farmers in the highlands of northwest Ethiopia. Data was collected from 150 households that grow the trees. Survey with semi-structured questionnaire interviews was used to collect information on tree species grown, tree growing niches and uses, as well as, selected socio-economic characteristics. The number of trees and types of tree species grown by each household was calculated with and without adjusting to farm size. Linear regression model and other tests were employed to identify the most important determinants of tree growing behaviour of households and spatial variables affecting the abundance and frequency of tree species. About 25 tree species were found grown by farmers. The total number of trees, tree species and their spatial patterns differed markedly among farms. Multiple linear regression of tree abundance and frequency of tree species on household characteristics showed significant relationship. The number of livestock owned by the household, land holding size and age of the head of the household affect positively the number of trees and number of tree species

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grown by the households. Gender affected the species and spatial pattern of trees. Our result support the proposition that farmers assign their parcels of lands to land uses that increase the rent value of the land, and this rent value was affected by spatial variables. Our results suggest that future policy and extension program should target increasing the number of tree species on resource endowed households, and increasing the number of trees on younger and less resource endowed ones. Our finding that farm land and boundary planting to be important tree growing niche may indicate future intervention points.

**Key words**: Northwest highland, Smallholder, Trees, livelihood, niche

## INTRODUCTION:

The northwest highlands of Ethiopia have a long history of intensive land use and deforestation. The major causes of deforestation have been land clearing for arable land and pasture, cutting trees for timber and fuel. The rapidly growing human population, civil unrest, as well as, severe episodes of drought have their role for the problem. The country has already felt biomass deficit and started state initiated tree plantation by the end of the nineteenth century (Bekele, 2003; Kassa *et al*., 2011). Currently, despite increased recognition of importance of trees outside forest and plantation forest cover increment globally (FAO, 2010), tree planting in northwest Ethiopia is highly restricted around homesteads (Kassa *et al*., 2011).

Outside Ethiopia, in parts of Africa, Asia and Latin America, smallholder tree growing have been constrained by a wide range of factors, which vary kaleidoscopically according to owners characteristics, the tree species and the environment it is grown, as well as market drives and policy variables (Arnold, 1997; Adesina and Chianu, 2002; Amacher *et al*., 2004). The importance of resource endowments of households in the farm land, labor and livestock was reported to affect small holder tree planting (Adesina and Chianu, 2002; Pattanayak *et al*., 2003). These factors and their interaction with the allocation of scarce resources and the trade-off in the household were also reported to affect tree planting (Salam *et al*., 2000). The importance of government incentives in promoting tree planting was also reported from Indonesia (Nibbering, 1999)**.** However, Dewees (1993) reported that government initiated tree planting incentives did little good in Malawi with complicated problem to implement the initiative. In the Philippines, Emtage and Suh (2004) reported the importance of household demand and consumption of wood for timber and fuel being the most important factors in driving household decision to plant trees.

The decision to grow trees by smallholder farmers is also affected by market incentives, such as availability of markets for outputs and inputs, their price and associated income loss (Arnold, 1997; Warner *et al*., 1997; Arnold *et al*., 2006). On the other hand, Patel *et al*., (1995) reported that the decision to grow or not to grow trees among households may be influenced by differences in factor costs, differences in factor endowments and poorly functioning factor markets. The importance of markets and policy variables in affecting household tree planting increases as they are important in shaping risk perception and risk construction of the decision maker in the household in the farming system (Murray and Bannister, 2004). Where farmers perceive uncertainties in land and tree tenure are too poor to enjoy remote benefit stream, they do not show interest in investing on long rotation crops such as trees (Bannister and Nair, 2003). These factors at the farm level affect the spatial and temporal pattern and also management of trees (Nawir *et al*., 2007).

