

## Full Length Research Paper

# Status of soil properties of scattered *Faidherbia albida* (De) in agricultural landscapes in Central Highland of Ethiopia

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Scattered trees in general and scattered *Faidherbia albida* in particular are preserved in agricultural landscapes in Ethiopia. A study on this tree species was conducted at Meskan District of Gurage Zone, Ethiopia with the objectives of assessing the status of soil properties under it and its population distribution in agricultural landscapes. Twenty four soil samples from the surface layer (0-10 cm) were taken from under six isolated mature *F. albida* trees at 3 concentric transects (1, 3 and 5 m) from the tree trunk and compared with soils taken from the adjacent open areas, 12 m far from the trees. In addition, 24 undisturbed soil samples were also collected from same points using core samplers for bulk density and moisture content determinations. The collected soil samples were analyzed following standard laboratory procedures. Assessment of the population distribution of the species was carried out at three different altitudinal zones, that is, 1800-2000 m above sea level (asl), 2000-2200 m asl and 2200-2400 m asl and from four land use types (homestead, farmlands, woodlots and grazing land). A complete count and Y frame transect sampling methods were used to estimate number of stem per ha. The results revealed that organic matter (OM%), organic carbon (OC%) and total nitrogen (TN%) significantly differ between radial distances. The three parameters, were higher at 1 m distance compared with the values at 5 and 12 m distances. Though the difference is statistically not significant, available P and moisture content (MC) showed a decreasing trend, and bulk density (BD) and carbon nitrogen ratio (C/N) showed an increasing trend with increasing distance from the trees trunk. Population status of *F. albida* in the farms is dominated by higher diameter classes, with only 2% share of stems in the younger DBH-class of less than 5 cm. This may not indicate a threat to the species as it appear as the community do not cut and harvest the whole tree but only lop which eventually may prolong the life span of the trees. Thus, this finding suggests that scattered *F. albida* trees are important agro-forestry resource to sustain soil fertility and subsequently crop yields. They are also important sources of multiple products such as fodder and shade for livestock during dry period, fuel and fencing material for households.

**Key words:** *Faidherbia albida*, soil property, population status, sustainability, Ethiopia.

## INTRODUCTION

### General background

In Ethiopia, a downward spiral of soil fertility has

contributed to a corresponding decline in crop yields, an increase in food insecurity continued dependence on food aid. One option for helping to move towards food security, which still remains a major challenge in the country, and to concurrently minimize environmental

degradation, is to promote agro-forestry that specifically involves indigenous trees species (Lalisa, 2010; Kindya, 2004; Poschen, 1986). A number of potential tree species for agro-forestry use in the drylands of Eastern Africa are available for the purpose of both resource conservation and poverty alleviation (Kindya, 2004).

*Faidherbia albida* (formerly called *Acacia albida*) is one of the dominant tree species deliberately retained on farmlands across most African dryland ecosystem (Phombeya et al., 2005; ICRAF, 2000; Poschen, 1986). *F. albida* is a multipurpose tree that is used to provide fodder and fuel wood and also to prevent soil degradation and promote biodiversity (Mokgolodi et al., 2011; Phombeya et al., 2005; Poschen, 1986; Adamu, 2012). The existence of *F. albida* in agricultural landscape in Ethiopia signifies the success of this traditional land-use practice in serving multiple purposes including improving crop yield and soil fertility. Modern scientists have also developed keen interest in understanding how *F. albida* promotes more sustainable agricultural production systems (Mokgolodi et al., 2011).

Several authors have reported the effects of the tree species on soil fertility and associated crop yields in Ethiopia (Manjur et al., 2014; Kiros et al., 2009; Hadgu et al., 2009; Kamara and Haque, 1992; Poschen, 1986) in Ethiopia. For example, Hadgu et al., (2009) and Kamara and Haque, (1992) found higher soil moisture content, organic carbon, total nitrogen, available P in the zone under *F. albida* tree canopy than zones far away from the tree canopy. Another study by Poschen (1986) reported higher crop yield in Zone under *F. albida* tree canopy than Zone far away from the tree canopy. Similar study by Manjur et al. (2014) indicated that there are significantly higher soil nutrients (C, N, P K) and yield of maize under *F. albida* and *Croton macrostachyus* trees than far from canopy in Southern Ethiopia.

