

*Full Length Research Paper*

# **Contribution of parkland agroforestry in supplying fuel wood and its main challenges in Tigray, Northern, Ethiopia**

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Received 21 September, 2019; Accepted 29 January, 2020

**Agroforestry is an aged practice in the Ethiopian farming systems of which parkland trees comprise the large part of agricultural landscapes. It is also the most dominant agroforestry practice in the semi-arid and sub-humid zones of Ethiopia. However, there is lack of research based evidence that shows the contribution of parkland agroforestry on fulfilling households' fuel wood demand and towards improving the smallholder farmers' livelihood. Hence, the main objective of this study was to assess the role of parkland agroforestry practice on fulfilling households' fuel wood demand, improving livelihood and to identify the main constraint. Primary data was collected from actual field measurement and questionnaire based face to face interview with randomly drawn 138 parkland agroforestry user and non-user. Guided field observations, interview with key informants and focused group discussion were also conducted. About 108.56 ton (79.2%) annual fuel wood consumption was harvested from the parkland trees; whereas the non-parkland agroforestry households were mainly dependent on the surrounding natural forests to meet their fuel wood demand. The Propensity Score Matching model result indicated that there was significant difference ( $p < 0.05$ ) among the parkland agroforestry introduced and non-introduced households on the time they spent to collect fuel wood and income. Parkland agroforestry plays a crucial role in the households' livelihood improvement (for example, income) and also to stabilize the pressure on local forests. However, the major challenges faced to improve the parkland agroforestry practice are farmland distance, free grazing, farmland size, general prohibition of fire wood selling, lack of farmers' awareness, lack of extension support and dry climatic condition. Therefore, to enhance the multiple benefits of the parkland agroforestry, the main constraints that hinder the sustainability of the parkland agroforestry should be addressed.**

**Key words:** Agroforestry, fuel wood, livelihood, household, local forest, parkland.

## **INTRODUCTION**

The problem of deforestation is much higher in East Africa than other parts of the continent (Kassie, 2015). The increasing populations of smallholder farmers in

developing countries are the main driving force for deforestation and land degradation meant for intended benefits such as agricultural expansion, fuel wood and

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fodder (Liman, 2015).

In Ethiopia, the steadily growing population pressure and the need for agricultural expansion and fuel wood consumption increased exploitation of forest resources which can ultimately lead to unsustainability and depletion of the total forest area (Fekadu, 2015). In the country, dependence of urban dwellers on surrounding rural areas for fuel wood consumption for long period of time and the associated population growth has aggravated the level of deforestation and forest degradation especially in recent times (Gebreegziabher et al., 2012). Agroforestry can help to enhance fuel wood availability, sustainably and to mitigate deforestation (Ernstberger, 2017) and climate change.

Parklands are scattered trees in croplands. They are a very common type of agroforestry system in the tropics and characterized by well-known scattered trees on cultivated and recently fallowed lands (Raj and Lal, 2014). Such a system of integrating tree species into farmlands provide productive, protective and socio-economic as well as cultural roles that can improve the livelihoods of the society, particularly for smallholder farmers in the developing world suffering from hunger, poverty, and malnutrition (Raj and Lal, 2014).

Parkland agroforestry is a system practiced by many local populations, and is very important for food security, microclimate amelioration, income generation and environmental protection. It is found at different corners of the world, primarily in the semi-arid and sub-humid zones of Africa (Boffa, 1999). Kindeya (2004) reported that agroforestry practice is an aged practice in the Ethiopian farming systems, of which parkland trees comprise the large part of agricultural landscapes and it is also the most dominant agroforestry practice in the semi-arid and sub-humid zones of Ethiopia. Parkland trees are used to satisfy the needs and demands of the households. Some of the major roles they play includes: heating, cooking, household utensils, cultural values, provision of pollen and nectar for honey production, construction of houses and handles of farm implements (Negash, 2007), traditional medicines (CIFOR, 2005), economic benefits, fodder values, employment opportunities as well as contribution to regional and national economy (Abebe, 2005). Parkland agroforestry is a major source of fire wood, which contributes significantly to household income and appears to be important for local economies (FAO, 2013).