In Ethiopia smallholder tree growing and their characterization was reported earlier (Teketay and Tegineh, 1991; Mekonnen, 2009; Abebe *et al*., 2010). Especially, the importance of land holding size, family size, gender and education of household head, and livestock holding in constraining and shaping household tree planting decision have been reported in the Gedeo and Guraghe highlands (Abebe *et al*., 2006; Ayele, 2008), around Ginchi and Menagesha (Mekonnen *et al*., 2006; Mekonnen *et al*., 2009; Duguma and Hager, 2010), and in Tigray (Mekonnen, 2009; Gebreegziabher *et al*., 2010). These sources have also indicated the importance of some factors influencing household's tree planting behavior. For example, Mekonnen, (2009); Gebreegziabher *et al*., (2010) found that households with relatively more male labor, relatively higher income, and a higher proportion of off-farm income, are more likely to plant trees in northern Ethiopia.

The importance of Eucalyptus in current tree planting practice of farmers in Ethiopia has been stressed by many authors (Mekonnen *et al*., 2007; Jenbere *et al*., 2012). Some studies have suggested that the fast growing *Eucalyptus* trees are particularly profitable in northern Ethiopia where rate of return for farmers investment are above 20 percent (Jagger and Pender, 2003) including on less favored lands (Holden *et al*., 2003). Kidanu *et al*., (2004) has shown that *Eucalyptus* can be planted with proper management on water logging problematic soils in the highlands of Ethiopia without significant nutrient depletion and crop yield loss. In general, in a country where 84% of the population lives in the rural areas, biomass energy is the main source of energy for 62-66% of the total population, and farm forestry contributes up to 20% of the total wood increment of the forest resources (EFAP, 1994), increasing farmer's participation in tree planting could be among the solutions for the observed biomass deficit. Although there are some studies elsewhere in Ethiopia, additional information is important for sound policy advice that will help to boost the participation of smallholder farmers in tree planting and enhance the contribution of trees to improve rural livelihood. The objectives of this study, therefore, are: 1) to identify the most important tree species grown by farmers; 2) to investigate the pattern of tree growing in the land use system, and 3) to study determinants of the number and diversity of tree species and spatial pattern of trees grown by smallholder farmers and their implication on the lives and landscape in rural Ethiopia.

## Materials and methods

### Study area

The study was conducted in the Ambober-Wuzaba district of Gondar. It is located north of Lake Tana between latitude 12°31'2.87"N and longitude 37°31'24.37"E, approximately 30 km south of Gondar Town. Part of the village was occupied by Bete Israel (Jews of Ethiopia) before their emigration to Israel. The village is also connected by 10 km dry weather road to the main highway that connects Ethiopia and Sudan. This geographical location implies that the area is highly connected to the emerging and growing national and regional market. The average land holding size is 0.56 ha. The farming system is mixed croplivestock system where trees also form valuable component. The area is a transition zone between low production potential cereal-livestock zone in the east and high production potential cereal-livestock zone in the west and south. A typical household is entitled over three parcels of land. The first parcel of land is located surrounding the homestead, and has never been subjected to government land redistribution program. The second and the third parcels are located away from the homestead and their location is mainly dictated during the government land redistribution program which occurred four times in the past.

## Sampling and data collection

Combinations of random and purposive sampling were employed to select 150 households from the list obtained from the district land administration authority. The selected households were interviewed with a questionnaire to collect major explanatory variables supposed to affect the decision to select and grow trees. The variables include, age and sex of head of the household, land holding size, number of cattle owned, family size, including age structure and years since managing the land. The number of cattle was recoded in Tropical Livestock Unit (TLU). Focus group discussion, transect walk and farm visits were employed to collect tree related data. The location of each household was recorded with GPS (Garmin GPS 75). During focus group discussion exhaustive list of the tree species has been obtained, followed by ranking and prioritizing to select the most important ones. The focus group discussion also revealed the importance of bisecting the village into sub-villages (got), Ambober and Woyiniye, mainly based on their spatial location to the main road. During farm visits, we recorded and measured every tree species encountered on a farm or communicated by any member of the household for its presence, including presence in particular tree growing niches. Tree growing niche on a farm refer to the location of trees on the farm and their establishment pattern at the location. The niches that were distinguished were trees in the homestead area, trees mixed and scattered on cropland, trees on boundaries of the farm, and trees on woodlots.