A study by Sanda and Atiku (2013) showed that a significant differences in OC, N, P and K between distance from tree trunk in Nigeria. Saka et al. (1994) and Umar (2012) also found significant effects of *F. albida* on soil and crop yields in Malawi and Zambia, respectively. In the current study area, large tracts of agricultural landscape is covered by scattered trees predominantly, *F. albida*. However there are no studies that considered the effects of these trees on soil properties, and the status of the population of the tree species in study area. In recent years, farmers seem to have hampered the regeneration of *F. albida* because of the widespread poor agricultural practice and lack of awareness. Hence, research based information is crucial in order to convince land users and policy makers for corrective measures for promoting the integration of this multipurpose tree in the farming system. Such information can also be helpful in designing appropriate land use measures for improving

soil nutrients, crop yield and biodiversity in agricultural landscapes. Therefore, this research was designed with the objectives of assessing (1) the variability in soil properties (MC, BD, pH (H<sub>2</sub>O), SOM, organic C, total N and available P between radial distances from tree trunk (2) the overall relationships of the selected soil physical and chemical properties and radial distance, and (3) status of the population distribution of the trees at three altitudinal zones and four land use patterns.

## MATERIALS AND METHODS

### Geographic location

This study was conducted at Meskan District located between 38°15'10.7"- 38°33'510.9" E and 8°1' 598.8" - 8°16' 3029.6" N in Gurage Zone of Southern Ethiopia. This District was selected based on the existence of abundant *F. albida* trees under in agricultural landscapes. The population status of *F. albida* was assessed in three localities: Goyban, Mekicho and Ile while soil status was assessed only at Ile (Figure 1).

### Biophysical environment of the study area

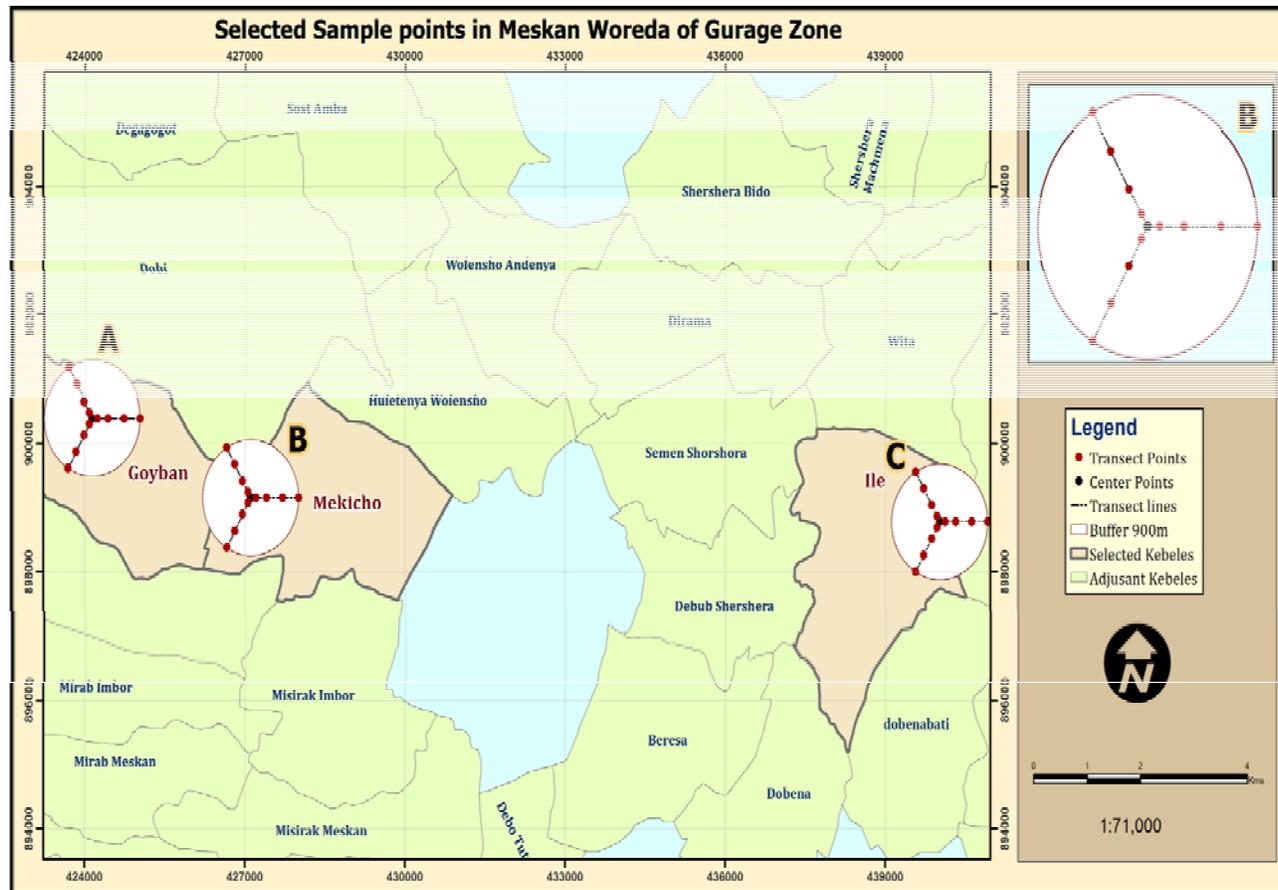
According to climatic record near the study area, the mean annual rainfall in the District (Figure 2) is 1058 mm and the mean daily maximum and minimum temperatures are 27.7 °C and 6.5°C, respectively (Figure 2) National Meteorology Services Agency, 2005. The main growing season begins towards the end of June and continues up to the end of October. The District has an altitude ranging from 1800-3500 m above sea level (asl). The dominant soil types of the District included eutric Cambisols, chromic Luvisols, chromic Vertisols, eutric Fluvisols, Leptosols and pellic Vertisols. The soil in the specific study site (Ile) is pellic Vertisols. The major land use and land cover in the area include farmlands, grasslands, plantation forest of mainly eucalyptus species, natural forest including area enclosure and degraded hillside. Growing indigenous on-farm trees such as *Faidherbia albida*, *Acaica abyssinica*, *Acacia seyal*, *Cordia africana* and *Croton macrostachyus* together with annual crop is a common practice in the area. The dominant annual crops associated with the on-farm trees includes teff (*Eragrostis tef* (Zucc.)), wheat (*Triticum sativum* L.), maize (*Zea mays* L.), sorghum (*Sorghum bicolor* L) and green paper (*Capsicum frutescens* L.).