In the study area, many farmers practiced parkland agroforestry (PLAF), but still there is lack of research based evidence. This investigation shows clear evidence about the contributions of PLF towards improving household's livelihood and its major constraints to sustain such function.

## MATERIALS AND METHODS

### Description of the study area

The research was conducted in Hawzen district of eastern Tigray

Northern Ethiopia. Hawzein district is geographically located at 13° 47' 30" to 14° 9' 25" North latitude and 39° 11' 40" to 39° 33' 20" East longitudes (Figure 1). From the total 80949.8ha area of the district, about 17687 ha (21.85%) were farmland with approximately 0.53 ha land holding size per household. Varying land forms, ranging from plain and semi plain agricultural areas to steep slope escarpments are dominated. Gheralta Mountains are the main features of steep slope escarpment of the district (HWEPLAU, 2017).

According to the HWFED (2017a, b) total population size of the district is about 127,265 with 2875 household heads, of which 93.4% lives in rural Kebeles. The average family size is about 4 persons per household. The district is the second most densely populated in Eastern zone (about 67.8 people per square kilometere), next to Atsbi-wenberta district, which is above the zone's and the region's rural areas average population density, 61.6 and 55.5 people per square kilometere respectively (Kidanemariam, 2011).

### Research approach and design

Fuel wood consumption of the study area was quantified with interviews, combined with precise field measurements (Jensen, 1995). Based on these assumptions and nature of the enquiry, the combinations of both quantitative and qualitative approaches were also used to obtain the required data. By applying quantitative tools, attempt was made to address the existing situations in relation to the amount of fuel wood generated from the parkland agroforestry system. Opinions of the respondents on the benefits and constraints of the parkland agroforestry system were also collected.

### Data sources and methods of data collection

The required data was collected from primary and secondary data sources. The primary data were collected through actual field measurement of each household's fuel wood consumption, household survey based on face to face interview using semi structured questionnaires, focus group discussion (FGDs) and key informants interview. Secondary sources of data were also collected from the agricultural office of the district, government documents, and articles of scholarly journals, book chapters, and newspapers.

### Sampling technique and sample size determination

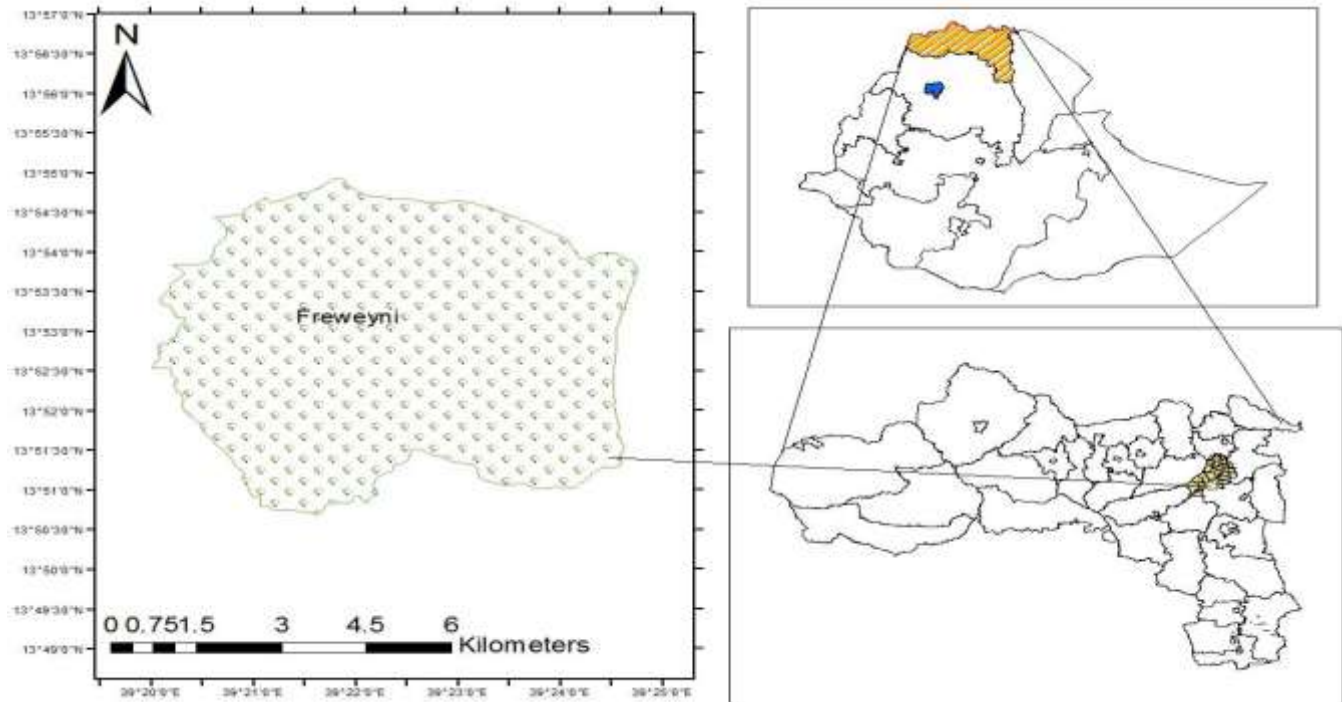
Purposive and Simple Random Sampling (SRS) techniques were employed. In the first stage, the study site (Freweyni Kebele) was selected purposely based on its relative abundance of the parkland trees on farmlands. In the second stage, households were stratified into parkland agroforestry users and non-users; then from 1,192 farmer households and 83 parkland agroforestry user household heads were identified as a sample frame. The simplified formula employed to determine the sample unit households were:

$$n = N/1+N (e)^2$$

$$n = \text{sample size, } N = \text{total population, } e = \text{level of precision (0.05)}$$

$$n = 83/1+83(0.05)^2 = 69$$

Then, 69 parkland agroforestry user households were taken, using the SRS technique for sampling. Therefore, 69 parkland agroforestry introduced households were selected randomly using the lottery system. In the same area, another 69 households who have farmlands but without parkland tree was identified and all members of this group were directly taken to use as sampling unit



**Figure 1.** Map of the study area.

as they were limited in number. In this study, equal weight was given for both (parkland agro forestry user and non-user) households in order to see contribution of the parkland agro forestry practice on the farmers livelihood.

#### Data analysis

Data were organized in Excel spread sheets and analyzed using SPSS version 20 software package. To reduce bias due to confounding variables, Propensity Score Matching (PSM) model was also used to analyze the contribution of PLAF on household's livelihood improvement.

## RESULTS AND DISCUSSION

### Parkland agro forestry and livelihood of the households

The actual households fuel consumption measurement result showed that from the total parkland agroforestry users, about 137.3 ton (94.9%), was woody biomass and the rest 7.35 ton (5.1%) was non woody biomass; especially cattle dung and crop residues. From the total annual household fuel consumption, 108.65 ton (75.03%) was harvested from the parkland trees found on farmlands. The Propensity Score Matching model (PSM) result showed that the parkland agroforestry user households were spending a mean of 1.56 h per week to collect fuel wood; whereas the households that have not practiced parkland agroforestry spent a mean time of 3.4

hours per week (Table 1). This indicates that each parkland agroforestry user households were required to assign on average of about 74.9 h per year for fuel wood collection; whereas the non-parkland agroforestry user households were required to assign about 163.2 h per year for fuel wood collection, which is more than 2 folds higher than the parkland agroforestry user households. Kassie (2015) reported a similar result that, to collect 30 kg (one bundle) of fuel wood from the natural forests and shrub lands in Maytemeko watershed (in Amhara National Regional State, Ethiopia) required about 4 h; while for the households who used their own farmland trees, it was about 1 h to collect the same amount of fuel wood.

The time required to collect fuel wood from the natural forest and shrub lands may increase with deforestation, since the forest cover will be pushed up to the marginal areas. This showed that the tasks of fuel wood collection from the surrounding common areas are time consuming and it is proportionally correlated with distance of the site in which the fire wood is found. In line with the present result, Palmer (2009) reported that fuel wood scarcity has a positive effect on labor inputs to fuel wood collection from common areas.