The tree species considered do not have similar growth habit. For this study, we considered only those tree species which can grow up to five meters.

Therefore, we employed the number of mature trees on the farm and the number of species or frequency of mature tree species on the farm to develop dependent variables. The first variable was the total number of trees per household with and without adjusting the variability in farm size into hectare, and the second was the number of species per household with and without adjusting per hectare. The survey was done from January-August 2009 and December 2009-October 2010.

## Data analysis

GPS data was uploaded to Google Earth ™ for spatial analysis. Household data was rectified for possible outliers. Those observations which were found outliers were removed from analysis. Therefore, we used the data from 135 households for further analysis. The data obtained was analyzed for descriptive statistics, one way analysis of variance (ANOVA), independent t-test and regression by using Ordinary Least Square Estimation (OLS). Differences in the total number of trees and the number of tree species among tree growing niches were tested by using one-way ANOVA. Independent t-test was employed to test differences in the number of trees and number of tree species grown between male headed and female headed households, and also differences between Ambober and Woyiniye sub-villages (*got*). Multiple regression by using OLS was employed to study the importance of different household socio-economic characteristics supposed to affect the tree growing behaviour and hence the diversity and density of trees grown by a given household. The explanatory variables included in the analysis were villages, gender and age of the household head, number of years the household resided on present landholding, family size, size of landholding in hectares, size of livestock owned in tropical livestock unit. The dependent variable used in the analysis was diversity statistics of trees grown by the household as measured by the absolute density of trees and number of tree species on the farm with and without adjusting for the variability in our sampling unit, the farm size.

## Result

A total of 25 tree species were found to be grown by farmers for different purposes. The average number of trees owned per household was 98.21, and the average number of tree species grown per household was 6 (Table 1). The average land holding is 0.56 ha, scattered on different parcels with average distance between plots 2.1 km. Tree species did vary depending on planting niche, village and gender of head of the household. The most dominant tree species were *Eucalyptus camaldulensi*s followed by *Rhaminus prinoides*, *Ficus thoninngii*, *Albizia schimperiana*, *Cordia africana*, *Acacia abyssinica* and *Croton macrostachys* (Table 2). In Ambober village, *E. camaldulensis* accounts 90% of the total number of trees followed by *F. thonningii* (3%), *R. prinoides* (2.3%). Whereas at Woyiniye, *E. camaldulensi*s accounts 49% of the total number of trees followed by *R. prinoides* (19%), *C. macrostachys* (4%), *E. tirucali* (4%), and *F. thonningii* (3%) (Table 2).

There was significant difference in the number of trees and number of tree species among tree growing niches. The highest number of trees was recorded from woodlots followed by inside farm boundaries and homesteads in decreasing order. In terms of number of tree species, the

**Table 1 Descriptive statistics of the variables**

| **Variable** | **Mean** | **Std. Deviation** |
|---|---|---|
| Village dummy | 0.62 | - |
| Sex of household head dummy | 0.75 | - |
| Age of household head in years | 45.75 | 13.91 |
| Years of land ownership | 20.78 | 9.53 |
| Family size in number | 5.13 | 2.14 |
| Farm size in hectares | 1.10 | 0.86 |
| Livestock (TLU) | 2.28 | 2.33 |
| Abundance of trees | 98.21 | 149.36 |
| Density of trees per hectare | 92.23 | 121.73 |
| Species richness (number of species per land holding) | 5.90 | 5.03 |
| **Number of species per hectare** | **7.34** | **7.59** |