### Experimental design, soil sampling and analysis

For the soil study, six isolated mature trees of *F. albida* were selected at six adjacent farmlands under similar soil types, climate and landscape. Twenty four soil samples were taken from the surface layer of 0–10 cm at three concentric transects of (1, 3 and 5 m) and compared with soils taken from adjacent open areas located at 12 m from the trees trunk. Approximately, 1 kg of soil sample was collected from each sample site and analyzed at Holetta soil laboratory. The samples were air-dried at room temperature, crushed, homogenized and passed through a 2mm sieve before analysis for pH, C and available P. They were also further sieved through 0.5 mm size for analysis for TN. For bulk density and

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**Figure 1.** Farm sampling method. (A, B & C) GPS points were randomly located in three Peasant associations of (Goyban, Mekicho and Ile) in Meskan district (B) from each GPS point three axes departing  $120^\circ$  from each other were demarcated, and four GPS points were located along each axis, at 100, 300, 600 and 900 m from the center; (B') detail of a Y-sampling frame indicating the 13 GPS points and the GIS polygons representing the adjacent farms to each of the points, which were selected for field survey.

moisture content determination undisturbed soil samples were also collected with a manual core sampler of 5 cm height and \* 3 cm in diameter at soil depth (0-10cm).

Available Phosphorus was determined by Olsen's method of bicarbonate extraction (Olsen and Summer, 1982), total nitrogen was analyzed by Kjeldahl procedure (Jackson, 1958), and organic carbon was determined by Walkley-Black dichromate method (Walkley and Black, 1934), pH was measured using (1:2.5 soils to water ratio) using digital pH meter. Bulk density was determined using core method after oven drying wet undisturbed soil samples at temperature of  $105^\circ\text{C}$  for 24 h. Soil-water content was determined by standard procedures described for the gravimeter method after oven drying to a constant weight at  $105^\circ\text{C}$  (Anderson and Ingram, 1993) for 30 h. Bulk density was calculated by dividing the weight of oven-dried soil with the volume of the core. OM was estimated by multiplying OC by 1.724. All the chemical and physical analysis were carried out in a soil-testing laboratory of Holetta Soil Laboratory, Addis Ababa Ethiopia.

#### Assessment of population status of *F. albida*

Inventory of *F. albida* was carried out in three Peasant Associations

namely Goyban, which is a high altitude area (2200-2400 m asl); Mekicho a mid altitude area (2000-2200 m asl), and Ile a low altitude area (1800-2000 m asl). Three GPS points were selected randomly one in each locality, then a Y-frame transect sampling scheme applied for selecting 39 farms for detailed study. That means 13 farms were selected from each locality along the three transects line approximately at 100m, 300m, 600m and 900m from central farm (Figure 1). The selected farms were further categorized into four land uses (homestead, farmlands, grazinglands and woodlots). The size of each farm/plot was determined through interview of the owners and field survey. Total count method was used to estimate the number of stems per plot. In addition, Diameter at Breast Height (DBH), total height and canopy width and length were measured using caliper, clinometers and measuring tape, respectively. In addition, semi-structured interview, field observation and informal discussion was held to capture qualitative data.