The annual mean income of the parkland agroforestry introduced household in the year 2016/2017 was about 25915 birr (equivalent to 863 USD) and this was greater than the mean annual income of 21684.4 Birr (equivalent to 722 USD) earned in the same year by the households who was not introduced parkland agroforestry (Table 1)

**Table 1.** Contribution of parkland agroforestry inhouseholds' time saving and income diversification in the year 2016/2017 in Hawzeien district, Northern Ethiopia.

Variable	HHs time spent to collect fire wood (Hours/week)		
	Mean $\pm$ SD	Minimum	Maximum
PLAF users	1.56, 0.69	1	3
Non users	3.4, 1.38	1	5
Total	4.96, 2.07	2	8
	HHs Income (Birr/year)		
PLAF users	25915, 15785.77	1700	66338
Non users	21684.4, 13812.65	2888	55480
Total	47599.4, 29598.24	4588	121818

PLAF is parkland agroforestry; SD is standard deviation, 1USD= 30 Ethiopian Birr.

**Table 2.** Propensity score matching regression result.

Outcome variable: Hours spent	Coef.	Std. Err.	t	P> t	[95% Conf. Interval]
Treated	-1.84058	0.1867261	-9.86	0.000	-2.209842 -1.471318
_cons	3.405797	0.1320353	25.79	0.000	3.144689 3.666905
Outcome variable:INC	Coef.	Std.Err.	t	P> t	[95% Conf. Interval]
Treated	4230.565	2525.176	1.68	0.096	-763.1243 9224.255
_cons	21684.41	1785.569	12.14	0.000	18153.33 25215.48

Hours spent= hours spent, INC=income.

though there were some uncontrolled factors that can influence the income of each households.

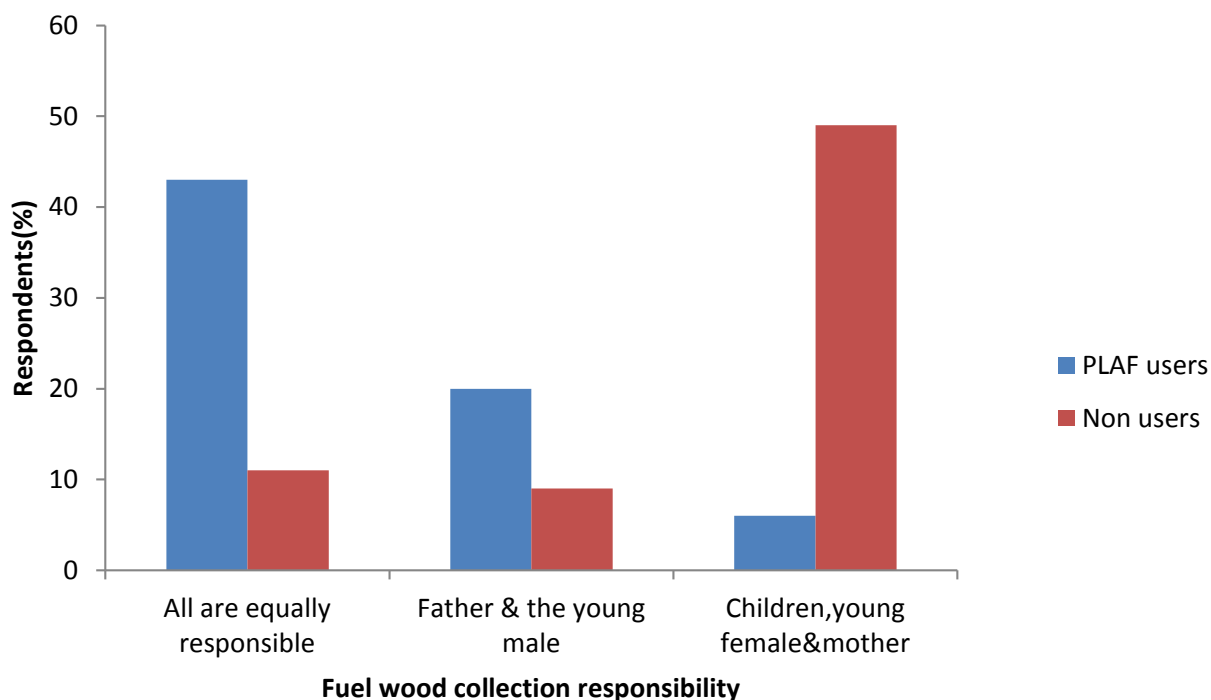
The PSM model result showed that there is statistically significant difference ( $P < 0.05$ ) among the parkland agroforestry user and non-user households on the time they were spent to collect fuel wood from the different sources. The parkland agroforestry user households saved 1.84 h per week than the non-parkland agroforestry households (Table 2). This implies that the parkland agroforestry introduced households have more additional time (88.3 h) per year to assign to other income generating activities and attending regular schools than the non-user households.