**Table 2 Mean tree abundance (std. Error) separated by village, gender and tree growing niches**

| | **Village** | | **Gender** | | **Growing niche** | | | |
|---|---|---|---|---|---|---|---|---|
| | Ambober | Woyiniye | inside farm | Homestead | Boundary | Woodlot | Female | Male |
| *Acacia abyssinica* | 0.04 (0.031) | 0.48(0.83) | **1.04(0.22)** | 0.32(0.11) | 0.25(0.10) | - | 0.18(0.08) | 0.47(0.09) |
| *Albizia schimperiana* | 0.02(0.022) | 0.56(0.11) | **1.57(0.35)** | 0.25(0.10) | 0.03(0.02) | - | 0.17(0.11) | 0.55(0.11) |
| *Arundo donax* | - | 0.17(0.16) | - | - | 0.55(0.54) | - | 0.02(0.02) | 0.18(0.18) |
| *Bersama abyssinica* | - | 0.31(0.09) | 0.70(0.26) | - | 0.31(0.18) | - | 0.21(0.17) | 0.27(0.09) |
| *Carisa edulis* | 0.02(0.022) | 0.11(0.046) | - | 0.15(0.10) | 0.22(0.12) | - | 0.11(0.09) | 0.09(0.04) |
| *Cordia africana* | 0.98(0.47) | 0.58(0.09) | **1.03(0.23)** | **1.41(0.39)** | 0.17(0.07) | - | 0.41(0.15) | 0.73(0.15) |
| *Croton macrostachys* | 0.39(0.15) | 0.95(0.15) | **1.35(0.34)** | **1.57(0.33)** | 0.47(0.13) | - | 0.43(0.17) | 0.97(0.15) |
| *Dodonea anguisitifolia* | - | 0.68(0.25) | 0.05(0.05) | 0.58(0.41) | **1.62(0.69)** | - | 0.01(0.01) | 0.73(0.26) |
| *Eucalyptus camaldulensis* | **44.34(18.94 )** | **11.97(3.88)** | 0.09(0.07) | 0.08(0.08) | **1.57(0.66)** | **69.47(18.00)** | **14.45(8.65)** | **18.68(5.47)** |
| *Euclea schimperina* | - | 0.07(0.03) | - | 0.12(0.07) | 0.13(0.10) | - | 0.13(0.09) | 0.04(0.03) |
| *Euphorbia abyssinica* | - | 0.03(0.02) | - | - | 0.1(0.07) | - | 0.07(0.07) | 0.01(0.01) |
| *Euphorbia tirucalli* | 0.30(0.23) | **2.04(0.50)** | - | - | **6.52(1.57)** | - | 0.73(0.48) | 2.03(0.52) |
| *Ficus sur* | - | 0.03(0.01) | 0.02(0.02) | 0.01(0.01) | 0.06(0.04) | - | 0.02(0.02) | 0.03(0.01) |
| *Ficus thonningii* | **1.62(0.61)** | 0.79(0.21) | 0.30(0.12) | **2.14(0.67)** | **1.31(0.45)** | - | 0.33(0.17) | **1.12(0.26)** |
| *Grewia ferugenea* | - | 0.03(0.01) | 0.03(0.02) | 0.06(0.04) | - | - | - | 0.03(0.01) |
| *Olea europea* | 0.11(0.08) | 0.38(0.07) | **1.06(0.21)** | 0.20(0.07) | 0.06(0.04) | - | 0.13(0.06) | 0.39(0.07) |
| *Opuntia ficus indica* | - | 0.01(0.01) | - | - | 0.04(0.04) | - | - | 0.01(0.01) |
| *Otostegia schimperi* | - | 0.03 (0.02) | - | 0.10(0.07) | - | - | - | 0.03(0.02) |
| *Phytolaca dodecandra* | 0.11(0.11) | 0.09(0.02) | 0.04(0.03) | 0.05(0.03) | 0.29(0.10) | - | 0.09(0.04) | 0.10(0.03) |
| *Prunus persica* | 0.17(0.11) | 0.12(0.04) | 0.02(0.02) | 0.48(0.14) | 0.02(0.02) | - | 0.05(0.04) | 0.16(0.05) |
| *Pterolobium stellatum* | - | 0.02(0.01) | - | - | 0.08(0.05) | - | 0.01(0.01) | 0.02(0.02) |
| *Rahminus prinoides* | **1.14(0.48)** | **4.50(1.09)** | **13.82 (3.40)** | **1.08(0.47)** | 0.70(0.40) | - | **1.41(0.55)** | **4.66(1.16)** |
| *Rhus glutinosa* | - | 0.09(0.03) | 0.05(0.04) | 0.12(0.08) | 0.12(0.07) | - | 0.06(0.05) | 0.08(0.03) |
| *Rhus vulgaris* | - | 0.07(0.03) | 0.02(0.02) | 0.08(0.06) | 0.11(0.06) | - | 0.05(0.05) | 0.06(0.03) |
| *Rosa abyssinica* | - | 0.14(0.04) | 0.01(0.01) | - | 0.44(0.14) | - | 0.05(0.04) | 0.13(0.05) |
| Mean number of tree | 49.25(18.83 ) | 24.54(4.08) | 21.52(4.02) | 8.87(1.31) | 15.18(2.33) | 69.47(18.00) | 19.09(8.70) | 31.57(5.58) |
| | **t-vale=24.71(1.99)**a | | **t-value=-12.48(-1.11)** | | **F=9.10b** | **Sig=000** b | | |
| Mean number of tree species | 0.73(0.08) | 1.37 (0.09) | 1.40(0.09) | | 1.85(0.20) | | 1.40(0.16) | 1.32(0.16) |
| | **t-value=-0.65(-3.10)***| | | | **t-value=-0.67(-3.68)** | | **F=14.10** | **Sig=000** |