#### Statistical analysis

The data of soil properties in response to radial distance were subjected to GLM test with one-way-ANOVA (SPSS Inc, 2006). Then, the means for treatments that showed significant differences

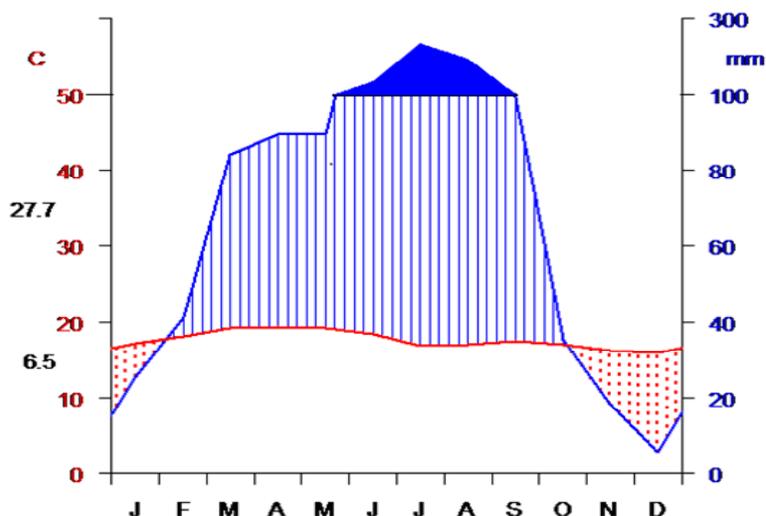


Figure 2. Climatic condition of Meskan area based on a long-term data (1990–2012).

Table 1. Mean of soil MC (%) and BD ( $\text{g cm}^{-3}$ ) of soil at 1, 3, 5 and 12 m.

Property	Distance from tree trunk (m)				ANOVA
	1	3	5	12	
MC (%)	29.53±1.01 <sup>a</sup>	28.75±1.13 <sup>a</sup>	28.35±1.45 <sup>a</sup>	28.32±1.49 <sup>a</sup>	ns
BD ( $\text{g/cm}^3$ )	1.12±0.04 <sup>b</sup>	1.13±0.03 <sup>b</sup>	1.14±0.06 <sup>b</sup>	1.15±0.02 <sup>b</sup>	ns

Values followed by the same letters in a row are not significantly different at  $p < 0.05$ ; or  $0.001^*$ .

by F-test were separated by Tukey's honestly significant difference test (Tukey-HSD test) and significance were declared at 0.01 and 0.05 significant levels, which is the most widely used multiple comparison procedure (Zar, 1996). Correlation test was conducted to assess the relationships between the different soil properties and radial distances. The soil properties analyzed and compared were bulk density ( $\text{g cm}^{-3}$ ), moisture content (%),  $\text{pH}(\text{H}_2\text{O})$ , OC (%), SOM (%), total N (%), available P (ppm) and C/N. Similar GLM test with one-way-ANOVA was used to evaluate the effect of land use and altitude on stem number of *F. albida*. In addition, simple descriptive statistics was used to describe distribution and characteristics of trees and qualitative data.

## RESULTS and Discussion

### Soil physical properties

Results of soil moisture content and bulk density are presented on Table 1. Both soil moisture content and bulk density did not show any significant difference ( $P < 0.05$ ) difference between the radial distances (Table 1). However, relatively higher moisture content of (29.53±1.01%) was recorded at 1m distance, while similar lower moisture content of 28.75±1.13%, 28.35±1.45%, 28.32±1.49% were recorded at 3m, 5m and 12m distances, respectively (Table 1). This result

goes well with the finding of Manjur et al., [2014] who found non-significant difference in moisture content between radial distances from tree trunk under *F. albida* and *C. macrostachyus* in Southern Ethiopia. The result also conforms with the studies by Hadgu et al., (2009) and Kamara and Haque (1992) who found no significant difference in moisture content between radial distance in Ethiopia. On the other hand, the present result disagrees with the finding of Rhoades (1995) who found higher moisture content under the canopies of *F. albida* trees than outside the canopy. Though not significantly different, lower BD of 1.12±0.04  $\text{g/cm}^3$  was observed at 1m, and slightly higher BD of 1.13±0.03  $\text{g/cm}^3$ , 1.14±0.06  $\text{g/cm}^3$  and 1.15±0.02  $\text{g/cm}^3$  were measured at 3m, 5m and 12m radial distances, respectively (Table 1). This observation contradicts with that of Manjur et al., (2014) found a significant difference in bulk density between radial distances from *F. albida* and *C. macrostachyus* trees in Southern Ethiopia. But the result is consistent with findings of Abebe (2006) who reported lower non-significant bulk densities under *F. albida*, *C. macrostachyus* and *C. africana* trees in Eastern Ethiopia. It also matches with the finding of Belsky et al (1989), who reported lower bulk density under trees than outside the canopy in Kenya.