Regarding households' total annual income, variations were observed among the annual income of the parkland agroforestry introduced and non-introduced households. The total annual income of the parkland agroforestry user households was higher than the non-parkland agroforestry user households; however, the variation was not significantly ( $P > 0.05$ ) different (Table 2).

### Parkland agroforestry and fuel wood collection

From the parkland agro forestry introduced households

(n=69), the responsibility of harvesting and transporting fuel wood for the whole family, only male and only female were 62.3, 29 and 8.7% respectively (Figure 2). Majority of the household heads are of the opinion that the big trees require participation from all family members, initially to prune some selected branches of a tree which is commonly and traditionally performed by the male family members and transporting task also left mostly for all family members after the foliage and smaller part of branches are consumed by livestock. This indicates that the trees grown in the farm lands were important not only to provide fire wood and other products but also to minimize the work load of women and children by creating opportunities for labor division among all family members to harvest fuel wood and this in turn could have impact on the families' socio-economic developments. FAO (2013) pointed out similar result that combines agricultural crop and fuel wood production through agroforestry to save woodland trees and frees up labor, especially for women, who traditionally collect fire wood. On the other hand, the survey result derived from the non-parkland agroforestry users showed that fuel wood collection responsibility in these households was inclined to same particular family members rather than distributing it to all of the family members. 71% of the non-parkland



**Figure 2.** Fuel wood collection responsibility among family members of the PLAF introduced and non-introduced households in Hawezien district, Northern Ethiopia.

**Table 3.** Parkland trees found on each household farm plots and species composition in Hawezien district, northern Ethiopia.

Tree species	No. of trees	Percent	No. of HHs planted
<i>F.albida</i>	652	80.8	69
<i>A. abyssinica</i>	118	14.6	53
<i>C. africana</i>	19	2.35	16
<i>E. camaldulensis</i>	12	1.5	10
Others	6	0.74	5
Total	807	100	

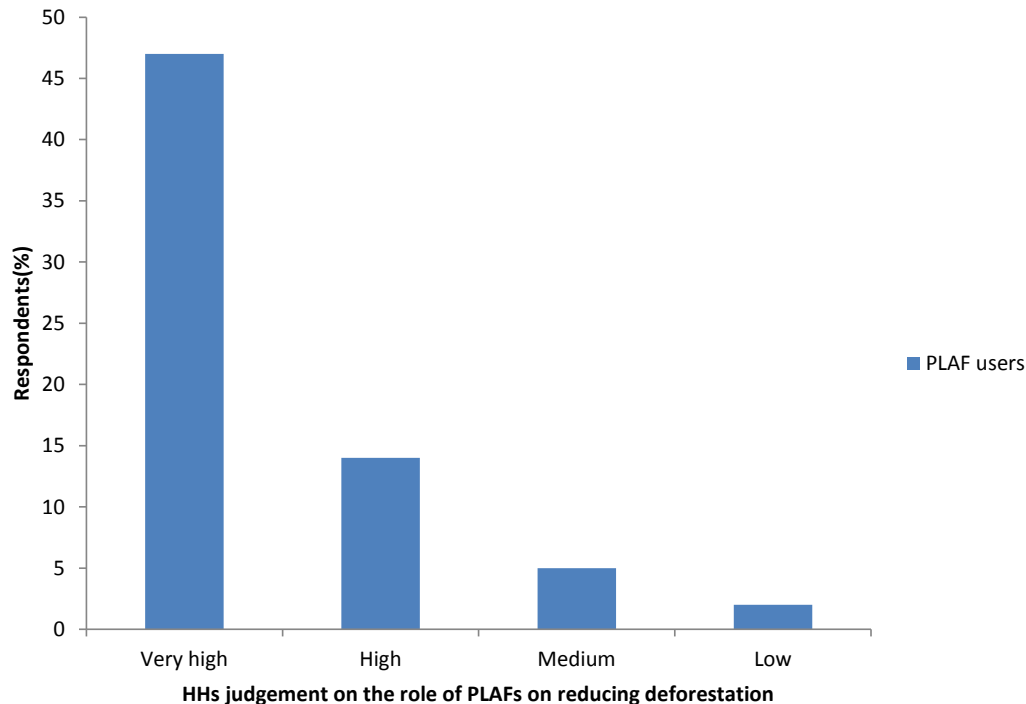
agroforestry introduced households (n=69) affirmed that the fire wood collection responsibility in their family mostly rest on the shoulder of children, young female and the mothers. About 15.94% of the respondents also replied that all family members had equal responsibility on fuel wood gathering activities and only 13% opined that the father and the young male were the most responsible to collect fuel wood from the surrounding forest and non-forest areas (Figure 2).