a=mean difference and in bracket t-values for one sample t- test, b=ANOVA and the corresponding F-test and significance value highest was recorded on homesteads and the least on woodlot (Table 2). The most important tree species scattered inside farm are *R. prinoides, A. schimperiana, C. macrostachys, O. europaea, A. abyssinica, and C. africana*. The most abundant trees on homesteads are *Ficus thonningii, C. macrostachys, C. africana, O. europaea and R. prinoides*. Tree species which were found abundantly on boundary planting include *E. tirucali*, D. *anguisitifolia, E. camaldulensis* and *F. thonningii*. Woodlots are mainly practiced by *E. camaldulensis* (Table 2). The highest number of trees recorded on woodlot mainly arises from the extremely high planting density of E.camaldulensis by farmers as there is little working knowledge regarding the management of this species on farmers' field. Rather the increase in the number of trees and number of tree species inside the farm and boundaries may indicate increasing trend of tree planting by smallholder farmers amid increasing parcel fragmentation and miniaturization. The OLS model has explained that 37% of the variation was observed among households in the total number of trees they grow ($F=13.09$, $P < 0.001$). When the dependent variable was adjusted for the size of land owned (number of trees per hectare) and fitted for the same explanatory variables, the prediction power declined to 26.6% ($F=8.34$, $P < 0.001$). Variables such as the number of livestock in TLU, size of land owned, and age of head of household significantly predicted by both of the models. Nevertheless, family size was significant in the regression model when the dependent variable is adjusted for size of land owned but not in the first model (Table 3).

Similarly, the OLS models developed to predict the socioeconomic factors responsible for the variation observed in the frequency/number of tree species predicted 48% of the variation in the dependent variables ($F=19.80$,

**Table 3 Ordinary Least Square (OLS) estimation for tree abundance with and without adjustment for sample size**

| **Variables** | **Model 1** | **Model 2** |
|---|---|---|
| | Total number of trees in a household | Number of trees adjusted for hectare |
| Village dummy | -37.95 (-1.57) | -10.25 (-0.48) |
| Sex of household head | -14 .67 (-0.56 | 3.58 (0.16) |
| Age of household head | 2.51 (2.29)* | 4.08 (4.21)*** |
| Years in number since land owned | -0.49 (-0.27) | 0.64 (0.41) |
| Family size | 5.30 (0.98) | 8.24 (1.72)* |
| Farm size in hectares | 42.45 (2.51)** | -68.09 (-4.57)*** |
| Livestock in TLU number | 27.44 (5.15)*** | 19.77 (4.20)*** |
| Constant | -108 (-2.32)* | -116.51 (-2.82)** |
| Joint significance (F-test) | 185871.72 (13.09)*** | 92334.73 (8.34)*** |
| **Adjusted $R^2$** | **0.37** | **0.27** |