**Table 2.** Mean  $\pm$  SEM of soil OC (%), OM (%), TN (%) available P (ppm), pH (H<sub>2</sub>O) and C/N at 1, 3, 5 and 12 m.

Property	Radial distance from tree trunk (m)				ANOVA
	1	3	5	12	
OC (%)	2.74 $\pm$ 0.08 <sup>a</sup>	2.62 $\pm$ 0.07 <sup>ab</sup>	2.44 $\pm$ 0.09 <sup>b</sup>	2.35 $\pm$ 0.04 <sup>b</sup>	*
OM	4.7 $\pm$ 0.14 <sup>a</sup>	4.5 $\pm$ 0.18 <sup>ab</sup>	4.21 $\pm$ 0.15 <sup>b</sup>	4.04 $\pm$ 0.08 <sup>b</sup>	**
TN (%)	0.21 $\pm$ 0.02 <sup>a</sup>	0.19 $\pm$ 0.01 <sup>ab</sup>	0.18 $\pm$ 0.00 <sup>b</sup>	0.17 $\pm$ 0.00 <sup>b</sup>	**
P (ppm)	17.10 $\pm$ 2.02 <sup>a</sup>	16.10 $\pm$ 0.66 <sup>a</sup>	14.81 $\pm$ 0.88 <sup>a</sup>	15.16 $\pm$ 0.11 <sup>a</sup>	ns
C/N	13.49 $\pm$ 0.83 <sup>b</sup>	13.72 $\pm$ 0.4 <sup>b</sup>	13.95 $\pm$ 0.40 <sup>b</sup>	14.23 $\pm$ 0.24 <sup>b</sup>	ns
pH	6.18 $\pm$ 0.06 <sup>a</sup>	6.15 $\pm$ 0.09 <sup>a</sup>	6.11 $\pm$ 0.07 <sup>a</sup>	6.12 $\pm$ 0.07 <sup>a</sup>	ns

Values followed by the same letters in a row are not significantly different at  $p < 0.05$ ; or 0.001\*.

### Soil chemical properties

Among the selected soil chemical properties, OC, SOM and TN showed significant differences with radial distances (Table 2). Soil pH did not show significant difference. A roughly similar soil pH of 6.18 $\pm$ 0.06; 6.15 $\pm$ 0.09; 6.11 $\pm$ 0.07 and 6.12 $\pm$ 0.07 were observed at 1, 3, 5 and 12 m distances from the trees trunk, respectively (Table 2). This result goes well with the finding of Manjur et al., (2014), who reported similar soil pH among radial distances from trunks of *F. albida* and *C. macrostachyus* in Southern Ethiopia. Another study by Kamara and Haque (1992), also found similar soil pH under and outside the canopy of *F. albida* in Ethiopia. Jiregna et al., (2005) also reported a similar pattern of soil pH under and outside canopy of *C. africana* and *C. macrostachyus* in Eastern Ethiopia. OM was significantly different between radial distances ( $P < 0.01$ ). Higher OM of 4.7 $\pm$  0.14% was measured at 1m whereas lowest OM of 4.04 $\pm$ 0.08% was measured at 12m. Both OC and OM content showed a continuous decline with radial distances from the tree base. This may reflect the strong influence of trees on organic inputs. Likewise, organic carbon significantly varied at ( $P < 0.05$ ) among radial distances. Higher OC of 2.74 $\pm$ 0.08 % was found at 1m while lowest OC of 2.35 $\pm$ 0.04% were found at 12m distance (Table 2). In general soil under tree canopy contained better soil chemical attributes than outside the tree canopy. These results agree with previous reports by Abebe, (2006) and Manjur et al., (2014) who found higher OC under the canopy *F. albida*, *C. africana* and *C. macrostachyus* than outside canopy in Ethiopia. It is obvious that OM has a positive influence on soil fertility, plant nutrition and biological activity in the soil (Brady and Weil, 2002).

Total nitrogen also showed a similar significant difference ( $P < 0.05$ ) between radial distances. Higher TN (0.21 $\pm$  0.02%) was measured at 1m distance and lowest TN (0.17 $\pm$ 0.00%) was measured at 12m distance (Table 2). This results matches the findings of Hadgu et al., (2009) and Umar et al., (2012) who found higher N content under the canopies of the trees than far away from the influence of trees in Ethiopia and Zambia.

Another study by Kamara and Haque (1992) also found a higher N content under *F. albida* canopies than outside the canopies in Ethiopia. Similar other studies (e.g. Abebe, 2006; Manjur et al., 2014; Sanda and Atiku, 2013; Saka et al., 1994) reported a similar pattern of difference in total N between radial distances.