This shows that the children and women found in the households who have no parkland trees on their farmlands took the responsibility of fuel wood collection from the local forest and shrub lands. Kassie (2015) reported similar result that fuel wood collection responsibility from the nearby forest and shrub lands is performed by mothers and daughters.

### Common parkland tree species on the farmlands of the study area

All the mature parkland trees found in the farm plots of the parkland agroforestry introduced households (n=69) was counted and a total of 807 mature scattered trees were recorded in the Fireweini village. Thus, households had owned different number of trees with a minimum of 2 trees (in 2 farmers) to a maximum of 27 trees (in 1 farmer) and on average, there was about 11.7 trees per household heads and 16.3 trees per ha.

It was also shown that *Faidherbia albida* was the most dominant parkland tree and it was the only tree species found under all of the parkland agroforestry practice households accounting to about 80.8% (Table 3). The main purpose of keeping this tree species by all of the



**Figure 3.** The PLAF user households' judgment on the role of PLAF on reducing deforestation in Hawzen district, northern Ethiopia.

households and in a dominant number was mainly for its better fodder value, complementary nature of the tree with growing annual food crops, fencing service and fuel wood production. Due to this reason, *F. albida* had been the most dominant parkland tree species; followed by *Ampelocissus abyssinica*, 14.6%; *C. Africana* 2.35%; *E. camaldulensis* 1.5%; and 0.74% was covered by other tree species like *Olea europaea* (Table 3).

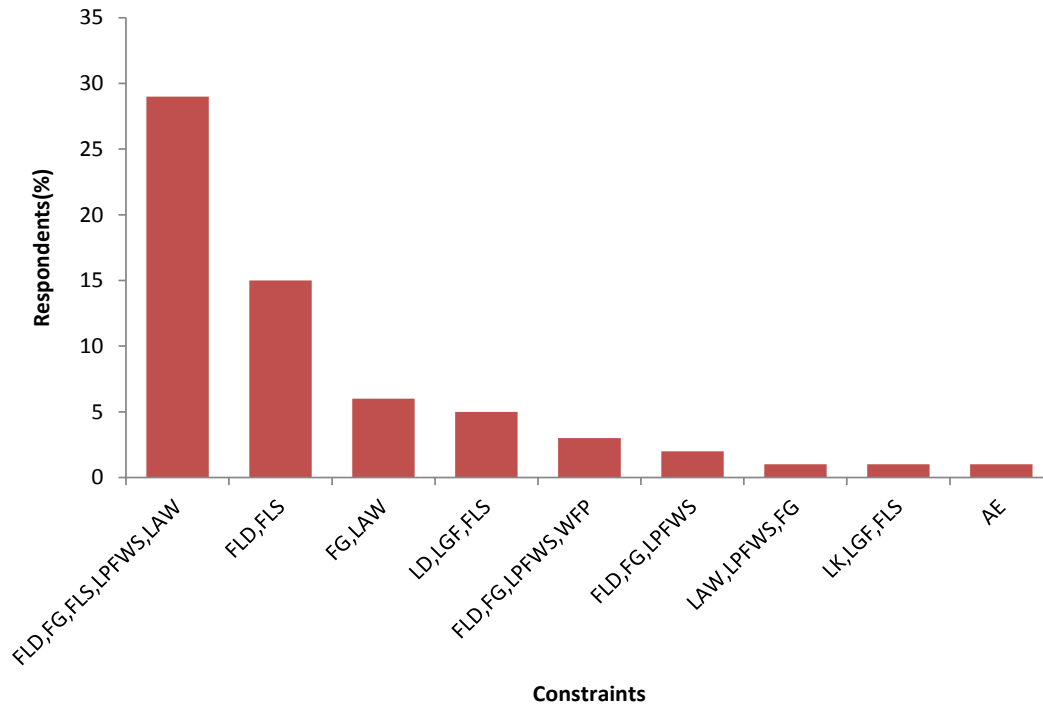
#### Farmers' judgment on the role of PLAF to minimize pressure on local forests