Figures in parenthesis are corresponding t-values for the coefficient and the astrix marks indicate their level of significance where *= P<0.01, **= P<0.05 and ***= p<0.1

However, when the number of tree species was adjusted for farm size, the prediction power declined to 30.4% (F=9.87, $P < 0.001$). Variables such as the number of livestock in TLU, size of land owned, family size, and age of head of household significantly predicted by both of the models. However, village dummy was significant in the regression model when the dependent variable is adjusted for size of land owned but not in the first model (Table 4). The independent t-test analysis was run to test if there was significant difference between villages and between sexes of heads of households. There was significant difference (P < 0.05) in the mean abundance of trees between Ambober (64 trees) and Woyiniye (119 trees) when the variability in landholding size among households was not taken into consideration. However, when the mean number of trees was adjusted for variability for farm size, the difference becomes statistically insignificant and is lower than that of the unadjusted one (Table 5). The independent t-test for the mean difference in the count of tree stem number showed non-significant difference between female (58 trees) and male (112 trees) headed households. Nevertheless, there was significant difference in the number of tree species maintained by male headed and female headed households (Table 5).

## Discussion

The number of trees and number of tree species grown by farmers in our study area is comparable to other studies. For instance, (Duguma and Hager, 2010) found 27 tree species grown by farmers in central highlands of Ethiopia, and (Mekonnen, 2009; Gebreegziabher et al., 2010) reported the average density of trees per hectare to be 150 trees in northern Ethiopia which is higher than our result. According to Warner et al., (1997) the pattern of trees grown on farm and the drivers of this pattern can be

**Table 4 Ordinary Least Square (OLS) estimation for tree species with and without adjustment for sample size**

| **Variables** | **Model 1** | **Model 2** |
|---|---|---|
| | Total number of tree species in a household | **Number of tree species adjusted for hectare** |
| Village dummy | 0.78 (1.06) | **2.82 (2.18)*** |
| Sex of household head | 0 79 (0.99) | **1.98 (1.43)** |
| Age of household head | 0.10 (3.03)* | **0.12 (2.08)*** |
| Years in number since land owned | -0.04 (-0.76) | **-0.10 (-1.08)** |
| Family size | 0.34 (2.05)* | **0.06 (0.22)** |
| Farm size in hectares | 1.64 (3.19)** | **-5.30 (-5.88)***** |
| Livestock in TLU number | 0.62 (3.83)*** | **1.11 (3.90)***** |
| Constant | -3.91 (-2.74)** | **3.64 (1.46)** |
| Joint significance (F-test) | 261.26 (19.80)*** | **399.28 (9.87)***** |
| **Adjusted $R^2$** | **0.48** | **0.30** |

Figures in parenthesis are corresponding t-values for the coefficient and the astrix marks indicate their level of significance where *= P<0.01, **= P<0.05 and ***= p<0.1

**Table 5 Test of equality of means of tree abundance (total number of trees) and number of tree species separated by village and sex of head of the household**

| | **Village** | | **Mean difference** | **Sex** | | **Mean difference** |
|---|---|---|---|---|---|---|
| | Ambober | Woyiniye | | Female | Male | |
| Number of trees | 63.51(98.43) | 119.19(170.14) | -55.68(-2.12)** | 58.49 | 111.70 | -53.21(-2.12) |
| Number of trees (ha) | 85.83(85.83) | 96.10(96.10) | -10.27(-0.47) | 71.99 | 99.104 | -27.11(-1.11) |
| Number of species | 3.49(3.49) | 7.36(5.27) | -3.87(-5.34)** | 3.24 | 6.81 | -3.56(-4.39)** |
| Number of species (ha) | 5.81(6.27) | 8.26(8.18) | -2.45(-2.04)** | 4.98 | 8.13 | -3.15(-2.47)** |

The figures in parenthesis on the mean are the standard deviation of the mean.