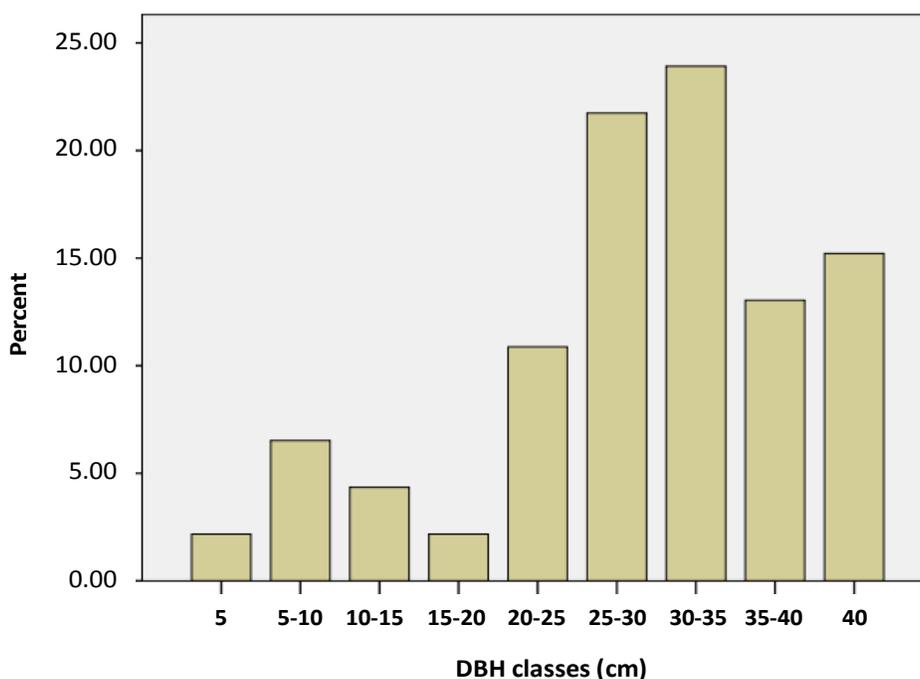
The observed higher SOM, OC and TN under canopy compared with open area could be explained due to leaf litter fall and decomposition of dead roots from the tree and nutrient cycling and nitrogen fixation by tree species. Shedding of its leaves during rainy period when there is limited livestock movement might be a contributing factor for higher soil fertility under canopy compared with outside the canopy. It is obvious that *F. albida* has the ability to fix atmospheric nitrogen and subsequently convert it to plant available nitrate form (Buresh and Tian, 2004). For instance, Kamara and Haque (1992) found higher content of N (3.85%) from fresh leaves of the trees in Ethiopia. On top of this, deep rooting system of *F. albida* enables the tree to take up nutrients from deeper soil horizons and that are subsequently returned to the top soil through litter fall. Some of the key informants estimated that the root of *F. albida* system extends up to 25m down ward for extraction of nutrients and moisture. In present study the contribution of external sources such as cattle dung is could be minimal as farmers regularly pollard the tree canopy for reducing shade that can pose problem on associated food crops.

On the other hand, available P did not show significant difference among radial distances (Table 2). However, relatively higher available P of 17.10 $\pm$ 2.02 ppm was measured at 1m while relatively lowest values of available P (14.81 $\pm$ 0.88 ppm), was measured at 5m (Table 2). This result goes well with findings of Abebe (2006) who found better available P under *F. albida*, *C. africana* and *C. macrostachyus* trees in Ethiopia. These results also confirm the findings of Kamara and Haque, (1992) who detected non-significant variability of available P among radial distance under *F. albida* in Eastern Harargie, Ethiopia.

The result, however, does not match with the findings by Manjur et al., (2014) who reported significant difference in available P among radial distances from tree

**Table 3.** Pearson's correlation matrix for OM (%), TN (%), Ava. P (ppm), pH, MC (%) and BD (g/cm<sup>3</sup>).

Soil property	SOM (%)	TN (%)	pH	BD (g/cm <sup>3</sup> )	MC (%)	P (ppm)	RD (m)
SOM (%)	1						
TN (%)	0.696**	1					
pH	0.467*	0.253	1				
BD (g/cm <sup>3</sup> )	-0.536**	-0.287	-0.503*	1			
MC (%)	0.582**	0.310	0.768**	-0.541**	1		
P (ppm)	0.225	0.485*	-0.358	0.006	-0.250	1	
RD (m)	-0.690**	-0.670**	-0.048	0.149	-0.088	-0.267	1

**Figure 3.** Distribution of *F. albida* in DBH-class (cm) in Meskan District, Ethiopia.

trunk under *F. albida* and *C. macrostachyus* trees in Southern Ethiopia.

Likewise, C/N ratio did not show significant difference among radial distances. Nonetheless, there is an increasing trend with increasing radial distance as shown in Table 2.