From parkland agroforestry user households (n= 69), majority (68.1%) of the household heads responded that the parkland trees found in their village had very high contribution in stabilizing the pressure on the local natural forest and non-forest areas by providing fuel wood/charcoal, fodder and other demands. These were even better than any other available technologies provided in the study area. Such practices are mainly introduced to minimize deforestation. Similarly, 20.3% of the respondents also replied that contribution of the parkland agroforestry in reducing the pressure on the local forests was high, 7.2% also said it was medium while the rest 3% of the respondents said low (Figure 3). However, no respondent believed that parkland agroforestry had very low/ no contribution on reducing the pressure on the surrounding common forests. This idea

was supported by Duguma (2010) who reported that agroforestry practice could be a promising option to solve environmental problems such as deforestation and to improve household food security by diversifying farm products and reducing vulnerability for seasonal food and fodder shortages.

#### Challenges of parkland agroforestry

The result indicated that 45.16% of the household heads (n=63), pointed out that the distance from home to farm plots, free grazing, shortage of farmland, prohibition of fire wood/charcoal selling and lack of awareness were considered as major limiting factors to have improved parkland agroforestry. About 24.2% of the respondents believed that farmland distance and the limited farmland size were identified as the major limiting factors. About 9.7% of the respondents also replied that small size of farmland were the only constraint to improve the parkland agroforestry practice, 8% said that free grazing and lack of awareness was the primary limiting factors for them and 4.8% believed that labor demanding nature of the parkland trees, lack of government support and shortage of farmland were main constraints; whereas 3.2% said that farmland distance, free grazing, general prohibition of fire wood/charcoal selling and weak local forest protection performance were major constraints (Figure 3). Some respondents (1.6%) also believe that lack of



**Figure 4.** Major challenges pointed out by the Parkland Agroforestry user HHs to maximize beneficial trees on their farmlands in Hawezien, Northern Ethiopia. FLD= farmland distance, FG= free grazing, FLS= farmland size, = LPFWS=legal prohibition of fuel wood selling, LAW= lack of awareness, LD= labour demand, LGF= lack of government focus, WFP= weak forest protection performance, LK= lack of knowledge for better tree species selection mechanism, AE= agronomic effect.

awareness, general prohibition of fire wood/charcoal selling and uncontrolled grazing were main limiting factors. Some others (1.6%) also believe that lack of better tree species identification mechanism, absence of government support and small farmland size was primary constraints. Also some others (1.6%) are of the opinion that the negative effect of trees on growing field crops and being obstacle for farming activities were the main challenging factors to improve the parkland agroforestry (Figure 3).