The figures in parenthesis on the mean difference are t-values and the corresponding level of significance where **=P<0.05.

examined in terms of farmer livelihood strategies and of the dynamics of rural change. A pattern or a combination of patterns may exist in a given land use system, depending upon the farming system.

Boundary planting areas and inside farms contribute the highest proportion of trees which is in agreement with previous reports (Duguma and Hager, 2010). This may be the result of fragmentation of farm lands and/or reaction to the current tenure insecurity (Deininger and Jin, 2006; Gebreselassie, 2006). Land use intensification, which includes plantation of more trees, with increasing population has been proposed (Boserup and Kaldor, 1965). Yet, diminished number and diversity of trees in other tree growing niches may be a reflection of the current tenure arrangement in the country (Rahmato, 2008).

Livestock ownership can both be a threat and opportunity for tree growing. In the presence of free grazing and open access property rights, livestock population may be a threat for tree plantations. Nevertheless, livestock ownership can also promote tree plantation and conservation of species that have forage values. In our study area the mean TLU values was 2.3 and livestock ownership positively affected the number of trees planted by households. A unit increase in TLU, increase the frequency of trees by 27 at $P < 0.001$ when the number of trees was not adjusted for farm size and by 20 trees at $P < 0.001$ when the number of trees was adjusted for farm size. Our finding agree with the finding reported from Guraghe highlands in Ethiopia (Ayele, 2008), and yet Gebreegziabher *et al*., (2010) had reported a decrease in the number of trees planted with increase in the number of livestock managed by households.

The size of farmland owned by the households did affect tree planting behaviour positively and consistently. Our finding with regard to farm size revealed that those farm households with larger plots of land maintained more trees compared to those farm households that owned relatively smaller size of land. The impact was so large that as the land owned increased by one hectare, the frequency of trees maintained per hectare in a household increased by 45 trees ($P < 0.001$). Ayele (2008) reported positive and significant relation between farm size and number of trees, and he found that an increase by a hectare in landholding likely to increase the number of trees per household by 934 in the Guraghe highlands in Ethiopia. Similar reports of positive effects of farm size on tree planting were also reported in Tigray, Ethiopia (Gebreegziabher *et al*., 2010; Mekonnen, 2009), in Laos (Darr and Uirbrig, 2004), in the Philippines (Emtage and Suh, 2004) and in Bangladesh (Salam *et al*., 2000).

Our investigation showed older households likely to grow more trees than younger ones. As age of the head of the household increased by a year, the number of trees planted by the household was likely to increase from 2.5- 4. Similar reports of positive impact of age and farm accumulated experience in favour of more tree on the farm has been reported (Gebreegziabher *et al*., 2010). Yet, others have reported age to affect on-farm tree planting negatively. This is especially true when tree planting is less profitable than other agrarian activity, and age was reported to increase the calculative capacity of the household for profits and also anticipated future risks. In other cases, age may hinder tree planting simply older farmers being less flexible and less willing to engage in innovative farm technologies (Thacher *et al*., 1996; Ayele, 2008).

Our result showed that family size did not affect significantly the absolute number of tress grown by households, but it affected the number or frequency of tree species. Family size may affect household tree planting either by increasing the wood demand for the household or by increasing the availability of human labour for tree planting. In our study area, however, larger sized families were likely to grow diverse range of tree species than smaller sized families. The importance of family size in influencing positively farm tree planting by increasing the availability of labour has been discussed in Ethiopia (Gebreegziabher *et al*., 2010; Holden *et al*., 2003; Mekonnen, 2009).