Correlation assessment between the different soil parameters (Table 3) revealed a positive correlation between SOM, N, pH and MC. Similarly, positive correlation was observed between TN and P. The relationship between SOM and BD was negative, which is expected. The higher the SOM, the lower the bulk density should be. Radial distances, and SOM and TN are also negatively correlated, which again is expected. This again confirms the positive effect of trees on SOM and TN. Similar inverse relationships between radial distances and SOM, N, P, K were reported from Ethiopia

by Kamara and Haque (1992) and Umar et al., (2012) from Zambia.

#### Distribution and characteristic of *F. albida* trees in the study area

Tree stem distribution by DBH class indicated 74% of the stems to fall in the DBH class over 25 cm, while only a lower proportion of (2%) fall in a yunder (juvenile) DBH-class of less than 5cm (Figure 3). This shows the dominance of mature trees. This finding matches with the study of Kamara and Haque (1992) who reported higher proportion of mature trees compared with young trees in a similar farming system in Ethiopia. The present results also goes well with finding from other area by (Adamu, 2012) and Reed et al., (1992) who found higher

**Table 4.** Mean±SEM of number stems of *F. albida* in relation to land use (Homestead, Farmlands, Grazing land and *Eucalyptus camaldulensis* woodlots).

Parameter	Altitudinal zone	HG	FL	GL	WL	ANOVA
Number of stems per ha	1800-2000	9.26±3.04	10.04±2.44	6.25±6.25	4.13±4.1	ns
	2000-2200	0.67±0.67	4.62±2.83	-	-	ns
	2200-2400	-	-	2.8±2.88	-	ns

Values followed by the same letter in a row are not significantly different at  $p < 0.05$ ; or 0.001\* significantly different at  $p < 0.05$ ; \*\* significantly different at  $p = 0.001$  and ns denotes not significantly different.

number of mature trees compared with young individuals in Nigeria and West Africa, respectively. Similar lower young population was reported elsewhere by (Kirmse and Norton, 1984).

The mean tree height and trunk diameters were 7.3m ±0.54m and 30cm ± 0.03cm, respectively (n = 30). The canopy cover of the tree range between 3-5m with mean of 3.7m ±0.36m.

#### Effects of land use and altitude on stem number of *F. albida*

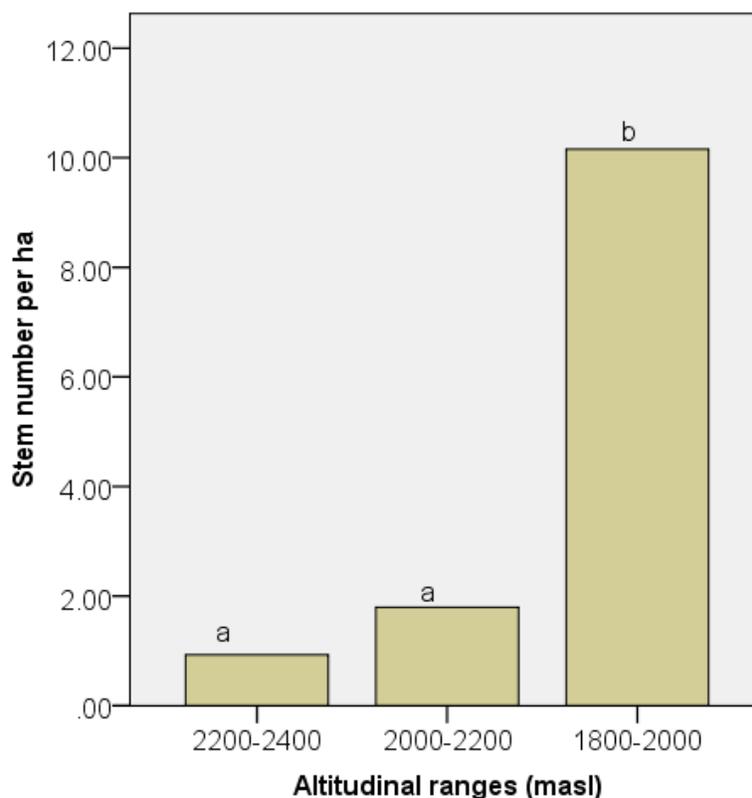
Within altitudinal zones, land use did not show significant influence ( $P < 0.05$ ) on number of stems. However, in terms of absolute values, farmlands had higher stem number of 10.04±2.44 per ha followed by homesteads (9.26±3.04 per ha), grazing lands (6.25±6.25) and woodlots (4.13±4.1) at lower altitude zone. Similarly, in mid altitude farmlands contained higher individual *F. albida* trees (4.62±2.83 per ha) followed by homestead (0.67±0.67 per ha) while grazing land and woodlots did not contain any *F. albida* trees. On the high altitude zone, overall lower number of stems (2.8±2.88 per ha) were found, and these are found on grazing land. There was no *F. albida* stem found in homestead, farmlands and woodlots at higher altitudinal zone. This indicates the altitudinal stretch of the species does not go beyond the mid altitude range described in this study. Moreover, the observed lower proportion of growing population in all considered land use may be attributed interest of farmers to preserve only mature trees and to high grazing pressure, *F. albida* is highly palatable to all herbivores particularly for camel and goat. The tree being one of the few species with green foliage during the dry season the young seedlings and saplings may be readily eaten if not protected. Hence, the young seedlings should be protected from livestock trampling and human disturbance. Lower level awareness about the value of the *F. albida* may be contributing factors which is also agreed upon by farmers and development agents. On the other hand, altitudinal zone significantly affected the number of stems ( $P < 0.05$ ). Higher number of *F. albida* stem (10.17±2.5 stem per ha) was found at lower altitudinal, the least at higher altitudinal (0.93±0.9 stem