The result from FGD (Focal Group Discussion) and from the key informants' interview also indicated that, free grazing, lack of government focus on the farmland trees improvement, farmland distance and lack of farmers' awareness were primary constraints to the PLAF improvement in the study area. The uncontrolled grazing of animals on farmlands after the field crops are harvested (dry season) was one of the most limiting factor in the study area, including destruction of the protected and new planted areas. In line with this idea, Mekonnen and Kohlin (2008) was reported that free grazing on agricultural landscape was the major constraint for tree planting and maintenance in central Ethiopia. In general, the distance of farm plots from home and fragmented farmland size is among the main constraints to maximize multipurpose trees (MPTs) on farmlands; to which majority of the PLAF user

households were agreed upon. This implies that as distance of farm plots are increasing, farmers' willingness to plant and protect trees are being decreased. This is mainly due to management problems on the farm, since trees require continuous care and close management efforts. It was due to this reason that more trees are observed on the farm plots found near the residential areas than the distant plots in the study area. Therefore, farmland distance and free grazing are strongly interrelated factors that have been major challenges to plant trees on distant farm plots. In the nearby plots, it was easier to grow and manage trees relatively since household members can prohibit animals from browsing after the field crops were harvested. In agreement with this result, Predo and Francisco (2012) have reported that the relative distance from home was negatively affect farmers interest to grow trees in Philippines.

The result from the focus group discussion also indicated that there is widespread problem of theft of tree products, especially animal fodder and fire wood when planted far away from living home (Figure 4).

### Non-parkland agroforestry households

Despite most farmers in the study area was integrated selective trees with their farmlands especially on the plots

found near their home, there were also some households who had no trees in their farmlands. Though these households had not integrated trees into their farmlands, majority of them believe that integrating selective trees on farmlands is advantageous. As a result, 91.3% (n=69) opines that integrating selective perennial trees in farmlands are beneficial alternative for them; while the rest 8.7% believed that though the parkland trees can contribute to farmers, the negative effect of the trees on the growing annual food crops and farming activities are out weighted than its benefits, hence they were reluctant to integrate trees on their farmlands.

According to the respondents introducing perennial trees into farm lands can damage annual food crops in different forms, including shading effect and becomes harbor for field crop attacking birds, weeds and becomes obstacle for agronomic activities. In agreement with this result, FAO (2013) identified a general problem of farmers' perception on trees as incompatible with their farming activities and may not benefit from planting and managing trees as well as shrubs on their farm plots. This can also influence the introduction and implementation of agroforestry practice in wider areas.

There were some relevant questions provided to the non-parkland introduced households (n= 63) to know the main reasons they remained without introducing trees in their farmlands if they were aware of the advantages of integrating perennial trees on farmlands.

Response from most household heads mainly revolved on a single factor that limits them to grow valuable trees on their farmlands. About 61.9% of the respondents pointed out that, the dry condition of the area was the most limiting factor for them to retain beneficial trees in their farmlands and 15.9% replied that dry condition, availability of firewood in near areas until the near past years and lack of farmers awareness were the main constraints on trees growth on farmlands. However, 14.3% believed that the dry condition and availability of firewood in nearby areas were the main limiting factors to grow trees on farmlands. From the respondents, about 3.2% responded that dry condition and absence of better tree species are main the constraints. The rest, 3.2%, of the household heads said that the dry condition, the negative effect of trees on the growing annual food crops, easily accessibility of fire wood until and lack of farmers awareness are the main reasons farmers do not introduce MPTs on their farmlands.

## Conclusion

Parkland agroforestry (PLAF) is major source of fuel wood for households and rely mainly on their own farmland trees rather than going to collect fuel wood from the local forests and shrub lands. PLAF played an important role in fulfilling households' fuel wood demand and thereby reducing the pressure on the local forests and shrub lands. Furthermore, the PLAF introduced

households earns multi-faced benefits and services drawn from the parkland trees. Significantly reducing the time that would be required to collect fuel wood from outside farmlands, helping to share the fuel wood collection responsibility among all household members more evenly and improving household income are among the major benefits of the PLAF in the area. The household heads also perceived that the practice of PLAF based on indigenous trees species is the most preferred type of agroforestry mainly for its relative high biomass production per tree, high survival capacity and no required to assign particular area (land use efficiency). Despite its potential to deliver socio-economic and environmental benefits, farm plot distance from home, free grazing, farmland size, the general prohibition of fire wood/charcoal selling, lack of extension support and low level of farmers' awareness are among the major constraints influencing households to improve the existing PLAF practices. The dry /unfavorable condition, accessibility of fire wood from nearby areas and lack of farmers' awareness were the critical limiting factors for the non-PLAF introduced households to integrate beneficial trees on their farmlands.

## CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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