Our result from the independent t-test analysis showed the presence of significant difference between the mean number of trees and number/frequency of tree species maintained by farmers living in Ambober and Woyiniye villages (Table 5). In Ambober, the most dominant trees planted by farmers was *E.camaldulensis* which accounts 90% of the total number of trees planted by farmers. At Woyiniye, *E.camaldulensis* accounts 49% of the total number of trees, followed by *R. prinoides* (19%). This differentiation may arise from the differences and dissimilarity of management objectives of the two tree species, the ease of transporting of the products to the market and also the location of the two villages in reference to the road. Despite very high planting density, *Eucalyptus* is largely harvested when it is pole size, and for markets as far as the Sudan. The product is bulky to transport which compels access to the road. On the other hand, *R.prinoides* is grown mainly for its leaves which are used for local beverages, the leaves can be carried and transported easily to any market by human or by any of draught animals. Therefore, those households located at Woyiniye farther out from the road tend to specialize in planting and growing *R.prinoides* which is easy to carry to the nearby market. According to the Von Thünen theory (1966), land is allocated to the use that gives the highest land rent value. Land rent value can be affected by spatial location in relation to road and market. Both *Eucalyptus* and *R.prinoides* have good market at Gondar, but *Eucalyptus* has additional market in the neighbouring Sudan. Households in our study area grow these two tree species disproportionally higher than other tree species supporting the basic land use model of Von Thünen. However, the potential danger may be that farms that are located near to the main road may be changed into monoculture plantation of *Eucalyptus*. This threat may expand with increasing demand of *Eucalyptus* products in Ethiopia and the neighbouring countries.

In contrary to previous reports, our finding showed no statistically significant difference in the total number of trees planted by female and male headed households. However, the difference was significant when it comes to the frequency/ number of species. Although Hansen *et al*., (2005) reported from Malawi that a high incidence of non-married women to be associated with increased tree planting, previous reports from Ethiopia (Ayele, 2008; Mekonnen and Köhlin, 2009; Gebreegziabher *et al*., 2010) had shown that tree planting by female headed households was much less likely than their male counterparts. In our study, however, the observed difference in the frequency of tree species/number of tree species brought by gender may be from the selective behaviour of female headed households. Female headed households specialize on planting those tree species that increase the rent value of their land, legitimate their tenure security from the government or that demarcate their property permanently from threat of border dispute from their powerful male neighbours.

## Conclusion and practical implication

This study characterized the role of trees in the farming system of northwest Ethiopia, and identifies the major tree species grown by farmers, planting pattern of tree species, constraints and incentives for tree growing and their implication for practice. The most important trees grown by farmers are *Eucalyptus camaldulenis*, *Rahminus prinoides*, and *Ficus thonningii*. However, all in all the farming system can be characterized as *Eucalyptus-Rahminus-cereal-livestock* farming system. Trees are grown scattered inside farm, on homesteads, boundaries, and blocks of woodlots. Planting around boundary areas and inside farms contribute the highest proportion of trees. The number of livestock owned by the household, land holding size and age of the head of the household affect positively the number of trees and number of tree species grown by the households. Future extension program should target increasing the **number of tree species** on resource endowed households, and increasing the **number of trees** on younger and less resource endowed ones. Female headed households' decision to plant trees, in addition to increasing the rent value of their parcel of land, was constrained by weakness or bias of local jurisdiction to settle boundary dispute. Strengthening institutions that can settle property border disputes with little transaction cost may lessen the constraints on female headed households for their decision to plant trees.

There is an increase in the number of trees and number of tree species planted inside the farm and boundaries. This may indicate increasing trend of tree planting by smallholder farmers amid increasing parcel fragmentation and miniaturization. However, fertile farms and parcels of land that are located near the main road are likely to be changed into monoculture plantation of *Eucalyptus camaldulensis*. This threat may expand with increasing demand of Eucalyptus products in Ethiopia and the neighbouring countries. This in turn will affect food production by taking parcels of land which otherwise would have been used for other food crops which bring less income than Eucalyptus.

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