per ha) (Figure 4). The observed significant variation in stem number in response to altitudinal gradient could be explained by difference in temperature and soil fertility and moisture. Some of the interviewed farmers perceived that the growth of *F. albida* is slow in the upper altitude than lower altitude as results of cool temperature and poor soil fertility in upper altitude. The observed higher stem number may also be associated with associated vegetation and soil types. For example, higher number of stems was found under woodland vegetation and Vertisols at lower altitude compared to afro-montane forest and cambisol at mid- and higher altitude (Table 4).

The measured density of *F. albida* in the study area also falls within the ranges of previous studies such as by Kamara and Haque (1992) who reported the average density of 6.52 trees/ha, and Poschen (1986) who reported the density range of 1-10 tree /ha, both in Ethiopia.

#### Perception of farmers on effects of *F. albida* on crop yield germination and population status

Out of the interviewed farmers (n=18), 60% perceived that *F. albida* might decrease crop yield underneath its canopy depending on crop types grown. The majority (10%) perceived that crop yield will decrease regardless of crop type, while about 30% perceive no difference under and outside the canopy. This finding is also supported by field observation. *F. albida* affects uniform germination of specific crops particularly crops such as maize and teff compared to wheat and barley. Similarly, farmers indicated that crop maturity differs under and outside the canopy; with those under the canopy maturing late compared to the crop outside the canopy. This may have to do with the shading effect of the tree as well as the associated higher soil moisture under the canopy. The presence excess OC may also favor vegetative growth at the expense of reproductive growth. Regarding threat to the tree species, despite the dominance of old diameter class, 100% of the respondent agreed that the tree would not face threat of disappearance in the future. This is justified by the fact that farmers cut only the branches rather than cutting if from the trunk. Multiuse nature of the tree has been



**Figure 4.** Stem number of *F. albida* in relation to altitude in Meskan District, Ethiopia.

emphasized the respondents for conserving it and caring for it by the interviewed farmers. All of the interviewed farmers confirmed the tree to provide diverse products such as fuel wood, fencing and livestock forage.

In general, based on interview, informal discussion and field observation, *F. albida* trees provide different ecosystem services such as increasing soil fertility, crop yield and biodiversity conservation. The tree also provide fuel wood, fencing and livestock forage. However, some ecosystem disservice was perceived by farmers, particularly depressing uniform germination of crop and crop yields particularly teff and maize if the canopy is left un lopped for more than 2 years.

The results of this study showed that significant differences in OM, OC and TN were observed between radial distances from *F. albida* trees while P, pH, MC, BD and C/N did not show any significant difference. Higher SOM, OC and TN were found in soils under the canopy of the trees compared with soil outside the canopy. Land use did not affect the distribution of *F. albida* while altitudinal zone significantly affected the distribution of *F. albida*. Higher number of stems were measured under farmlands at low altitude. The observed higher proportion

of mature individuals compared with lower proportion of young individuals signals the importance of planting new seedlings and protection of existing once from disturbance. Lower level of awareness about the ecological values of the *F. albida* may also be a contributing factor for decline of the population of the trees. The trees provide fodder for livestock feeding, fuel wood, fencing. It is obvious that a good stand of *F. albida* can be maintained only if rigorous and concerted efforts are made to plant and nurture the naturally growing trees. To keep the sustainability of this important multipurpose tree species, the following measures are recommend: the population of growing trees should be protected from livestock pressure and planting of new seedling in farmlands and closed area and degraded hillsides in order to conserve genetic pool of the species. The branches of the trees should be removed through pollarding for growing crops such as maize and teff in order to facilitate passages of light and rainfall for uniform germination under the canopy. Further research should be conducted in order to understand and select compatible annuals crops that could better grow under the canopy of trees.

## Conflict of Interest

The authors have not declared any conflict of interest.

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